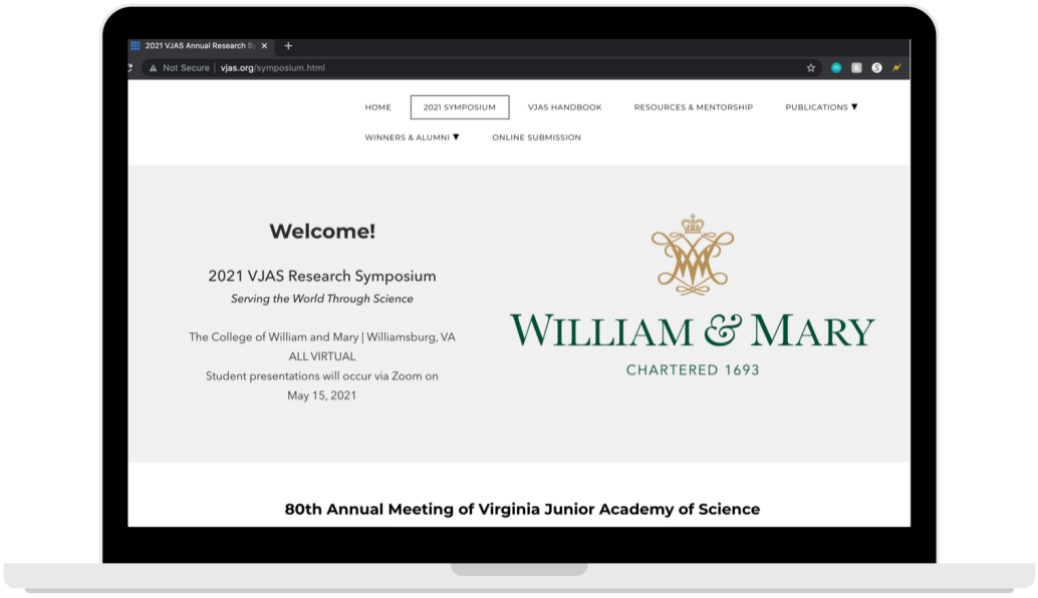
The Virginia Junior Academy of Science

Proceedings

80th Annual Virtual Meeting and Research Symposium



VOLUME 58

May 15, 2021

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.

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.

Officers of The Virginia Academy of Science

President ..... Michael Price
President-Elect
Vice President ..... Joseph D'Silva
Norfolk State University
Secretary ..... Christopher R. Osgood
Old Dominion University
Treasurer ..... Sujan Henkanaththegedara
Longwood University
Executive Officer ..... Philip M. Sheridan
Executive Officer Emeritus ..... Arthur F. Conway
Associate Executive Officer ..... Carolyn M. Conway

Virginia Junior Academy of Science

VJAS Committee Chair ..... Se W. Jeong
VJAS Committee Vice Chair ..... Michael E. Lovrencic
VJAS Director ..... Susan P. Booth
VJAS Associate Director ..... Robin W. Curtis

The College of William & Mary Local Arrangements Chair

Local Arrangements Chair ..... Joshua Erlich

Student Officers 2021-22

Arman is a junior at Colgan High School and the Governor's School at Innovation Park in Manassas, Virginia. Arman is an active researcher in environmental health and designs apps to improve healthcare delivery. He is invested in bringing similar STEM opportunities to all students.

Hamza Arman Lateef, Co-President VJAS 2021-2022

Harrish Ganesh is a senior at Thomas Jefferson High School for Science and Technology. He is an avid and experienced researcher within virology and neuroscience. Harrish loves to promote STEM outreach while pursuing his hobbies such as guitar and basketball. As a VJAS Co-President, Harrish aims to improve student outreach.

Harrish Ganesh, Co-President VJAS 2021-2022

Charlotte Cunningham
Vice President

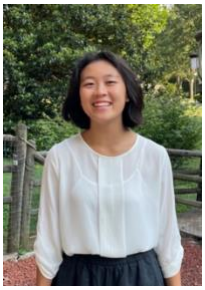
Charlotte is a Junior at Washington-Liberty High School in Arlington. She has presented her research papers at the annual VJAS Symposium for the past four years in the categories of Chemistry and Medicine & Health. As Vice President of the VJAS Student Officer Committee, she hopes to help more students and their advisors experience success in their submitted papers and presentations. Outside of her research, Charlotte runs on her school's cross-country team, is the Founder and President of her school's Global Health Club and holds a leadership position in a local youth philanthropy organization. She also manages her own licensed neighborhood business. She plans to pursue coursework in college that combines medicine, research, writing, and business to become a global health leader.

Laasya is a junior at Mills E. Godwin High School in The Center for Medical Sciences. Her passion for research paves the way for her interdisciplinary ambitions in STEAM, with her fascinations largely being in machine learning and neuroscience. She continues to ignite her curiosity by being an active participant in VEX VRC Robotics and volunteering with CodeVA. As the secretary, she is dedicated to retaining organization within the VJAS Student Government to expand the adventure of STEM fairs to a greater range of students.

Laasya Konidala
Secretary

Ashwin is a senior at Collegiate School in Richmond. His natural curiosity fuels his problem-solving skills and passion of STEM related studies. He is an active member of his community service council and several clubs in his school community, loves playing guitar and tennis, and is fascinated by space science. He strongly believes that every student should have the opportunity to explore scientific research and as a VJAS Communication Liaison Officer, he is excited about increasing research awareness with outreach programs in area schools.

Ashwin Johri
Communication Liaison



Eujine Kim is a senior at Central Virginia Governor's School for Science and Technology in Lynchburg. She loves science, and her main field of interest is biology. Eujine is the president of her base school's Environmental Club and a member of the Bee Club because of her interest in the life sciences. She also has a fascination for words and their connection to science, which led her to the position of coeditor-in-chief of the VJAS Voice. She hopes this magazine can inspire students to embrace research.

Corrina is a senior at East Rockingham High School and Massanutten Regional Governor's School. She is an active member of her cross country and track teams and enjoys displaying her musical talents. Corrina plays several instruments in marching band and concert ensemble. She also sings in multiple school choirs. Corrina is fascinated by scientific research and does not like to restrict her curiosity to just one field. Through serving as the Co-Editor in Chief of the Virginia Junior Academy of Science, she hopes to encourage further outreach and inclusion into VJAS programs. She wants to share her love of science with others through interesting stories and connections to other VJAS participants.

Corrina Peachey
Co-Editor in Chief
VJAS Student Advisory

Committee: Yash Saxena, Nitya Kumar, Akul Miriyala, Caroline Klotz, Chirayu Nimnonkar, Pranav Jothi, and Lillian Sun.

Tarannum M Lateef, MD MPH; VJAS Junior Officer Liason
Associate Professor
Departments of Pediatrics and Neurology
Children's National Medical Center
George Washington University
Washington DC

Table of Contents

Abstracts of Student Research Papers by Section

Animal & Human Sciences (MS AH)

Honorable Mention

Do dogs 10-15 lbs. prefer a certain type of bed?

Patrick Jiminez *Gunston Middle School*

Sleep is incredibly important for dogs. They need between twelve to eighteen hours of sleep per day, and in order to achieve this, they benefit from a good bed to sleep in. The purpose of this experiment was to test what dog bed is chosen most often by dogs ranging from 10 to 15 pounds. With this knowledge dog owners can help their dogs get better sleep by purchasing an appropriate bed. The hypothesis was that the small thin bed would be chosen more frequently because the dog could curl up with little side walls closely surrounding the dog, giving them a sense of protection. The small bed was also thinner, so the dog may have been able to feel the ground better compared to the other beds. The experimental procedure included setting all of the beds exactly five feet from a central point, placing the dog on that point, leaving for five minutes and then observing the dog's behavior on recorded video and recording the results on a table. The results showed that the small bed was the most frequently chosen, with it being selected in 44 percent of the tests. Up next was the "poof" bed, with the results showing it was chosen in 34 percent of the tests. Finally, the cupcake bed was the least chosen, only being selected 22 percent of the time. It should be noted that given the experimental design, it is somewhat subjective about what "choosing" a bed really meant, instead marking interest shown through sniffing and/or pawing. Given the opportunity to redesign the experiment, I would extend the time allotted for each trial, in hopes that the subject would eventually lay down in a bed, giving a clearer indication of its preference.

Honorable Mention

The Effect of Color on Attraction to Food on *Vanessa cardui*

Addison Kofron *George Moody Middle School*

Butterflies are important insects that play an important role in the ecosystem. Scientists are constantly exploring those roles and how they can help improve butterflies' living environments. Butterflies eat nectar from a variety of different colored flowers and contribute to pollination. If the butterflies do not have a proper living environment to eat, they will not be able to reproduce. By testing the effect of different colors on the *Vanessa cardui*, also known as the Painted Lady, butterfly's attraction to food, scientists can help restore their habitats as they are vulnerable at the moment due to pollution, climate change, use of pesticides, and destruction of natural habitats for construction.

The hypothesis for this experiment was if the colors red, blue, purple, white, orange, yellow, and no color were displayed with the food source, then the butterflies that received exposure to red were the most attracted to the food. Fifty-two butterflies were used to test the hypothesis. A translucent tarp was wrapped around a tent to allow sunlight to enter and create a greenhouse effect. The 52 butterflies were placed in a mesh cage with plenty of room to fly. There were 6 colored disks of the following colors: red, orange, yellow, blue, purple, and white. No color was the control group. The seven disks were all placed in the mesh cage along with a petri dish with a cotton ball soaked in sugar water. After the colored disks and sugar water were placed in the mesh cage, the number of butterflies that landed on a certain color in a ten-minute time period was recorded. This process was repeated 20 times. Of relevance, the mean for the color yellow was the highest with a mean of 5.25. The predicted color red had a mean of 2.05. The control group of no color had a mean of 1.1. In conclusion, the butterflies had the greatest attraction to the color yellow and the smallest attraction to the control group of no color.

First Place

Opening Up a Can of Worms

Rania Lateef *Louise A. Benton Middle School*

Background/Main Objectives: Artificial turf is increasingly used on athletic fields, yet many questions remain about its health impacts. Freshwater planarians or flatworms provide an excellent animal model to study the neurotoxicology of artificial turf due to the planarian's unique ability to regenerate a centralized nervous system. It was hypothesized that: 1) If bisected planarian worms are exposed to artificial turf that is airborne or dissolved in water, their regeneration rate and total regeneration capacity will diminish. 2) If whole planarians are exposed to artificial turf that is airborne or dissolved in water, their reproductive capacity will decrease. Methods: Petri dishes were prepared, for each of the 3 experimental conditions: a) No exposure to artificial turf; b) Artificial Turf in air; c) Artificial Turf in water. Each petri contained the head fragment of a bisected worm. For exposure to turf in water, 30 pieces of turf were placed in each petri dish filled with water. For exposure to turf in air, petri dishes were placed in a wooden chamber with turf placed on the floor of the chamber and a hair dryer was used to blow the turf around the chamber. Growth was measured every other day. For the fertility experiment, I counted the number of worms in each group after 3 weeks. All safety protocols were followed including use of gloves, goggles, and adult supervision. Results: Planarians exposed to turf in air did not have a significantly different regeneration rate (0.21 mm/day) compared to the controls who had no exposure to turf (0.23mm/day). However, the planarians exposed to turf in water, regenerated much slower (0.10 mm/day). Planarian regeneration capacity or the percentage of total regeneration compared to the initial fragment was less for the planarians exposed to turf in air (76.5%) and water (30.8%) compared to controls (91.7%). There was minimal difference between the fertility of planarians exposed to turf in air or water. Conclusions: The effect of artificial turf on planarian regeneration is concerning. More research on the neurotoxicology of artificial turf is vital to protect the health of young athletes and especially their developing brains.

Second Place

Effect of Liquid Fertilizer on *Lumbricus terrestris* Growth

Samantha Lionberger *George Moody Middle School*

Lumbricus terrestris is a vital species of worm because it brings the organic matter to deeper layers of soil. Liquid fertilizer is a man-made product used in gardening, which uses elements in a solution to make the soil more nutritious (Falls, 2005). According to previous studies, fertilizer helped increase the population of worms (Tiwari, 1993) (Edwards, 1982). If a certain amount of fertilizer harms *Lumbricus terrestris*, then gardeners, lawn workers, farmers, and worm farmers. will need to know about it. If the worms were killed, the ecosystem could suffer because of the loss of the species. It was hypothesized that if zero milliliters of liquid fertilizer were added to the soil, then the *Lumbricus terrestris* would have the highest average growth rate.

First, forty containers were purchased. Next, the containers were filled with soil. Then, the proper amount of liquid fertilizer was added to the containers. Afterwards, one worm was measured and placed into each container. Finally, the containers were labeled with a sticky note and a sharpie. Proper safety precautions were used when handling the materials. This included having an adult present when drilling the holes into the containers, wearing protective gloves, and having an adult present when measuring.

The results showed that *Lumbricus terrestris* had the highest average growth rate in the soil with five milliliters of liquid fertilizer, with a mean of 0.6 cm per week. The container with zero milliliters of liquid fertilizer had an average of 0.57 cm per week, while ten milliliters had 0.4 cm per week. The container with fifteen milliliters had the lowest average with 0.28 cm per week. Based on the data the experiment showed that the hypothesis was not supported. Instead, the soil with five milliliters of liquid fertilizer had the highest average growth rate.

Honorable Mention

The Effect of Therapeutic Hypothermia and Whole-Body Vibration on the Behavioral Response of *Drosophila* Following Traumatic Brain Injury (TBI)

Aahana Puri *George Moody Middle School*

A traumatic brain injury (TBI) is a violent blow or collision to the head or body which impacts the normal functions of the brain. Traumatic brain injuries are a leading cause of mortality and disability worldwide. Current treatments can be invasive and not very effective, prompting the need for safer and more effective treatments. Thus, the purpose of this experiment was to investigate the effects of therapeutic hypothermia (TH) and whole-body vibration (WBV) in treating traumatic brain injury.

An apron, gloves, and goggles were worn throughout the experiment. A high-impact-trauma (HIT) device was used to inflict *Drosophila* with a traumatic brain injury. A 16°C cooler and vibration mat were used to expose the flies to therapeutic hypothermia and whole-body vibration respectively. *Drosophila* were separated into the control (no TBI, TH, or WBV), TBI, TBI with TH, TBI with WBV, and TBI with both TH and WBV. It was hypothesized that if *Drosophila* with a TBI were exposed to therapeutic hypothermia and whole-body vibration, the flies would react with the greatest improvement in behavioral response. *Drosophila* responses were measured using geotaxis and phototaxis behavioral tests. WBV following a TBI not only restored the flies' behavioral response to control levels but resulted in a 20% increase in phototaxis response and 5% increase in geotaxis response relative to the control. TBI followed by TH and WBV restored the phototaxis response to control levels and increased the geotaxis response by 10% relative to the control as well. This experiment indicates that TH and WBV used independently and in combination are potential treatment options for traumatic brain injury. Since both of these are newer treatments, future studies would involve varying testing times, treatment intensity, and the severity of TBI.

Third Place

The Effect of Sugar Substitute and Glucose Concentrations on HepG2 Human Liver Cancer Cells

Nishorgo Sarkar *George Moody Middle School*

Hyperglycemia is the excess of glucose in the bloodstream and is a major factor of diabetes. Because of this, many consume sugar substitutes to avoid hyperglycemia. Liver cancer is also a major public health crisis with some evidence of links between cancer and both hyperglycemia and sugar substitutes. The purpose of this experiment was to investigate the links between hyperglycemia/diabetes, sugar substitutes, and cancer. It was hypothesized that if Dulbecco's Modified Eagle Medium (DMEM) is concentrated with sugar substitutes and glucose, then HepG2 human liver cancer cells will have proliferation equal to the control and increased proliferation respectively. In the experiment, HepG2 liver cancer cells were cultured in DMEM in five separate groups, these being the control, with 1 g/L of glucose in DMEM during culturing, high glucose with 4.5 g/L of glucose, and aspartame, steviol glycoside (stevia), and saccharin, with 4.5 g/L of each respectively. The proliferation of each group after 5 days was measured with an MTT assay and then recorded. After the MTT assay, the control had an absorbance of 0.74 absorbance units under 600 nm, the high glucose group had 0.68 Abs units, aspartame had 0.65, stevia had 0.69, and saccharin had 0.67. Both standard deviation and a t-test was performed, with only aspartame being significant in both. Aspartame and saccharin have been shown to not be carcinogenic and recent years, with Stevia rebaudiana and sister species having possible therapeutic effects against cancer, possibly describing the lower proliferation. The data for the high glucose group was not supported by most data available, which showed the hyperglycemia led to increased cancer proliferation.

Chemical Science (MS CS)

The Effect of Material of Container on the pH of Water

Shriya Bandla *George Moody Middle School*

The purpose of this experiment is to find which type of container has the most impact on change of pH of water after 24-hours of storage. The goal of this experiment is to understand how the type of container of water storage can help with improving the health. It is understood that water with a pH around 7 or slightly alkaline is good for human health. pH stands for Potential of Hydrogen. It can be used to test acidity/alkalinity levels of water. Low pH can corrode or dissolve metals. High pH can give water a bitter taste. The hypothesis of the experiment is that water placed in copper container will have the highest change in pH. Readings were taken 10 different times. During each trial, water was stored in containers with different materials for 24 hours. 5 different types of material cups were taken. Then, the experimenter poured water from a pitcher into all the cups equally and measured the pH of all the cups. Then the experiment left the water cups for 24 hours. The pH of all the cups were wrote in a notebook. After 10 days, the data collected was analyzed. Water in all the containers increased in pH. The pH of water in the copper container increased the most. The water in the paper cup increased the least. This validates the hypothesis that copper container has the highest increase in pH of water after 24 hours of storage.

Honorable Mention

The Effect of Different Cleaning Agents on the Removal of Purple Acrylic Paint

Sonvi Chawla *George Moody Middle School*

The researcher tested the effect of different cleaning agents on the removal of purple acrylic paint. Hydrogen peroxide, rubbing alcohol, and white vinegar were all used as cleaning sources, but also contain diverse components in them, making them potential removers for acrylic paint. The purpose of conducting this experiment was to determine the best replacements for latex paint strippers and solvents. Paint thinners are used to thin out the paint and they can help scrape off paint easily. This liquid is not used on canvases, which is why the researcher hoped to find a solvent that can whiten or clean off acrylic paint. Before conducting this experiment, the tester primed all the same canvases with a white paint and water mixture. All the canvases were then left to dry for 24 hours. Then, the conductor gathered purple acrylic paint to apply on the canvas, making sure each IV level was marked correctly with ten lines below the name of the cleaning agent. One splotch of the same purple paint was applied on the primed canvas, and then was removed with the IV level one minute after. Each liquid had exactly ten trials and the same amount of paint applied on. A q-tip was used to remove the paint with the solvent. It was dipped in the liquid ten seconds before the time ran out, and after, was stroked four times across the splotch of paint. It was then flipped over and stroked back three times to dry it off. It was hypothesized that if rubbing alcohol was used to remove purple acrylic paint one minute after being applied to the canvas, then it would remove more pigment than the other solvents. Each splotch of paint was rated 1-3 on how efficient the solvent removed the paint. The hydrogen peroxide and white vinegar both removed splotches that were rated a three. The rubbing alcohol was the least effective. To improve this experiment, more liquids that are used to bleach or whiten dye should be used.

Honorable Mention

The Effect of the Temperature on the pH of Orange Juice

Myra Clark *Williamsburg Middle School*

The objective of this experiment is to measure the effects of varying temperatures of aqueous solutions (i.e., orange juice) on the pH of those solutions. It is believed that increasing storage temperature increases juice acidity, which can bring about worsened dental erosion. Dental erosion is caused by citric acid in orange juice wearing down the teeth and breaking chemical bonds in the teeth, leading to cracked, yellowed, chipped, and excessively sensitive teeth. Dental erosion can be quite painful and uncomfortable, and extremely damaging to the enamel, causing an increase in the risk of cavities, and poor dental health. This process can be accelerated by consuming products with a lower pH (higher acidity), and if warmer orange juice is found to have a lower pH, it is bound to speed up this process of dental erosion. To measure the effects of the storage temperature on orange juice acidity, five different storage temperatures were tested including -12°C, 3.9°C, 18.33°C, 95.056°C, and 100.22°C. Ten repeated trials were conducted for each level of the independent variable, with the dependent variable being the pH of the orange juice after being left in the environment of a specific temperature for 20 minutes. A notable trend in the data from this experiment is that the pH increases by approximately 0.042 as the temperature declines, and as the temperature of the orange juice escalates, the pH decreases by on average, 0.042. The room temperature/control level (18.333°C) orange juice's average pH was 3.793, the -12°C juice's average pH was 3.903, the 3.9°C juice's average pH was 3.828, the average pH of the juice kept at 95.056°C was 3.762, and the average pH of the orange juice stored at 100.22°C was 3.735. Based on the results of this experiment, it is conclusive that drinking warmer orange juice will speed up dental erosion because of the higher acidic content in the beverage when compared to the acidity of orange juice at a lower temperature. The pH of orange juice declines as the temperature increases, and the pH increases when the temperature decreases, because of the hydrogen ion concentration increasing as the temperature decreases, causing it to be less acidic, and the hydrogen ion concentration decreasing as the temperature increases, causing it to be more acidic.

The Effects of Different Solvents on Permanent Marker Ink

Adam Islam *Kenmore Middle School*

The purpose of this study was to investigate the effectiveness of different solvents on erasing permanent marker ink. This experiment hypothesized that the Goof Off® ink remover would erase the initial square of the permanent marker (Sharpie) with the least number of strokes. The independent variable was the type of treatment used which include water, a 1-to-4 ratio of soap and water, isopropyl alcohol, nail polish remover (Cutex® brand), and Goof Off® ink remover. The dependent variable was the number of strokes it took to erase the initial square of the permanent marker and the amount of smudging that it left. The control group was a permanent marker ink square that was stroked with a dry cotton swab. The constants were the area of the ink squares, the amount of solvent, the surface the ink was on (polished stone tile), and the way the ink was stroked. In the experiment, a cotton swab was dipped into one of the solvents then stroked in an upward motion on one of the squares of ink. After the initial square of ink was erased or 100 strokes were reached, a paper towel was used to wipe off the excess solvent and to dry the tile. The results show that the rubbing alcohol performed the best with an average of 10 strokes (rounded) to erase the initial square and left minimal smudges. The water, water and soap combination, and control all took over 100 strokes. The water and soap combination erased a little more of the ink than the control and water, but there was not a significant difference. The nail polish remover averaged 14 strokes (rounded) and left very dark smudges. The Goof Off® ink remover averaged 17 strokes (rounded) and left the least number of smudges out of the 5 solvents. These results do not support the hypothesis because Goof Off® did not perform the best when removing the ink. Overall, the study suggests that rubbing alcohol (70% isopropyl) is the best solvent as it needs the least number of strokes to erase permanent marker ink.

The Effect of types of Metals on Corrosion Rate

Richard John *George Moody Middle School*

Metals have different rates of corrosion which is affected by its reactivity which is affected by the structure of their valence electrons. The goal of this project was to discover the logistics on what metals were corrosion resistant and what metals were liable to corrosion. This would be a highly useful information source for determining which metals should be used for which part of a structure in different corroding environments. The hypothesis created was “If the type of metal is more reactive than the rate of corrosion will be high”. The experimenter first gathered the required materials and metal planes: steel, copper, aluminum, zinc, and lead. Then the experimenter deoxidized the various metals using bleach and then washing with water to ensure that there isn’t any previous corrosion left. Next the experimenter used a scale to measure the mass of each metal sample. Then the experimenter placed the metal samples into hydrochloric acid and waited 4min.Immeadietly the experimenter placed the metal into a glass water container. Then finally they dried them off and made bar graphs of the recorded data using Microsoft Excel. The higher reactivity metals zinc and aluminum were found to have a higher corrosion rate than the lower reactivity metals: steel, copper, and lead. In grams per hour Zinc had a corrosion rate mean of 2295.5171714286 and Aluminum had a corrosion rate mean of 180.06405714286. While also in grams per hour Steel had a corrosion rate mean of 0.67132142857143, Copper had a corrosion rate mean of 0.19012142857143, and Lead had a corrosion rate mean of 0.99816428571429. In conclusion the hypothesis was supported by the data provided by the experiment.

The Effect of Temperature on an Enzyme Catalyzed Reaction

Neel Joshi *George Moody Middle School*

First and foremost, many people know that an enzyme catalase solution performs well in warm environments and does not perform well in cold environments, but what if someone were to perform an enzyme-catalyzed reaction in extreme colds? The purpose of this experiment was to collect data on how an enzyme catalase solution works and if it would work in extreme colds. The hypothesis was based on the many articles and websites that said an enzyme-catalyzed reaction would perform better in warmer environments. If a person were to perform an enzyme-catalyzed reaction the first steps they would take would be to gather all the materials and create 4 enzyme catalase solutions. Next, the person in the context would cut up 28 3 by 3 cm squares. After this step, the person would put the coffee filters aside and set the enzyme catalase solutions where someone would want to put them and set a 30 min. timer. After 30 minutes the person will take the solutions at room temperature and start by dipping one coffee filter into the solution for 5 seconds and then with tweezers drop it carefully into the hydrogen peroxide watch until the coffee filter square sinks and rises where a person would time into their notebook, complete this procedure 7 times. The results proved that warmer temperatures are better when an enzyme-catalyzed reaction is occurring, but in the extreme colds the enzyme-catalyzed reaction performed better than I thought it would. In conclusion, an enzyme-catalyzed reaction will always perform better in warmer temperatures. Safety precautions were taken in this experiment.

The Effect of Heat on the Time it Takes Grease to Solidify

Logan Krohl *Kenmore Middle School*

I tested the effect of heat on grease to see if it makes it take longer to solidify. I did this to see if you were to put grease down the drain if the temperature of the grease would make it stay liquid for longer. The goal of this project was to find the effect of heat on grease. How I did this was by frying two pounds of bacon for grease. Then I put one tablespoon of grease in nine different cups. Three cups went in the refrigerator, three went into the freezer and three stayed at room temperature. Every thirty minutes I checked their temperature and if they were solid or not. If they did not leave anything on a toothpick then they were solid. I did this for ten hours. After ten hours all the grease had solidified. The three cups of grease in the freezer solidified after one hour. The three cups of grease in the refrigerator had solidified after three hours. The three cups of grease at room temperature took ten hours to solidify. This information tells me that no matter what you do to grease it will not stay liquid long enough to make it to the plant. My objective was to find a way the grease could get to the treatment plant instead of getting thrown out, but it will be impossible.

Second Place

The Effect of the type of browning prevention method on the brownness of Red Delicious apples after 24 hours

Julie Daisy & Marco Maxwell *Swanson Middle School*

Imagine cutting up an apple to take with you for lunch at school or work. You cut it up at 6:30 pm the night before and leave it in your lunchbox until the next day. At lunchtime, you open your lunchbox, hoping for a nice, crisp apple to sweeten your day, but instead, you find a bag of brown, mushy apple slices. The following experiment was conducted to find a way to prevent this disgusting phenomenon from happening, and to see whether lemon juice, a chemical commonly applied to apple slices, is truly the best method. After testing five different methods (cold water, lemon juice, salt water, honey water, and nothing) on a total of 40 apple slices and leaving them in a Ziploc bag for 24 hours, a rating scale was used to measure how much each slice had browned. These methods were chosen because of their popularity, and because they don't require materials that aren't easily found at a grocery store. On a scale of 1-10, 1 being the least and 10 being the brownest, the apple slices where lemon juice had been applied rated at an average of 3.25, the lowest of any method. The apple slices with no method applied on them were given ratings that averaged at 4. This was the control of the experiment. The conclusion that resulted was that applying lemon juice really is the most effective strategy to reduce browning on apples. If the experiment were to be repeated, the rating scale should be replaced by a quantitative form of analysis, for example measuring the square centimeters of brown on each apple slice. Safety protocols were followed while cutting the apples to ensure the safety of the experimenters. The goal of this experiment was to improve the way apples are kept and stored, in periods of time where they are not being eaten, to reduce browning, something that will greatly benefit the lives of all those who love apples.

Third Place

The Effect of Various forms of Analgesic Medications on its Solubility in Simulated Gastric Acid

Ira Prakash *George Moody Middle School*

Analgesics are drugs used to relieve pain that target the peripheral and central nervous systems. The medicines are broken down in gastric acid and then release the nutrients from the medicine to the bloodstream. Scientists have created several forms of the medication Ibuprofen which will alter the time taken to dissolve in gastric fluid. Chewable Tablets, liquids, tablets, and capsules are only few of many formulations in which the medicine is distributed. Results of this study will bring awareness to the health of many so fewer humans are in pain for a less amount of time. In this investigation, the form of each Ibuprofen medicine placed in the acid was the independent variable, and the solubility of the medication in simulated gastric acid was the dependent variable. Based upon prior research if the uncoated oral pill was placed in a beaker filled with simulated stomach acid, then it would be the most soluble and dissolve the fastest. In order to calculate solubility, the shake-flask method was utilized resulting in using glass vials. During the procedure, precautions were taken for the safety of the scientist and the environment. Two 500 mL bottles full of simulated gastric fluid was distributed into the four beakers, 60 mL each. During the dissolution process, the flasks were frequently observed. The gel-coated pill (Flask B) had the greatest mean of 37.7 minutes compared to the liquid in Flask C with the lowest mean of 12.2 minutes. The liquid exhibited the fastest dissolving rate, followed by the chewable tablet, then Ibuprofen's uncoated tablet, and lastly, the Gel capsule. This data did not support the research hypothesis. The findings were consistent with similar research. According to a previous study, gel capsules take longer to dissolve due to their external coating. Since a gel capsule contains an additional external layer, it lengthens the dissolving rate of the pill. This improvement of regulating the temperature to the heat inside the average human body will ensure that the properties of the stomach acid will remain the same in and out of the stomach.

The Effect of Bases on Staurolite

Daniel Simon *Louise A. Benton Middle School*

The objective of my research was to find ways to soften silicates and to test which tool would soften them most. I was specifically interested in softening the silicates which encase Staurolites. A silicate is a salt in which the anion contains both silicon and oxygen. Staurolite is a silicate mineral, which forms crosses. The main chemical difference between Staurolite and the silicates which surround them is the higher iron content of the encasing silicate. To soften the encasing Staurolite, I boiled the silicates with baking soda and soap and then tested them on the Mohs scale of hardness. The reason I wanted to find ways to soften silicates was because of my interest in rocks and minerals, and my desire to obtain “clean” Staurolite samples. My data showed that silicates softened more when boiled with baking soda but hardened over time when boiled with soap. My data showed that the method of using a knife was more effective in removing the silicate. For safety I used eye protection, a well-ventilated room, tied back long hair, wore long sleeves, and let the stones cool before touching them.

Honorable Mention

The Effect of SPF on Ultraviolet Exposure

Alexander Thomas *Swanson Middle School*

In this project, different strength sunscreens (15, 50, and 100 SPF), as well as aluminum foil, and facial tissue were tested to see how much ultraviolet (UV) light would pass through the material. During testing, the material was placed over a UV sensor, which measured the amount of UV light passing through. The data was recorded, and the material was swapped for a different one. After testing, some interesting conclusions can be made. First, the data shows that each higher tier of sunscreen did better than the last, supporting the hypothesis that higher SPF sunscreens would block more UV light. Even so, the results from the 50 and 100 SPF sunscreens were closer than expected. The 50 and 100 SPF were closer together than the 15 and 50 SPF, showing that there is less needed to get the highest SPF rating possible. Additionally, the data shows that aluminum foil is excellent at blocking UV light, as it never reads above 0, and that the facial tissue – which was meant to mimic clothing – was slightly better at blocking UV light than SPF 100. Some places for experimental error would be in the distribution of sunblock, which would alter results, and in the changing in base UV light levels. The experiment could be extended by testing the sunscreens effects over time, as well as testing different isolated active ingredients in the sunscreens. In conclusion, the data did support the hypothesis, and the data suggests that there is no need to buy the highest SPF possible.

First Place

The Effect of the Type of Salt on the Amount of Corrosion of Steel Wires

Ophelia Tulchinsky *Dorothy Hamm Middle School*

This experiment looked at the effect of the type of salt on the amount of corrosion of steel wires. The purpose was to model cars (wires) interacting with road salt (salts) and acid rain (vinegar). Acid rain comes from the pollution emitted by electrical power plants, and road salt comes from humans, deicing roads during icy conditions. One problem with acid rain is that it lowers the pH of the groundwater. When acidic clouds precipitate, the resultant acidic rain corrodes cars, buildings, bridges, etc. Road salt also corrodes objects, especially the roads. Cars driven over salted roads pick up salty road spray on the bottom of the vehicle, which then begins to corrode the cars/trucks. To explore the possible relationship between types of salt and corrosion, steel wires were used to simulate a car body panel. The wires were put into a bath of vinegar and one salt and covered. The wire/salt experiment was left for 3 weeks, undisturbed. Afterwards, the width of the grown corrosion at the exposed tip and the waterline of the wire were measured. The mass of the grown corrosion was also measured. The salts used were sodium chloride (NaCl), potassium chloride (KCl), magnesium sulfate (MgSO4), calcium sulfate (CaSO4), calcium dichloride (CaCl2), magnesium dichloride (MgCl2), and as a control solution, no salt was added to the vinegar bath. The width of the corrosion was measured at the tip of the wire and the control had the largest mean width at this location (6.78 mm). The calcium sulfate had the largest mean width at the waterline (6.38 mm). The calcium dichloride had the smallest mean width at the tip (2.72 mm), and smallest mean width at the waterline (2.07 mm). The control had the largest amount of mass (0.4403 g) and the calcium dichloride had the smallest (0.0872 g). These results indicate that adding salt to vinegar inhibits corrosion of steel.

Ecology & Earth Sciences (MS EE)

Honorable Mention

The Effect of different Concentrations of Sucralose on the Heart rate of a *Daphnia magna*

Aditya Badhrayan *George Moody Middle School*

The *Daphnia magna* or “water flea” is an organism that inhabits freshwater bodies and is known to clear up debris in their environment. Sucralose, an artificial sweetener, makes up 95 % of all artificial sweeteners in freshwater bodies and is known to hinder and affect the internal processes of the *Daphnia magna*. However, there was no research present on how Sucralose affects the heart rate of the *Daphnia magna*. Therefore, the experimenter decided to conduct an experiment on whether Sucralose affects the heart rate of the *Daphnia magna*. The hypothesis of the experiment was that if there was a greater concentration of Sucralose present in a Sucralose-Water solution, then the *Daphnia magna* would have an increased heart rate. There were 5 Levels of the Independent Variable. The control, which contained no Sucralose and fresh spring water to mimic the natural environment of the Daphnia magna. The experimenter then had 4 solutions of Sucralose and water with 25 % Sucralose, 50 % sucralose, 75 % Sucralose, and 100 % Sucralose of the max saturation of Sucralose in water. A microscope was used to view the heart rate of the *Daphnia magna* and there were ten trials for each Independent Variable. The experimenter used all appropriate safety precautions and measures when handling objects with glass such as the magnifying lens. Furthermore, all safety measures were taken when measuring the heart rate and disposing of the *Daphnia magna*, which was done by flushing them down the drain. The heart rate was measured in beats per minute (bpm). The hypothesis of this experiment was proven as the *Daphnia ma*gna that was present in a solution with a greater amount of Sucralose had a higher heart rate than the *Daphnia magna* present in the lesser concentration. However, the *Daphnia magna* in the 25 %, 50%, and 75 % solutions had a decreased mean heart rate than when in the control, meaning that although an increased amount of Sucralose leads to an increase in heart rate, the *Daphnia magna* still had a decreased lesser heart rate than when present in the control. This research conveys that to prevent harm to the *Daphnia magna’s* heart, which could lead to other damages, we must control the amount of Sucralose and other artificial sweeteners that are thrown into the environment.

The Effect of Oxybenzone and Zinc-oxide based Sunscreen on *Juncus inflexus* in a Simulated Marsh Environment

Renn Clark *George Moody Middle School*

Oxybenzone is a toxic ingredient in many sunscreens that can harm aquatic environments. The Chesapeake Bay is home to marshlands that can act as a nursery for juvenile fish and filters pollutants from run off. The purpose of this experiment was to evaluate the harmful effect chemicals in sunscreen can have on aquatic plants (*Juncus inflexus)* in a simulated wetland. *Juncus inflexus* were separated into four different groups and exposed to a 0.1% concentration oxybenzone sunscreen, zinc-oxide sunscreen, a 0.01% concentration oxybenzone sunscreen or no sunscreen. All safety procedures with adult supervision, were followed during the experimentation of this project. On day 1 group A (0.1% oxybenzone) had a cumulative stem length of 7,470 centimeters and on day 31 had 16,428 centimeters. Group B (0.01% oxybenzone) originally had 8,730 centimeters of cumulative length and on day 31 had 23,141 centimeters. On day 1 Group C (zinc-oxide 0.1%) had a cumulative stem length of 6,510 centimeters and after day 31 had a total of 18,276 centimeters. The control group (Group D) originally had a cumulative stem length of 6,750 and after day 31 had 25,492. The control group did significantly better than sunscreen groups A, B, and C in a student's t-test. The oxybenzone based groups and the zinc-oxide based group showed similar growth. Since all groups had significant growth, it is difficult to determine if the experimental arms containing sunscreen were harmed. The lack of harm to the plants in the oxybenzone groups may be due to the filtering effects of a simulated marshland environment. While these results are intriguing more research is needed.

Honorable Mention

The Effect of Public Transportation Use on Carbon Footprint per Capita

Emma Hemsch *Dorothy Hamm Middle School*

The purpose of this analysis was to determine the effect of a city's number of public transportation trips per capita on the city's carbon footprint per capita. It is commonly believed that public transportation use reduces the carbon footprint of people who use it regularly. It was hypothesized that if the number of public transportation trips per capita was higher, then the carbon footprint per capita would be lower, because when more people use public transportation instead of their own personal vehicles, there are less greenhouse gas-emitting vehicles on the road in total. The researcher used data from one source study for each variable. The two studies were chosen for their accessibility, simplicity, and credibility. The data for both variables was collected for 28 cities and entered into a data table. Then, the data was turned into a scatter plot graph to be analyzed more easily. Overall, the carbon footprint per capita was slightly higher in cities with more public transportation trips per capita. However, when the numbers of public transportation trips per capita were in two specific ranges, there was a more obviously positive trend in the carbon footprints per capita, excluding several outliers. The results of this analysis could indicate that cities with more public transportation trips per capita usually have a higher carbon footprint per capita.

Third Place

The Effect of Water Filter Design on Water Clarity

Nadia Lach-Hab *Dorothy Hamm Middle School*

The purpose of this experiment was to find an easier and more affordable way to find access to safe drinking water through water filtration as it is a pressing and very concerning problem right now. While conducting research, the researcher found two types of accessible and low-cost water filter types: sediment water filters, containing sand and pebbles, and activated carbon water filters. It was hypothesized that the activated carbon water filter (water filter B) would clean water better as activated carbon cleans water through absorption where most of the toxins and harmful bacteria are taken out of the water. To test this hypothesis, two water filters were constructed, one containing activated carbon, pebbles, and cotton balls, and the other containing sand, pebbles, and cotton balls. Pebbles can filter out big particles while cotton is already a basic filtering material. The project was testing the effect of water filter design on water clarity measured through exposure value in both two types of water filters. To complete this experiment, water samples were collected from a local river water source and placed through each of the researcher's homemade water filters three times. The samples of water that ran through the water filters were recorded and analyzed on the day of conducting the experiment. The Arduino my Science Journal application was used to measure exposure value, the amount of brightness that passes through an object. The researcher's hypothesis was rejected: the water filter containing sand had a relative exposure value of 6.9, the filter containing activated carbon had a relative exposure value of 6.6, and the untreated water samples had a relative exposure value of 1.3. This indicates that sand can filter out pollutants and create a big impact on purity.

What is the Effect of the Type of Soil and Contamination of Soil (Styrofoam) on the Survival *of Eisenia fetida*?

Eloise Minnigh *Williamsburg Middle School*

The purpose of this experiment was to determine the most suitable soil to facilitate the highest rate of reproduction in *Eisenia fetida*, a species of epigeic earthworm commonly known as compost worms*. Eisenia fetida* requires moist soil with sufficient organic matter to grow and reproduce. *Eisenia fetida* leaves behind nutrient rich castings and, thus, their prevalence is one key indicator of the health of the soil's ecosystem. In this experiment, three different types of soil were tested with and without Styrofoam contamination to see how many worms were alive after eight weeks. For each of the six types of soil, ten worms were put in a bucket. After the appropriate amount of time passed, the number of worms remaining alive in the buckets were counted. Once a week, 60 ml of water was given to the *Eisenia fetida*. It was expected that the compost soil without the Styrofoam contamination would have the most worms because compost soil has the most nutrients. Testing rejected the hypothesis that the compost soil without the 1tyrofoam contamination would have the most worms because compost soil had the least number of worms after eight weeks, whereas topsoil and soil from Arlington backyard (red clay) contaminated with 1tyrofoam had the most. The levels of variation were low; therefore, the data are most likely reliable. The red clay soil contaminated with 1tyrofoam had the highest level of variation and the compost soil and compost soil contaminated with 1tyrofoam had the lowest variation. The hypothesis for this experiment was rejected. The topsoil and soil from Arlington backyard (red clay) contaminated with 1tyrofoam proved to be the most suitable environment for the worms.

What is the Effect of Green Roofs on Building Temperature?

Charlotte Minnigh *Williamsburg Middle School*

The purpose of this experiment was to determine whether green roofs, also known as vegetated roofs, have an effect on the temperature of a building. Understanding how green roofs affect temperature is a key component of the work to eliminate Urban Heat Islands (UHI's). Urban Heat Islands are significant contributors to climate change by increasing energy demands and heating water runoff to the detriment of local marine life. Therefore, effectively utilizing green roofs to reduce UHI's could have a significant impact globally. In this experiment, three shoe boxes were modified to represent buildings. Sod, tar paper, and thermometers were purchased and added to the shoe boxes to create models representative of both buildings with and without a green roof. The tar paper and sod were added to the tops of the boxes accordingly. The thermometers were left in a room temperature place for 5 minutes, to make sure of minimal variation between the thermometers. The thermometers were placed inside the three boxes. The boxes were first left in a dark place for 30 minutes, then the temperature was immediately checked. The boxes were then left in a sunny place for one hour. The temperature was then immediately checked. The boxes were then left in a dark, cool place again for 15 minutes, and then an additional 15 minutes. Temperatures were checked accordingly. Tar paper heated up to the highest temperature but also cooled down to the lowest temperature. The green roof stayed within a narrower range of temperatures, due to the process of transpiration. During transpiration, water that is pulled from the leaves into the atmosphere also pulls the extra heat from the plant. Shading and color absorption also play a role in how green roofs affect temperature.

Honorable Mention

The Effect of Electromagnetic Field Density on the Biomass of *Chlorella vulgaris*

Anna Mohanty *Williamsburg Middle School*

The purpose of this experiment was to determine the effect of the flux density of an electromagnetic field on the biomass of the algae, *Chlorella vulgaris*. More efficient ways to increase the biomass of algae is crucial to biofuel production, which could be key in lowering carbon emissions. Algae is a promising biofuel source; however, it is commonly treated with large quantities of fertilizers to aid in growth (Miller, 2019), which is detrimental to both the environment and the biofuel quality. This experiment was completed by exposing cultures of *Chlorella vulgaris* to increasingly dense electromagnetic fields. A solenoid wire was coiled around one beaker five times, which connected via the wire to one coiled ten times, which was then connected to one coiled 25 times. An increase in the coils around the beaker meant an increase in the electromagnetic field density around that beaker. The wire was connected to an iron nail and an electrode current source. This and a control group were left for 150 hours; the cultures biomass being taken, then examined under a microscope for any cell abnormalities every 24 hours. The hypothesis— that the sample with five coils of density would have the greatest increase in biomass— was supported. It increased the most in biomass of all the groups. The ten coiled increased slightly, and the 25 and control groups decreased in biomass on average. On this basis, a low-density electromagnetic field would best assist in increasing the biomass of *Chlorella vulgaris* for biofuel usages

Second Place

The Effect of Salinity on Soybean Growth

Dylan Tallis *Thomas Jefferson Middle School*

The purpose of this study is to investigate the effect of salinity on soybean growth. The independent variable is the salinity of the water used to grow the soybeans (0-ppm, 1,000-ppm, 3,000-ppm, 10,000-ppm, and 35,000-ppm salt solutions). The control group is the 0-ppm salt solution. The constants are the number of seeds, amount of solution, temperature grown in, and time grown. The dependent variable is the growth of the soybeans. The hypothesis is: if the soybeans are grown in a 3,000-ppm salt solution then they will grow the fastest. This study is important because it shows ways to use farmland affected by saltwater intrusion and lessen the dependence on desalination. Three trials of five bags contained five soybeans, a paper towel, and 20 milliliters of salt solution each. All bags were placed in a cooler with a heating pad, to maintain temperature, and grown for five days. Each day the growth of the soybeans was measured with a string marked at every half centimeter. The data shows that soybeans germinate fastest when grown in a 3,000-ppm salt solution. These results support the hypothesis. In conclusion, the results suggest that full desalination isn't needed for agricultural purposes and that slightly saline water will help the crops grow, possibly even more than desalinated water would. Other studies that should be done are testing different soil salinities and different plants.

First Place

The Effect of Silver Nanoparticles on The Death Rate of Adult *Daphnia magna*

Annabelle Van Saun *George Moody Middle School*

Silver nanoparticles (AgNPs) are antibacterial, microscopic particles of silver utilized in applications across a diverse range of commercial consumer products. AgNPs are substantial contributors to runoff and ecosystem pollutants making them extensive threats to the organisms inhabiting the surrounding areas. In addition, in aquatic systems, AgNPs undergo physical and chemical transformation (e.g., agglomeration, settling) releasing Ag+ ions which are lethal to bacteria. *Daphnia magna* are small planktonic crustacean that commonly inhabit runoff collections and other freshwater bodies and are susceptible to change in water chemistry. The purpose of this experiment was to determine if AgNPs have an effect on adult *Daphnia* death in the following concentrations of three, six, nine, twelve, and 24 drops. Appropriate safety procedures were employed throughout this work. Groups of 30 adult *Daphnia* were collected and placed in eighteen spring-water-filled containers. Varying amounts of AgNPs were then introduced, with three repetitions done at each treatment rate. Over the course of ten days, the total number of dead *Daphnia* in each container was recorded daily. The results indicated a dose-response with the *Daphnia* introduced to the highest levels of AgNPs having the highest mortality rate with an average of 2.7 deaths per day when compared to the control average of 0.3 deaths per day. This data supported the research hypothesis that if groups of 30 adult Daphnia Magna were introduced to three, six, nine, and twelve, and 24 drops of 500 ppm AgNPs, then the Daphnia receiving 24 drops would die at the fastest rate. Throughout the experiment, it was noticed that the breakdown of dead *Daphnia* and the biodegradation of food cluttered the water before being removed daily. However, before it can be concluded that this may have contributed to or affected the overall death rate, further research and experimentation will need to be executed.

Engineering & Technology (MS ET)

Effect of Paper Boat Design on Time and Mass Recorded

Shangwen Cheng *Kenmore Middle School*

The purpose of this experiment was to test which origami boat design was most efficient. Four different designs were tested, and both the time they could stay afloat and the amount of mass (measured in beads) they could support were recorded. Design A was the control with no added features, Design B had tape attached to the bottom, Design C had a paperclip for structure, and Design D had both tape and a paperclip. It was hypothesized that Design D would do the best, as both added features were designed to help. Overall, Design B performed best, with a mean of 335 seconds afloat and 50 beads held. Second was Design D with an average of 281 seconds and 50 beads, and Design A was next with 252 seconds and 50 beads as well. Design C performed the worst overall, with a mean of 96 seconds and roughly 41.3 beads. The hypothesis was not supported, due to lack of supporting data.

Honorable Mention

How a Do-It-Yourself Mindset Became the Impetus for a Homemade Smart Mirror

Jarin Earle *Thomas Jefferson Middle School*

The primary objective of this project is to construct a “smart mirror” that is less expensive than those currently on the market. A smart mirror is a device that reflects the user’s image as well as an electronic display. My approach is to research the process of creating a smart mirror using the internet and YouTube and find equivalent, but less expensive components to build it. I built a smart mirror from scratch using social media and the internet and was able to produce a functional product with similar features to the professionally built devices. I demonstrated that individuals could own a high-quality smart mirror by researching the process and building it themselves.

Second Place

Herbal Low-cost Water Filters

Krish Gupta *Swanson Middle School*

Lack of access to clean water is a global issue which is known to lead to various diseases and significant suffering. Regular water filters rely on the principles of adsorption where dirt particles adhere to solid surfaces due to electrostatic charge and thus improves the quality of water. The goal is to design and study an efficient, low cost, easy to assemble water filter utilizing herbs that could be used in tropical rural areas having poor access to clean drinking water and compare its efficiency with regular water filters made from sand, gravel and cotton. Two natural and widely available indigenous herbs (*Azadirachta indica* commonly known as Neem and *Ocimum tenuiflorum* commonly known as Tulsi) were added to the regular filters. Then changes in water quality of the sample collected from a local river were tested. The results showed a reduction in water hardness and harmful nitrates while alkalinity and pH improved with the herbs. However, it indeed adversely affected the water clarity. It was concluded that natural herbs can be added to regular filters to improve water quality in a cost-effective manner. Adequate safety precautions were taken for handling of materials and careful disposal of materials, upon completion of experiment including adult supervision.

The Effect of Different Sport Helmets on Melon Splatter

London Hart *George Moody Middle School*

I think we can all agree that we want to save safe while doing something we love. If you use the proper protection gear you can! The purpose of my experiment is to try and find the helmet that will best protect your head while you play sports. Different sport helmets are created for the designated sport depending on the amount of damage and danger they can cause. I experimented various types of helmets on a cantaloupe to resemble your head. My independent variables were the different helmets I used football, softball, lacrosse, and no helmet for the control group. My independent variable was the amount of breakage and cracks in the cantaloupes. I had ten trials for each independent variable level all using new cantaloupes. I dropped the melons from 10 feet 5 inches which is also 3.2 meters. After they were dropped, they were placed to the side for examination where I filled in my data table with the number of cracks, the original circumference, and the largest and smallest crack lengths. The control, no helmet had the highest average (mean) number of cracks and the highest lengths of cracks. The softball helmet had the 2nd highest average amount of cracks and the 2nd highest lengths of cracks. The lacrosse helmet had the 2nd lowest average amount of cracks and the 2nd shortest lengths of cracks. And the football helmet had the lowest average amount of cracks and the shortest lengths of cracks. This experiment can help people find out if what helmet they are using can protect them. Although some may work more than others, it generally depends on the sport you decide to play for which helmet you should use.

The Effect of Rotational Speed on the Light Reflected by Parabolic Reflectors

Soumya Khadye *George Moody Middle School*

Birds often collide with cars, due to their lack of response to accelerated speeds. As a result, millions of birds die directly from car crashes in the United States alone. Although, parabolic reflectors may be used to direct light and create a diversion for birds. While stationary deterrents exist in the market, a small, rotating parabolic reflector attached to car can reflect ultraviolet light and save millions of avian lives. This experiment was a minute part of a greater project to make such a device possible. The purpose of this experiment was to determine which rotational speed for the parabolic reflectors (independent variable) results in the highest lux output (dependent variable). Four rotational speeds (15, 20, 25, and 30 rpm), and a control of 0 rpm, were tested upon a parabolic reflector for brightness. A light source was beamed onto a functioning reflector prototype and the average brightness was measured with a photometer. Be mindful of the safety precautions that need to be taken while performing the experiment, such as a hot glue gun, X-acto knife, and wires. The results stated that 20 rpm had the highest average of 156.255 lux. The data supported the hypothesis that stated the speed of 20 rpm resulted in the highest average brightness. Based upon the results, it was the most effective speed since it dispersed the light source evenly. The project met the design criteria which stated the parabola must reflect light across a large area and rotate. Although, amendments to the experiment include using aluminum to construct the parabolic reflectors and designing car attachment. Further experiments need to be conducted to finalize further details.

Third Place

How to Optimize Parameters that would Affect the Speed of an Electromagnetic Train

Lucy Lu *Ronald Reagan Middle School*

In recent years, the quest for environmentally friendly transportation has moved the science and technology towards electrical vehicles to reduce carbon dioxide emissions. The use of fossil fuels to power transportation is going away rapidly. One of the electrical transportations that have drawn my interest is electromagnetic train. The reason the electromagnetic train can move forward is because of electromagnetism. Electromagnetism is a manmade force based on an electrical power source. The difference between magnetism and electromagnetism is that magnetism is a natural phenomenon made from nature, whereas electromagnetism is manmade. An electromagnetic field can be manipulated through electrical power. A simple electromagnetic train is a battery with magnets attached to both ends, when it is placed in a copper coil (the track), the train will move from one end of the track to the other without any external force. Such simple electromagnetic train can be viewed on YouTube. However, the YouTube videos do not explain the science and engineering behind the train in details.

The purpose of this paper is to explore the parameters of a simple electromagnetic train, to optimize the parameters, and to improve the train speed based on the optimization parameters. Through the experiments, I discovered the improvement of the electromagnetic train is mostly about increasing the electromagnetic field that powers the train. In the quest for higher electromagnetic field strength, I came to understand the importance of tradeoff and balance in engineering.

The Effect of Various Types of Cancers on the Severity of Covid-19 Infection

Arjun Majety *George Moody Middle School*

COVID-19 is a pandemic that originates from Wuhan, China. SARS-CoV-2 is the virus that causes COVID-19 disease. This disease is highly contagious and spreads through aerosolized droplets transmitted from a sneeze or cough from an infected person, but also through a fecal-oral route. Many groups of the population are at high-risk for COVID-19 infection. Some of these groups include older aged, immunocompromised, and cancer patients. There are a multitude of reasons why cancer patients are at a higher risk for COVID-19. Overall, cancer patients have a weaker immune system. The purpose of this experiment was to see what demographic of cancer patients are at most risk for COVID-19. Specifically which type of cancer did that patient have and whether it was hematological cancer. R was used to analyze data from a public registry. The mortality rate for Hematological cancers was 29% in comparison to the 21% percent mortality rate for non-Hematological cancers. Acute Myeloid Lymphoma had the highest mortality rate among all cancer types, 38%. Thoracic cancer had the highest mortality rate out of all non-Hematological cancers, 31 percent. The data supported the research hypothesis that when the COVID-19 mortality rates for hematological and non-Hematological cancers are compared, hematological cancers will have a greater mortality rate. This increase of deaths amongst hematological cancers is because they target and attack the immune system and bone marrow. Due to the suppressed immune system, the host will not be able to fight off the COVID-19 infection, which explains why cancer patients have greater severity of COVID-19. Another major finding was that Acute Myeloid Leukemia had the highest mortality rate of 38%. Acute Myeloid Leukemia targets and attacks the bone marrow, red blood cells, and platelets. These are all necessary to fight COVID-1.

The Effect of Different Bicycle Gear Ratio on Speed

Tanvi Nareddy *George Moody Middle School*

The purpose of this experiment was to find which gear ratio speed was the best to use while biking. Biking can be used in races and transportation, so this information can be very useful. The hypothesis was, if a 5-6 gear ratio is used, then the speed of the bicycle will increase. The procedure was that the bike was ridden fifteen times for each independent variable, including the control. All other variables were kept the same including the bike, day the experiment was done, the experimenter, the timer, the pedals per minute, and as well as the timer. After experimenting, the results were that the fastest gear ratio was 2:7 with an average time of 31.966 seconds and the slowest time was the gear ratio of 2:3 with an average time of 52.646 seconds. In conclusion, a higher gear speed will increase the speed that the bike will go. However different gear ratios are needed for different tracks and pathways if you would like to go slower or faster.

Honorable Mention

The Effect of the Launch Angle on Flight Time and Flight Distance

Amogh Saunshimath *Short Pump Middle School*

The purpose of this experiment was to determine the relationship between the angle a glider is launched and its flight time and flight distance. In order to fly, one must produce enough lift. The angle the airplane takes off can possibly impact how much lift the airplane can produce. If the planes cannot produce enough lift, the plane would crash. One balsa glider was launched with a constant potential energy at 30-, 45-, and 60-degree angles with 15 degrees being the control. It was hypothesized that if the glider was launched at 60 degrees, then it would fly the farthest and have the longest flight time. The results present that launching gliders at different angles alter the flight distance and time. The 45-degree angle average had the greatest flight distance while 15 degrees had the longest flight time. The control average had the lowest flight distance and time. The results of the t-test conducted show that the flight distance data overall is significant while the flight time data was proven not significant. The results rejected the hypothesis which states that the 60-degree angle average would contain the highest distance and flight time. The results occurred because the plane was able to produce a sufficient amount of lift to fly when it was launched at a 45-degree angle. Further experiments could conduct whether modified wings produced more lift or if the plane produces more lift by inclining the runway.

First Place

The Effect of Machine Learning Algorithms on Counting the Fish Population

Camellia Sharma *George Moody Middle School*

Fish are an important source of food for humans and a vital part of the aquatic ecosystem. The fish population is reducing in all habitats due to numerous reasons including climate change and overfishing. The ability to count the number and type of fish in waterbodies is essential for rehabilitating the fish population. Scientist must rely on computerizes methods because it is not possible to physically count and categorize fish. FishPopAI presented in this research, is a hybrid computer vision (CV) and machine learning (ML) solution. The CV part used underwater images to count fish and calculate their metrics of fitted ellipse and bounding rectangle. The ML component used classifiers to identify fish. The levels of independent variable were convolutional neural network (CNN), K-nearest neighborhood (KNN), random forest (RF) and support vector machine (SVM) ML methods. CNN was the control variable. It was hypothesized that the CNN method would be most accurate. Photos and videos acquired through the experimental setup and public images were the input data. The images were preprocessed and then modified with CV algorithms such as edge enhancement and contouring. The aspect ratio of fitted ellipse and bounding rectangle of the fish were used for classification with the ML models. The accuracy of the four independent variables were 94.28%, 90.58%, 92.73% and 79.78%. The results supported the hypothesis since CNN had the highest accuracy. FishPopAI could be enhanced in future with more fish models and photos from the waterbodies. The project was done under adult supervision using safety gear.

Honorable Mention

The Effect of the Type of Stormwater Filtration Method on Collecting Litter

Isla Wearmouth *Kenmore Middle School*

The problem is that Arlington, Virginia has no stormwater filtration system. This means that whatever litter flows into the drains goes directly into our watershed. This topic came to the researcher's attention when she noticed that none of the common street drains had any type of grate or screen to block litter from polluting the water. The only current solution to this problem is a sign on the drains that states, "only rain down the drains", which is not very effective. The goal of this experiment was to figure out which type of filtration method is most effective at keeping out litter from our watershed. The filtration methods tested were a grate in front of a drain and a bag made of netting at the end of the pipe where the stormwater deposits. The hypothesis was that if the pipe bag method is used, it will be the most effective at filtering out litter because a similar method works in the filtration of water in a laundry machine. To conduct this experiment, the researcher built models of a grate and pipe bag. Each method was tested multiple times with 2 gallons of water and 24 pieces of litter. The results showed that the pipe bag method was most effective at catching litter. In ⅘ trials it let through much less litter than the grate, and in ⅘ trials it caught the same amount of litter as the grate. This supports the hypothesis. Arlington County could add these bag filters to the end of the stormwater pipes. To deal with the price of labor to empty the bags, people could be asked to volunteer to help change the bags every month or so. It is believed that using these pipe bags in Arlington could largely improve the state of our environment.

The Effect of Different Back-To-School Plans on the Spread of SARS-CoV-2

Annie Yuan *George Moody Middle School*

SARS-CoV-2 was a virus that emerged in Wuhan, China in December 2019. It causes a respiratory disease known as COVID-19 and is the source of 1.2 million deaths and prompted schools all over the world to switch to a virtual learning platform. The purpose of this simulation was to find the schedule proposed by Henrico County Public Schools that would be the safest for students and teachers returning to school to follow. It was hypothesized that if students and faculty engaged in parallel learning, then there would be less cases of COVID-19 over nine weeks in the simulation than if students and faculty engaged in hybrid learning or took no preventive measures of any kind. The experiment was done using a computer simulation on MATLAB's Simulink software. The only safety precautions taken were blue light-filtering lenses. The number of students and staff with COVID-19 prior to the school year and the number of individuals in total was put into the software along with the fixed R0 of 2.5, the incubation period, the recovery rate, and the percentage of asymptomatic carriers. The simulation was run for 63 virtual days. Group A, where 25,000 people went back to school and 25,000 others stayed in virtual learning, had the highest mean cumulative of 12,823 infected individuals. Group B, where all 50,000 people went back to school, had a mean cumulative of 10,851 infected individuals. Group C, where students participated in hybrid learning that switched on a day-to-day basis, had the lowest mean cumulative of 33 infected individuals. Finally, Group D, where students participated in hybrid learning that switched on a week-by-week basis, had a mean cumulative of 795 infected individuals. The safest schedule that caused the least number of coronavirus cases in the computer simulation was the hybrid plan switching day-to-day. The most dangerous schedule that caused the greatest number of coronavirus cases in the simulation was the parallel learning plan.

Human Behavior (MS HB)

First Place

The Effect of Traffic Level on Number of Stress Responses

Zara Musa *Williamsburg Middle School*

The rationale of this experiment was to determine if different traffic levels affect the amount of stress responses. Research has shown that the responses of a driver while driving is tied to stress. Drivers with a higher stress level act in an aggressive manner and experience error prone instincts. This is detrimental to not only the driver and other vehicles, but also near-by pedestrians and bikers too. How the traffic level affects the number of stress responses is important because it can lead to more strategically placed traffic signs and cameras. This is significant in highly congested environments, like busy intersections. This research is also important because it can lead to discoveries about the prevention of stress-induced illnesses. During this experiment an observer recorded the number of times someone honked, drove through red and yellow lights, and switched lanes without signaling. These are considered to be stress responses. The observer watched the northbound lane for 30 minutes three times during the day, 10:00 - 10:30am, 2:30 - 3:00pm, and 4:00 - 4:30pm. The last time, 4:00- 4:30, being considered “rush hour.” As the observer was observing the traffic, a timer was used to make sure she stayed within the time limit. The time of day that had the highest amount of stress responses in all was 4:00pm. The hypothesis- that the level of traffic is higher, then there will be more instances of stress responses- was supported; the highest level of traffic (4:00pm) had the highest amount of stress responses compared to the other two times of day (10:00am and 2:30pm). The second highest level of traffic was 10:00am, it had the second highest number of stress responses. Lastly, the lowest level of traffic (2:30pm), had the lowest number of stress responses.

Mathematics: Patterns & Relationships (MS MP)

Second Place

The Effect of Poverty Percentages on Voter Turnout

Sattwik Nath *George Moody Middle School*

Poverty is one of the largest conundrums when it comes to voting. The United States has a 10.5 percent poverty rate, poverty has a severe effect on the turnout of a vote. If the poverty level can be used to predict the voter outcome, then the government will know which areas to support for the highest voter turnout. This will not only create a fair representation of our demography in the government but also increase the trust and confidence in the electorate process. For this experiment, data related to Population and Voting Rates for Congressional Districts for 2018 was taken from the United States Census Bureau. A linear regression statistical model was created by analyzing this data. The hypothesis for this project was, If the percentage of population below the poverty level decreases, then the percentage of voter turnout in a Congressional District increases. The results of the experiment were supportive of the hypothesis, and it was determined that given the percentage of people below poverty level in an electorate, one can predict the percentage of voter turnout. Further accuracy of voter turnout prediction could be made possible by considering other variables like education, gender, race, and age.

Third Place

The Effect of Mail-in Voting Fraud on a Battleground State's Election Result

Zareef Said *Ronald Reagan Middle School*

The legitimacy of the past election has been questioned by many people. Donald Trump, the former president made claims that due to the addition of mass mail-in voting the past election was the most fraudulent election in United States history. This experiment aimed to figure out how valid these claims are, it explored the different steps of mail-in voting and what could have possibly gone wrong. To test the hypothesis that when there is a 0%-1% of fraud occurring that on average the result of the election does not change, a Markov chain model that simulated all the steps of mail-in voting was created in the programming language python, after this the model was run a number of times with the probability range of 1%-0% and the results were all averaged out. I did this again with the probability range of 0%-5%. The results supported my hypothesis since on average when the probability of fraud occurring was between 1% and 0% the election result did not change, however when the probability range was 0%-5%, 5% of the time the election result changed. The results show that although the United States election system is pretty secure there are still small improvements that we can make.

First Place

The Effect of School Size, Per-Pupil Expenditure, and Percent of Teachers with Advanced Degrees on SOL Pass Rates

Henry Stievater *Swanson Middle School*

The Virginia Standards of Learning (SOLs) are standardized tests taken by all students in Virginia from ages 3-12 and are used as indicators of teacher and student ability. The purpose of this experiment is to see if there is any correlation between SOL pass rates from the 2018-2019 school year (the dependent variable) and school size (based on student population), percent of teachers with advanced degrees, or per-pupil expenditure (the independent variables). The hypothesis is that schools with a larger percent of teachers with advanced degrees will have higher SOL pass rates, smaller school sizes will have higher SOL pass rates, and per-pupil expenditure will have no effect on SOL pass rates. The null hypothesis is that none of these variables will have any effect on SOL pass rates. The data used in this experiment was collected from the Virginia School Quality Profiles. The data was loaded into a custom Python program, which analyzed the data for correlations. In a linear best fit, the standard error is less than the magnitude of the slope in every case, therefore, the null hypothesis is rejected. Surprisingly, for every SOL, per-pupil expenditure appears to have a negative correlation, and school size appears to have a positive correlation. Also, for each SOL, the percent of teachers with advanced degrees has a positive slope. That is, the more the school spends per student, the lower the school's pass rate is on the SOLs, and the larger the school, the higher the school's pass rate on the SOLs is, and the greater the percent of teachers that has advanced degrees is, the higher the school's pass rate on the SOLs are. Thus, it can be concluded that schools are spending unwisely, and that larger schools have better access to resources, and that more highly educated teachers can teach better. The hypothesis regarding teacher degrees is accepted, but the hypotheses regarding school size and per-pupil expenditure are rejected.

Physical Science & Astronomy (MS PA)

Honorable Mention

The Effect of Different Materials on the Absorption of Sound

Sanaya Bothra *George Moody Middle School*

As we know, depending on the material, the sound absorbency will be different. For instance, a material's characteristics and properties come from the structure and the way a material is built can have a big impact on sound absorption in our everyday lives. A material's characteristics and properties can be many things like how dense the material is or even how the material is built. Many people struggle with finding the best sound absorption material for their home. The experiment will help people decide what is best for their home in future scenarios. To proceed with this experiment, all the materials were set up and placed in their assigned positions. Then the sound was played in a box insulated with each sound absorbent material and then without any insulation (control). After the experiment, the data was collected, and the results showed that from greatest to least sound absorbed, wool absorbed the most followed by, acoustic foam, cork, and lastly, styrofoam. In conclusion, the dense characteristic of the wool absorbed the most sound. It supports the research hypothesis because although before it was stated dense materials tend to reflect sound the most, wool isn't completely dense or dense enough. Wool also is porous since there are small spaces between the millions of threads.

Honorable Mention

The Effect of Resistance of Different Types of Metals on Electrical Conductivity

Abhinav Gitta *George Moody Middle School*

The purpose of this experiment was to see the correlation of electrical resistance on electrical conductivity. Metals are generally the best conductors compared to other materials. Metal, usually copper or aluminum, is used in real life applications, such as electrical wiring. The hypothesis for this experiment was: If the metal has a lower resistance, then the electrical conductivity will increase. The metals tested were silver, gold, aluminum, brass, and nickel. Copper was the control variable. The resistance and conductivity were measured with a digital multimeter. Each metal was tested 10 times. Then their ability to conduct electricity was tested with a circuit. Electrical conductivity is the measurement of how easily a material can carry electricity. Without conductors, electricity would not be able to flow efficiently, and electronics like microwaves and laptops would not be able to work. A problem in electric transmission is loss of energy. Electricity is a form of energy resulting from charged electrons, but unlike other forms of energy like coal or biomass, it is not possible for electricity to be stored when not in use. Consequently, an average of 72,000 terajoules of energy is lost every year. This is caused by resistance in the transmission wires. This results in loss of money and power. Current “solutions” like high voltage power lines do little to lower the amount of energy loss. A possible solution is superconductors. Superconductors are metals when cooled down to very low temperatures, lose all electrical resistance, resulting in zero loss of energy, and have other benefits, such as not overheating and being able to carry a current for an indefinite amount of time. The importance of the relationship between electrical resistivity and conductivity aids in everyday life.

The Effect of Different Types of Masks on Airborne Particles

Alina Hashimee *Ronald Reagan Middle School*

People say all masks work the same and they all prevent germ particles from escaping, but do they all work the same? When this pandemic started people started wearing masks, some wore bandanas, and some wore surgical masks. As more people started wearing masks, the debate of which type of mask worked better started arising. People believed that with a mask they could go back to normal, but does your mask really prevent germ particles from escaping? This made me very curios, I wanted to test if this was true, I wanted to see which mask works the best. I tested the three most common used masks a bandana, surgical mask, and a kid's mask. My hypothesis is that a surgical mask would work the best in preventing airborne particles from escaping. I see lots of more people wear these masks, and doctors who are treating Coronavirus victims wear these masks, so my guess is that if doctors are wearing these masks while treating coronavirus victims and they don't obtain the virus afterwards then they should be the best. By completing this project, I hope to help people who have questions about the efficiency of their masks.

First Place

How Does the Type of Current at Different Voltages Affect Electromagnetic Force?

Theodore Hwang & Dorothy Hwang *Gunston Middle School*

Electromagnets are constantly used in daily life, but which current is the most effective alternating currents (AC) or direct currents (DC)? This project set out to investigate how the type of current affects electromagnetic force at 3, 6, and 24 volts (V). Rubber gloves and goggles were worn when dealing with electricity. Two nails wrapped in copper wire were used as the alternating current and direct current electromagnets. They were tested at different voltages to see how many staples each one attracted, and then the results were compared to each other. The hypothesis was that the alternating current electromagnet would be more powerful and effective than the direct current electromagnet. However, the results did not support the hypothesis, instead showing that the direct current electromagnet was stronger. At 3, 6, and 24 volts, the mean of the staples attracted using the direct current electromagnet was 0.25 to 0.75 more than the alternating current electromagnet. The medians also opposed the hypothesis, as the direct current electromagnet's medians were 0.5 to 1 more than the alternating current electromagnet's medians. It was concluded that direct current electromagnets are more efficient than alternating current electromagnets, and can be used in transformers, audio equipment, construction, and generators.

Honorable Mention

The Effect of Different Materials on the Volume of Sound

Livia Kouts *Ronald Reagan Middle School*

During a music lesson a few months ago, I had to put blankets around my door, so that anyone on a zoom call outside the room wouldn't be interrupted by the sound of my practice. But that left me thinking, if the door and wall weren't enough to soundproof the room, which materials commonly used in housing construction were providing the most soundproofing? To solve this question, I designed an experiment and tested four materials to determine how each would reduce the volume of a loud noise source. Three of those materials are commonly used in housing construction, plywood, sheetrock, and insulation foam board. I added a fourth material, acoustic panels to see if they would perform better than standard construction materials. My hypothesis was that plywood would soundproof the best out of all the materials. I hypothesized this because plywood was the densest material I was testing, and denser materials cause sound to lose more energy. My experiment proved this hypothesis correct; plywood blocked the greatest amount of sound compared to the other materials. The information from this experiment can help anyone who needs to use common construction materials to improve soundproofing in their home.

Second Place

Multiphonics on Euphonium: Solving the Mystery of the Third Note

Aleksander Kurgan *George Moody Middle School*

Multiphonics is an interesting and advanced technique that bridges music and science. This technique involves playing two notes at the same time on a monotone instrument. When the two notes are played simultaneously, they interact with each other to create the aural phenomenon of a third note. This project focused on a specific brass instrument called euphonium where multiphonics are created by playing a note while singing another. The hypothesis that the experimenter investigated was as follows: "If the experimenter used multiphonics on the euphonium instrument then it would create a new note using the cooperation of the two notes that were played." The experimenter also analyzed whether correct third notes were generated. The experimenter began the study by deciding to test the hypothesis by using 12 notes on the bass clef line. These twelve notes were sung with one note, A4, and these experiments were recorded and repeated five times. Next, the experimenter analyzed the data by assessing the recorded notes, computing median notes, comparing them to reference data, evaluating their correctness, and calculating probabilities. Using this analysis, the experimenter came to several insightful conclusions. The main conclusion was that the hypothesis was correct: the use of multiphonics on euphonium always created a third note. The second statistical finding was that the use of median notes was important in determining results and comparing to reference data. The third conclusion was that the third note that was created by the multiphonic with euphonium was accurate since it agreed the reference (exact) note 83.3% of the time. The fourth statistical finding was that this accurate result had a low 0.0368 probability of being produced by chance. While this was not the first time that multiphonics were analyzed, this project has produced conclusions that bring new and rigorously investigated insights into multiphonics on the euphonium instrument.

The Effect of Surface Shape on Wakes

Colton Moore *Swanson Middle School*

How different bow shapes on boats create wakes of different heights in the water around the boat. Through my experiment using a pulley system, I found that a V-shaped bow had the smallest wave height.

Third Place

The Effect of Different Materials on Reduction of EMF Radiation

Tess Vithoulkas *George Moody Middle School*

Electronic devices such as microwaves and cell phones all emit electromagnetic radiation, which has been shown to cause health problems (Altunkaynak, 2016). Electromagnetic radiation is energy that moves in the form of electric and magnetic fields (Geetha, 2009). Studies have shown that microwave ovens leak radiation, most often through the door; this leakage is dependent on time, frequency, and distance (Lopez-Iturri 2015). Humans have had reactions to exposure such as headaches, dizziness, fatigue, sleepiness, memory loss, depression, hallucinations, and insomnia (Pall, 2015). To reduce unwanted electromagnetic radiation, shielding can be used. A shield absorbs and/or reflects the electromagnetic waves as they pass through it (Geetha, 2009). The purpose of this project was to determine which shielding material blocks the most radiation. Metals conduct electricity and absorb and reflect EMF radiation; copper has the highest electrical conductivity of the shielding materials used for this experiment (Geetha, 2009). The hypothesis was if a copper mesh shield is used, then the least amount of radiation will be detected. Four different commercially available shielding materials were selected as the independent variable. The control group used no shielding material. Each shielding material was taped to the glass door of the microwave oven. After a warmup run, readings were taken every 10 seconds using the Tacklife Model: MET01 EMF Tester. A total of 10 readings were recorded for each trial. This was repeated with all 4 of the other shields. A t-test was performed on all five groups, comparing each group to the control. Although the copper mesh showed the lowest mean radiation of all groups, there was a lot of variability in the groups to show that they were all equal. Therefore, the results were inconclusive.

Plant Science & Microbiology (MS PM)

The Effect of Different Disinfectants on the Growth of *E. coli*

Nikki Alemzadeh *Louise A. Benton Middle School*

This research evaluated the effect of four commonly used household disinfectants: Bleach (sodium hypochlorite), Clorox wipes (ammonium chloride), baking soda (sodium bicarbonate), and vinegar (acetic acid), on the growth of E. coli K-12. E. coli K-12 was cultured in four separate agar plates and each disinfectant was placed in each one of those plates. After four days the distance around the disinfectant disc with no bacterial growth was measured. The agar plate with bleach had the greatest inhibition distance in millimeters. The results confirmed that bleach is the most effective disinfectant out of the four disinfectants studied. Safety measures including wearing gloves, a lab apron, and goggles for personal protection against bacteria exposure were used. All agar plates were disposed of in biohazard waste containers (In medical facility).

Honorable Mention

The Effect of Houseplants on Indoor Air Quality

Aditya Banerjee *George Moody Middle School*

During this Covid-19 pandemic time, people are staying at their homes for long periods of time. This research project is about finding the best houseplant to improve air quality in our homes. The objective was to check and find out to what extent the indoor plants can clean our breathing air. It will also help in learning how to love nature and take care of the plants. Of course, the indoor plants will beautify our home as well as an outcome. My hypothesis was that if the Spider Plant is used, then the air quality will improve at a higher rate by reducing the toxin and other PM dust particles as compared to the other indoor plants used in this research. In this experiment, 6 different indoor plants were bought along with an air quality measuring instrument. After calibration, the air quality was measured for each plant for a span of 2 days. The measurements were also taken without any plant which will serve as the control. This whole process was conducted 3 times to get better and accurate results. All the measuring parameters from the air quality meter were plotted on a spreadsheet. Finally, after all the iterations were completed, the average of those results was plotted on a bar graph. The results were very diverse because some of the plants performed better at some indicators of air quality while other plants did better on others. In general, it has been observed that the English Ivy performed the best. The results from English Ivy were better than others. The data showed that English Ivy took out maximum amounts of toxins (HCHO, TVOC) from the air and a lot of PM dust particles as well (such as PM1, PM 2.5 and PM10).

The Effect of Different Types of Sugars on The Growth Rate of Yeast

Sriram Darsi *George Moody Middle School*

Many bakers around the world have been noticing that they spend most of their time just creating the yeast. Yeast is made up of flour, sugar, and water and after they mix it, they wait about 2-3hours per batch of yeast. This takes up a lot of time if you do it every day and make multiple batches. The purpose of this project is to determine which sugar would have the fastest growth time of yeast. The hypothesis was that if I use granulated sugar then it will have the fastest growth time. 50 batches of yeast were made divided by 5 you would get 10. We had 5 independent variables and for each type of yeast, there were 10 trials. The 5 independent variables were Granulated, brown, cane, caster, and powdered sugars. Group 1 was the control group; it used only granulated sugar. Group 2 was the yeast that used the brown sugar. Group 3 was the yeast that used cane sugar. Group 4 was the yeast that used caster sugar. Lastly, group 5 was the yeast that used powdered sugar. Each yeast was measured by centimeters in a time limit of 40 minutes. The yeast growth is written below, and the data was calculated into a mean for each group. The mean for Granulated sugar is 1.6cm, for the Brown sugar it was 1.3cm, for the cane sugar it was 1.4cm, for the caster sugar the mean was 1.7cm, and for the powdered sugar, the mean was 2cm. The mode for the experiment is 1. The range for this data is 0.6cm. The median was 1.6 for this data set.

Second Place

The Effect of Radiofrequency Radiation During *Phaseolus vulgaris* Seed Germination on Subsequent Plant Growth

Cameron Joyce *George Moody Middle School*

The amount of mobile device usage worldwide has grown exponentially in the past few years, requiring more cell towers to meet the growing demand for Wi-Fi and cell service. Cell towers emit radiofrequency radiation (RFR), which has a potentially adverse effect on living things, including plants. The purpose of this experiment was to test whether or not RFR had an effect on long-term plant growth in vivo after the seeds were irradiated during germination. The hypothesis for this experiment was that if *Phaseolus vulgaris* (bean) seeds are irradiated during germination, then plant growth and yield will be delayed or inhibited in seeds that were irradiated during germination compared to seeds that were not irradiated. Fifty bean seeds each were exposed to RFR from a Wi-Fi extender and to no RFR for 4 days after setup. Then the germinated seeds were planted outside in a garden plot for 63 more days and observed for the number and percentage of sprouted stems, plant height, time to grow the first bean, percentage of plants with beans, and bean yield per group. The results showed that there was no statistically significant difference between the germination percentages across groups. Similarly, there were no statistically significant differences for any of the longer-term plant growth variables between groups. In conclusion, no adverse effects of irradiation during germination on later plant growth were observed. However, this is an understudied area and further research should investigate the practical implications of continuous RFR exposure during long-term plant growth due to potential impacts on food production and related economic factors.

First Place

The Effect of Tea Leaves (*Camellia sinensis*) on Pea Plant (*Pisum sativum*) Germination Time.

Deepanshi Kumar *George Moody Middle School*

Tea is the second most consumed drink in the world, meaning millions of people are using tea leaves every day. Tea leaves are oxidized at different levels which result in three main categories of tea: green, oolong, and black. The fermentation or oxidation process of tea leaves results in new polyphenol compounds to be synthesized in the leaves. The purpose of the research conducted was to understand how tea leaves affect seed germination, so that used or excess tea leaves do not have to be wasted in countries with food shortages. The research hypothesis was “If 0.6 mL of uncooked tea leaves are placed with a pea plant seed during germination, then the seed will germinate the fastest.” The procedure for this experiment was to first prepare the pea seeds by placing them on a wet paper towel and applying the tea leaves (independent variable) to them, then placing them in a Ziploc bag. This was repeated for each level of the independent variable. When cooking the tea leaves and preparing the pea seeds, eye and hand protection was worn. The germinating seeds were checked every day at a constant time and the dependent variable, which was how long it took for the seeds to germinate, was recorded. The results showed that the pea seeds with cooked tea leaves germinated the fastest. The peas with uncooked tea leaves took approximately 8 days while those with cooked tea leaves took approximately 6 days. The ANOVA test gave a p-value of 2.3 x 10-7 which showed that the data from the research was accurate. The experiment rejected the hypothesis but did show that cooked tea can leaves accelerate pea seed germination time. The tea leaves affected the seeds in this way because of the polyphenolic compounds, namely the flavins and the urubigins, and their supply of oxygen and water. The data and research collected through this study indicates that tea leaves can be reused to accelerate pea seed germination, helping reduce waste in global communities.

The Effect of Pollutants on a Native Plant

Mia Moret *Kenmore Middle School*

The purpose of this experiment was to determine which pollutant has the greatest negative impact on the growth rate of native plants. This experiment was based on Four Mile Run which is a 9.4-mile-long stream in Northern Virginia. Therefore, pollutants and amounts of pollutants were based on some of the most common pollutants and the amount of pollutants that go into Four Mile Run. The plant used was called the Jewelweed plant. Four Jewelweed plants were used and watered with different pollutants in the experiment for 45 days. Only one of the plants did not grow at all. This was the fertilizer plant. The hypothesis was rejected. The plant being watered with gasoline was thought to have grown the least, but the plant with fertilizer did not grow at all Water pollution is a significant issue that needs to be studied and monitored. This study reflects on that issue.

Honorable Mention

The Effect of Legumes on the Germination of *Lactuca sativa*

Jaya Shah *Williamsburg Middle School*

The purpose of this experiment was to figure out how legumes affect the germination rate of *Lactuca sativa* (lettuce). Upon conducting research to understand natural fertilizers, it was found that fertilizer tree systems are commonly used to help fertilize soil. But there was no implementation of this system in indoor container gardening. Fertilizers are expensive and not everyone can afford them. The intent of this experiment was to be able to inform others on whether legumes help promote the germination and growth of plants, and whether they can be used as an alternative to chemical fertilizers. The experiment examined three levels: 1) lettuce, 2) lettuce and legumes, and 3) lettuce, legumes, and nitrogen fertilizer. It was hypothesized that the level, lettuce, legumes, and nitrogen fertilizer would do best. This experiment was conducted by planting twelve lettuce seeds each in aluminum containers. There were three aluminum containers (one for each level), and each were watered daily with the same amount of water. The legumes used were a combination of oats and peas, and they were combined and counted as “cover crop.” For every one lettuce seed, there were eight cover crop seeds surrounding it. In the end, the hypothesis was rejected. The key results of this experiment were as follows: For the just lettuce level, 11/12 of the seeds germinated, 4/12 lettuce seeds germinated for the lettuce and legumes level, and 6/12 lettuce seeds germinated for the lettuce, legumes, and nitrogen fertilizer level. The rejection of the hypothesis displayed that lettuce without legumes and nitrogen fertilizer did best. These results illustrated that very little money is needed to grow good food, all that is needed are basic variables such as water and soil.

The Effect of Different Instruments on the Amount of Bacterial Growth and How Fast it Grows

Dalia Singer *Swanson Middle School*

This experiment was conducted to compare how much bacteria grows in different instruments used by middle schoolers on the mouthpiece and spit valves of trombones and trumpets. What was observed in this experiment was the effect of different instruments on the amount of bacterial growth and how fast it grows. The different instruments that were used were trumpet and trombone; 4 trumpets and 4 trombones. The places swabbed on each instrument were the mouthpiece and the spit valve. For the control, a mouthpiece of one of trumpets and one of trombones were sterilized and the same went for the spit valves. The same instruments were used for the control. The hypothesis that was given is this experiment was: one of the trumpet mouthpieces will have the most bacteria. The results did not support the hypothesis because the data supported was that one of the trombone mouthpieces had the most bacteria by a large amount compared to all the other data samples. What was observed was when the bacteria was swabbed from different instruments, the instruments that were cleaned the most recently were the cleanest, and had the least amount of bacterial growth. While collecting the bacteria samples, standard procedures, including wiping down the tables, washing hands and putting on gloves were followed in order to make this experiment as safe and effective as possible.

The Effect of the Different Types of Water on the Different Types of Bean Plants

Michelle Telmuun *Swanson Middle School*

The purpose for doing the science fair project is to test the effects of the types of water on plant height. The different types of water that was used was sparkling water, tap water, distilled water, alkaline water and the plants were measured for 30 days in total. The results/answers that was obtained were that sparkling water grew the most in trial 1 and there were outliers for alkaline water and distilled water. Sparkling water also had the greatest range with a range of 39 cm, while the rest had 31 or less. The science fair project that was made contributes to the area that it was focusing on by helping the scientific community and gardeners know what water to use to help their plants grow. The objectives were not met because it turned out that tap water grew the least and it was in the 20 – 30 cm range.

Third Place

The Effect of Continuous Light on *Helianthus annuus*

Lucy Yoder *Sabot at Stony Point*

The purpose of this study was to determine whether exposure to continuous light affects the growth rate of Helianthus annuus (commonly known as sunflowers) in comparison to 12 hours of light per day. The hypothesis was that continuous light would increase the growth rate of the plants. Two sets of plants were grown from seeds that were cultivated under grow lights. One of the sets was exposed to light 24 hours per day (continuous light group) and the other was exposed to 12 hours of light per 24-hour period (partial light group). The mean height of plants under continuous light was taller than the mean height of partial light plants at all stages of testing. The continuous light plants developed leaf chlorosis. The data supported the hypothesis in that the continuous light plants grew faster and were taller than the partial light plants.

Honorable Mention

The Inhibitive Effect of Palmolive Dish Soap Concentration on Bacteria Growth

Alice Zhang *George Moody Middle School*

Dish soap is commonly used in the kitchen to clean cutlery, utensils, or dishes. Dish soap works by killing bacteria and releasing grease on dishes. However, the amount of dish soap can easily be misused. Using too much dish soap can cause problems to the environment as well as people. Triclosan, an active ingredient in dish soap ("Active Ingredients in Dish-Washing Detergent"), could damage the skin, and even cause skin cancer ("5 Things to Know About Triclosan") a too high concentration. But, if too little dish soap is used, bacteria would not effectively be killed, which could cause serious illnesses, such as *E. coli* poisoning. Based on this, the purpose of the experiment was to determine the optimal concentration of Palmolive dish soap that would effectively kill bacteria and prevent a misuse of dish soap. The experiment was conducted by testing *E. coli* growth in different concentrations of dish soap, 0, 1%, 3%, 5% and 10%, which were prepared with a LB broth base (2g/100mL). The bacteria were left to grow in an incubator shaker overnight, and then measured using a spectrophotometer. A lab coat, safety goggles, gloves, and a mask were used while conducting the experiment. The optical absorptions of the different groups were converted into the amount of bacteria grown. The results were presented using means and standard deviations. The bacteria inhibitive effects for the different concentrations of dish soap, 1%, 3%, 5%, and 10%, were 32.04%, 49.91%, 82.64%, and 99.38%, respectively. The data collected did not support the hypothesis that if 5% Palmolive dish soap concentration was used, then it would k ill 99.9% of the bacteria. This study demonstrated that the optimal concentration for dish soap in bacteria killing was 10%.

Botany A (HS BOT-A)

Second Place

The Effect of Various Allelopathic Plants on the Suppression of *Taraxacum officinale*

Bhavana Adhikari *Mills E. Godwin High School*

The purpose of this experiment was to see whether various allelopathic plant species suppress the growth of *Taraxacum officinale*, or the common dandelion. With the increased demand for food production, the agricultural system must produce a larger yield of crops at a faster rate without abusing pesticides and fertilizers that harm the environment. Because of its ability to inhibit the growth of various other species, allelopathic plants could be used as an alternative to chemical herbicides. 25 seedlings of each level of IV (*Mentha spicata*, *Ocimum basilicum,* and *Salvia rosmarinus*) and the control, the absence of a plant, were grown alongside *T. officinale* for 28 days. A permission form was signed by a parent that indicated that they had read and understood the risks and possible dangers involved in the research and they consented to their child participating in this research. It was hypothesized that if *S. rosmarinus* was grown in succession with *T. officinale*, then the height of *T. officinale* would be the shortest. The results implied that allelopathic plants suppressed the growth of *T. officinale* and that they could be used as a natural herbicide. The mean height of *T. officinale* was the lowest for *S. rosmarinus* and the control had the highest height. T-tests were performed on the data and overall, the data was statistically significant. The results did support the research hypothesis since *S. rosmarinus* did have the lowest average height of *T. officinale*. The results were due to the allelochemicals exuded that interact with the roots and leaves of other plants. Further studies could be conducted on how allelopathic plants inhibit other species of weeds or can be used as a natural fertilizer.

The Effect of Smoke Exposure on the Transpiration Rate of *Ocimum basilicum*

Veda Akula *Mills E. Godwin High School*

The purpose of this experiment is to determine the effects of smoke exposure on the transpiration rate of *Ocimum basilicum*, more commonly known as the basil plant. The air pollution that has been a result of rapid and universal industrialization and could have a substantial impact on the amount of water plants lose on a long-term scale. Each *Ocimum basilicum* subject's transpiration rate was measured after twenty-four hours. The corresponding units were altered due to the level of the independent variable that stated what fraction of that time the plants would be exposed to smoke for. The control was the environment with no smoke exposure to properly correlate the changes smoke and air pollution might have on basil plants. It was hypothesized that the subjects exposed for twenty-four hours would have the lowest transpiration rate, and the results supported this hypothesis after a procedure was performed with caution pertaining to potential hazards upon ingesting smoke. The t-test results showed that all trials held data of significance. It can be implied that the smoke clogged the pores of the plants' stomata, the part of the leaf that opens and closes to let out water depending on the organism's environment. The results from this procedure could initiate further studies concerning the effectiveness of various methods that could reduce smoke exposure to plants or could statistically analyze the impact smoke exposure could have on various other qualities of *Ocimum basilicum*, particularly ones that focus on its widespread use in agriculture and medicine.

Honorable Mention

The Effect of Lipid Second Messenger Phosphatidic Acid (PA) on Spinach (*Spinacia oleracea*) under Salt Stress.

Maria Angel Zamora *Mills E. Godwin High School*

The purpose for this experiment is to determine whether the addition of lipid second messenger Phosphatidic Acid (PA) will aid spinach growth under saline conditions. Salinization has severely decreased crop production and is estimated to affect 23% of cultivated lands worldwide, and by 2050 agricultural production must be increased by 60% due to population increases. the agricultural industry is looking for new ways to combat this issue. It was hypothesized that if 5µm of PA was used then Spinach (*Spinacia oleracea*) will show the most optimal results under salt stress. There were 6 IV levels were 5 µm PA, 30 PA, a no added PA control group treated with salt, and an additional 3 levels with the same concentrations treated without saltwater serving as the positive control. The plants were observed, grown, and watered for 21 days. T-tests were conducted between all of the data sets, and it was revealed that the data was overall statistically significant. The 5µm level performed the best under salt stress with an average total growth of (2,80cm) compared to the no PA control group (1.40 cm). Implying that PA was beneficial to the plant under salt stress conditions. Since it is a second messenger to the SOS1 (Salt Overly Sensitive 1) the SOS1, an Na+/H+ antiporter, catalyzing the exchange of Na+/H+ across the cell membrane talking Na+ out of its root cell's cytosol to the xylem and eventually to exit the plant allowing spinach to deal with saline environments.

The Effect of Natural Fertilizers on Nutrition of *Beta vulgaris.*

Riya Chawla *Mills E. Godwin High School*

In many parts of the world, the agricultural industry has attempted to find an efficient approach to improving the nutritional value of crops while effectively increasing the quantity of crops. The data collected in this experiment will be relevant to the overall food industry as well as farmers who look for various approaches to growing healthier crops. The implications of the data gathered may benefit societal understanding of agricultural approaches to increasing nutritional value in crops. The purpose of this experiment was to find the effect of natural organic fertilizers on the nutritional value of *Beta vulgaris*. It was hypothesized that if shrimp shells or coffee grounds were used as a natural fertilizer, then the nutritional value of the *Beta vulgaris* would be greatest in plants grown with the shrimp shells. The test group consisted of 75 beet plants, and three different fertilizing treatments were used. With the control treatment, no natural fertilizer was used, and it was shown to be the most effective. Three t-tests were conducted, and the calculated values indicated that the data was significant with the probability of error less than 5%. The shrimp shell fertilizer was not shown to be the most effective because the soil mixture may have already had an appropriate amount of nutrients, and by adding shrimp shells or coffee grounds, the balance of nutrients was changed in a way that was detrimental to the beet plants. As a result, future experiments involving plantings should undergo soil testing prior to planting. All approved safety protocols were followed, and safety precautions were taken during the experiment.

The Effect of Dextrose Solutions on *Raphanus sativus*

Joey Chen *Mills E. Godwin High School*

This study was conducted to determine the effect of using dextrose solutions on *Raphanus sativus*. *Raphanus sativus* is an important plant and it plays a major part in the agricultural industry. In addition, *Raphanus sativus* has shown potential in the medical industry as it contains special characteristics. This research could benefit the quality and quantity of *Raphanus sativus* being grown around the world. The levels of independent variables determined to be water, 5% dextrose solution, and 10% dextrose solution. The control for this project would be water due to the fact that the majority of plants are grown with water. An experimental hypothesis was formulated that stated, “If a 10% dextrose solution was used, then *Raphanus sativus* will grow the best.” To conduct the experiment, *Raphanus sativus* seeds were planted and 3 solutions (water, 5% dextrose solution, and 10% dextrose solution) were created. The pots were separated into three groups and each group was watered with 1 of the 3 solutions over the course of four weeks. Results showed that the data was not statistically significant, and dextrose solution showed a significant decrease compared to the control. There could have been external variables that affect the results. The most likely reason for error could be due to the environment and chance. Proper safety precautions were followed throughout the experiment. Overall, while the data was not statistically significant, it can be concluded that dextrose solution has negative effects on *Raphanus sativus* growth.

The Effect of Different Worms on the Growth of *Tagetes patula*

Nachaal Chidambaram *Mills E. Godwin High School*

The purpose of this experiment was to find out which vermicomposting worm produced the best results in plant growth in marigolds. The hypothesis stated that Earthworms would work the best with the marigolds and result in the tallest plants. The worms were added to the soil to help the plants grow faster. The worms helped aerate the soil, and by increasing micro-organisms activity more surface area was created. The vermicomposting worms would break down any compost or waste in a sustainable way that would help the environment. So much annual waste is created each year and vermicomposting could be a solution for the worlds waste problem. In this experiment four pots placed next to one another, and three of them contained different types of worms (earthworms, nightcrawlers, and red wiggler worms), while one pot didn't contain worms and that pot was the control group. The height of the marigolds were observed and recorded over a period of four weeks. The data collected from this experiment, and a t test was performed. The data was overall significant with 5 out of 6 tests being significant at the 0.05 level. The red wiggler worms had the tallest plants on average, and when compared to the other data points it was always significant. The results are most likely due to the red wiggler worms and not chance. The research that was done could lead to more studies that would investigate how these worms perform with different plants.

The Effect of Various NPK fertilizers on Spinach Plant Growth

Pranav Chintkuntlawar *Mills E. Godwin High School*

The purpose of this experiment was to find the effects of different NPK fertilizers on Spinach plant growth. There are 690 million people in the world that are experiencing hunger and using a different fertilizer can increase the growth of plants to solve this problem. The plants were grown with the 10%N-10%P-10%K, 30%N-10%P-10%K, 15%N-30%P-15%K, and 18%N-18%P-21%K fertilizer combinations. The plants were grown for 28 days and watered every other day, with the plant height and the number of leaves being measured at the end. UV-A light was used as a grow light in this experiment. The control of the experiment was the 10%N-10%P-10%K combination as it gave an equal amount of NPK. It was hypothesized that if the 10%N-10%P-10%K combination was used, then the plants will have the best growth.

The results showed that the 15%N-30%P-15%K combination had the best plant growth (4.64 centimeters and 2 leaves). The t-test results showed that the data for plant height was statistically significant for half of the comparisons and statistically insignificant for the remaining. The t-test for the number of leaves data showed that none of the values were significant. Both results, however, did not support the research hypothesis. This most likely might have been because there was not a consistent amount of water given throughout the experiment, which acts as a source of error. This research can be implemented on other plants to see if there is an effect of specifically the 15%N-30%P-15%K combination that increases plant growth.

Honorable Mention

The Effect of Vitamin C on *Raphanus sativus* Plants

Julia Hudgins *Mills E. Godwin High School*

The purpose of this experiment was to study the effects of different concentrations of vitamin C with constant concentrations of vitamin E on *Raphanus sativus* (radishes) under ultraviolet (UV) light, and determine which concentration was the most beneficial for growth. This will increase the knowledge of vitamin C and E relationships and how they protect crops from UV radiation. The hypothesis stated that if a *R. sativus* plant is given 1 gram of vitamin C and 1 gram of vitamin E, then the *R. sativus* plant will grow more efficiently under UV light. The independent variable includes 1 gram, 2 grams, and 0 grams of vitamin C. All levels were combined with 1 gram of vitamin E. The independent variable of 0 grams was the control. Each group was under an UV lamp for five weeks; watered with their nutrients and had their height measured once a week. At the end of the fifth week, the number of leaves was counted. The results show that the plants with 1 gram, on average, grew 0.63 cm more than 2 grams and 1.72 cm more than 0 grams. The results also revealed that 1 gram had, on average, 0.2 more leaves than 2 grams and 0.4 more leaves than 0 grams. The reason for the results was the combination of both vitamins' antioxidant properties resulting in more effective protection from UV radiation. T-tests were done and revealed that the data was not significant for the experiment. The results supported the research hypothesis.

First Place

The Effect of Added Polyamines on *Glycine max* Responses to Drought

Beverly Eborn *Central Virginia Governor's School*

The purpose of this research was to discover if added polyamines affected the growth rates and root-to-shoot ratios of droughted and nondroughted soybean plants. Soybean plants were given exogenously added polyamines and placed into drought conditions. The height of each plant was measured every two or three days, and the growth rate was calculated using the slope of the line of best fit for each plant's graphed measurements. After 14 days of growth, each plant's dry biomass was divided into 'roots' and 'shoots,' and the root mass of each plant was divided by its shoot mass to determine the root-to-shoot ratio. The experiment was conducted twice—once with a moderate drought, and once with a severe drought. Two-way unbalanced ANOVA tests were run to determine significance. It was found that added polyamines had a positive significant effect on the root-to-shoot ratios of soybean plants in moderate drought conditions (p-value =.041), but not in severe drought conditions; however, drought had no effect on the root-to-shoot ratios in both moderate and severe drought. This result did not support the research hypothesis that added polyamines would lower the root-to-shoot ratios of droughted plants. Alternately, both added polyamines and drought were found to have a significant effect on the growth rates of droughted plants in severe drought conditions. Polyamines had a significant effect on growth rates throughout the experiment (p-value =.007). This result did support the research hypothesis that added polyamines would increase the growth rates of soybean plants in drought.

The Effect of Different Brands of Sunscreen on *Elodea canadensis*

Sydney Fairchild *Central Virginia Governor's School*

The purpose of this study was to determine the effects of different brands of sunscreen on the health and lifespan of *Elodea canadensis*. The hypothesis was “If I expose *Elodea canadensis* to different types of sunscreens, then the sunscreens that contain oxybenzone will make the plants lose chlorophyll faster while the sunscreens without oxybenzone will not affect the plant as quickly.” The three different types of sunscreens used were Coppertone, Neutrogena, and Hawaiian Tropic and kept a control group that had no sunscreen added. Two tanks were set up per group and the elodea was soaked in the spring water. Every Wednesday 5mL of sunscreen was mixed with 40mL of water was added to the tanks. Pictures were taken and compared the coloration of the plants throughout the project with photoshop. A single factor ANOVA test determined significance, with a p-value of .002 and an alpha level of .05. A Tukey test then determined where significance was present, with a Qt value of 3.74 and a Dmin of 12.86. A significant difference was found between the Coppertone and control group as well as the Coppertone and Hawaiian Tropic group, therefore my research hypothesis was supported. The results show that oxybenzone has a negative effect on *Elodea canadensis.*

The Effect of Different Amounts of Greywater Filtration on the Growth Rate of Radishes

Sassan Fiske & Estee Ruiz *Washington-Liberty High School*

The purpose of this study was to find the effect of different amounts of natural greywater filtration on the growth rate of radishes. The independent variable was the amount of filtration. The experimental groups were greywater not filtered, greywater one time filtered, greywater three times filtered, and greywater filtered five times. The control group was the plants that received tap water as a water source. The dependent variable was the height of the radish plants. The constants were the amount of greywater given to each plant, amount of sunlight each plant received, the type of plant, and the type of filtration method. The hypothesis was this: If radish plants are watered with greywater that has been filtered once, twice, and five times as well as tap water, then the radish plants watered with tap water will prove to grow the best because greywater in general contains ingredients such as soap that are harmful to plants and no matter how much filtering does, it will not be able to fully rid of the harmful substances. The null hypothesis was this: If radish plants are watered with greywater that has been filtered once, twice, and five times as well as tap water, then the radish plants will all grow the same amount. An amount of greywater was filtered with coconut coir compost for three different levels, once, three times, and five times, and the filtered greywater was used to water 20 plants for each level. The radish plants were watered 10 mL of the given level every other day and the results were recorded for a three-week period. The results showed that the control group had the highest plant growth and the experimental group with the highest plant growth were the plants with greywater filtered five times. These results supported the hypothesis and rejected the null hypothesis. In conclusion, the study showed that the greywater filtered five times had a more positive effect on radish plant growth than regular greywater, greywater filtered once, and greywater filtered three times.

Honorable Mention

The Effect of Mangroves and Limestone Powder on the pH of Water

Estelle He *Mills E. Godwin High School*

The purpose of this experiment was to determine the effects of mangroves and limestone powder on the pH of water. Ocean acidification causes damage to marine organisms. Using natural methods to limit the reduction of pH provides an inexpensive method to alleviate decreasing pH. It was hypothesized that the combination of no mangroves or limestone powder would have the lowest pH. The levels of the independent variable were no mangroves or limestone powder (control), mangroves only, and both mangroves and limestone powder. A saltwater environment was created, and different combinations of mangroves and limestone powder were placed into each tub. To simulate acidification, 1.0 mL of vinegar was added to each tub once a week. A permission form was signed by a parent that indicated that they had read and understood the risks and possible dangers involved in the research and they consented to their child participating in this research. The pH of the water in each container was measured for 25 days using a digital pH meter. Data collected revealed the container with no mangroves or limestone powder had the lowest pH of 8.06 compared to mangroves only (8.14), and both mangroves and limestone powder (8.15). A t-test was performed that revealed all t-tests comparing the control to the other levels of the independent variable were significant. Results collected indicates the research hypothesis was supported as the combination of no mangroves or limestone powder had the lowest final pH. Results obtained can be explained as the calcium carbonate in limestone reacts with water and carbon dioxide to form bicarbonate raising pH. Additionally, mangroves increase the alkalinity of water through degradation of organic sediments. Further research can be conducted to investigate combinations of plants and rocks to greater raise pH and counteract the effects of Ocean Acidification.

Effects of Plastic Micro-particles on *Helianthus annuus* Growth

Lily Doebler *Central Virginia Governor's School*

This study's purpose is to determine whether various types of microplastics have a significant effect on the growth of *Helianthus annuus* (common Sunflower) crops. Two groups of crops were grown with a 16% percent concentration of ultra-fine glitter to soil, and data was collected by recording emergence dates and the dry root to shoot ratio at the end of a month-long growing period. These groups were compared to an additional control group. The experimental groups (craft glitter and polyester glitter) and control had standard deviations of .09, .11, and .05 respectively. An ANOVA test ran for emergence showed no significance, with a p-value of .19 exceeding the alpha value .05. An ANOVA test ran on the root to shoot ratio showed significance with a p-value of .01, and a post hoc Tukey Test determined that polyester glitter contaminated samples were significantly varied from the control group, as well as having the largest root to shoot ratio of the groups. The research hypothesis, stating that craft glitter contaminated samples would show the longest emergence date and the largest root to shoot ratio, was not supported by the findings in the research. This experiment explores the potential consequences of plastic contamination in soil and agricultural environments. Ultimately, it is concluded that microplastic contamination does have an effect on the growth of plants, depending on what type of plastic is used.

Third Place

The Allelopathic Effect of Allelochemicals such as Juglone in *Juglans nigra* on *Zea mays* and Glyphosate Resistant Weed, *Amaranthus retroflexus*

Matthew Huson *Washington-Liberty High School*

Glyphosate-based herbicides are detrimental towards the environment and lead weeds to develop immunity from chemical herbicides, leading to “superweeds” terrorizing horticulture throughout the US. The study of allelopathy, the process of a tree producing biochemical inhibitors to influence the growth, and germination of other organisms, could be a field of study which could provide an alternative to damaging herbicides. The Eastern Black Walnut (*Juglans nigra*) is a tree native to Eastern US with allelopathic traits. If a Black Walnut solution (from husks of black walnut seeds) inhibits the growth of plants and vegetables, then a Black Walnut solution will inhibit the growth of pigweed (a glyphosate resistant weed) because the residue contains allelochemicals that hurt germination, growth, and reproduction of plants. An aqueous solution comprised of Black Walnut husks was created to understand whether allelopathic traits in the Black Walnut would inhibit the growth and germination of Redroot Pigweed and Corn. In varying amounts, the solution was given to Corn and Pigweed seeds over the course of a 15-day data collection period. As the amount of IV increased, Corn germination was minimally impacted, as shown by an ANOVA test with a value greater than 0.05 (0.108). On the other hand, Pigweed germination was significantly impacted by the increase in the amount of IV through each experimental group. The ANOVA test was less than 0.05 (8.32 x 10), hinting at a strong relationship between the IV and pigweed germination. The Black Walnut Solution had minimal effect on Corn germination but did strongly inhibit the germination rate of Pigweed throughout the 15-day trial. As the Black Walnut Solution increased the germination rate of Pigweed decreased, while the germination rate of corn stayed the same. This accepts my hypothesis and shows the potential of using allelopathy in herbicide studies or as a possible herbicide itself.

The Impact of Invasive species English ivy (*Hedera helix*) on the Nitrogen, Phosphorous, Potassium level and pH Balance of Native Soil

Maya Lennon & Elyse Lanquaye *Governor's School@Innovation Park*

English ivy (*Hedera helix*) is a highly invasive species prevalent in the Northern Virginia region. This plant species reduces biodiversity, kills surrounding plant species, and typical removal methods have little impact on it. Recent studies indicate that English ivy may alter nutrients available in the soil it grows in, thereby diminishing other plants' ability to receive what they need. This project is aimed to measure the concentrations of nitrate, phosphate, and potash in the soil where English ivy proliferates. Three test sites were located - two had English ivy in tandem with other plants, and one had English ivy alone. A RapiTest soil probe was used following proper safety protocols to measure pH, temperature, and fertility whose values gave the concentrations of the aforementioned nutrients in the soil. A T-test showed no statistical difference between the ph values of the different locations; however, an ANOVA was calculated as $p<0.05$, rejecting the null hypothesis and supporting a difference between soil nutrient composition at different locations.

The Effect of the Contaminant on the Growth of the Radish Plant

Noor Long *Washington-Liberty High School*

Environmental pollution is defined as the contamination of the physical and biological components of the earth/atmosphere system to such an extent that normal environmental processes are adversely affected. It has a wide range effects on many different things, whether they are human made or not. Pollution in water and/or sources can lead to the chemical contamination of plants, which in turn can affect humans and animals. The purpose of this experiment was to test the effect of the water contaminant on the growth of the radish (*Raphanus sativus*) plant. Different contaminants were placed in water, and that was used to water the radish plants. The hypothesis is if a radish (*Raphanus sativus*) plant is watered with average tap water, then it will grow taller and faster than the other plants, because the tap water contains very little chemicals or pollutants. The experimental variables were Brand 2 Lysol, Pure Canola Cooking oil, and Morton's Sea salt, with the control as spring water. The control (spring water) had the highest mean of 4.92 centimeters while the lowest group was the water contaminated with salt, with a mean of 0.14 centimeters. The mean for the Lysol was 3.62 centimeters, and for experimental group 3, which was cooking oil, the mean was 3.60 centimeters. An ANOVA test was run to determine the statistical significance of the data, and the resulting p-value was 1.42639E-24, which is less than 0.5 so the null hypothesis was rejected. As for the results of the T-Tests, one test was conducted between the data groups of the control, and experimental group one. The T-Test value was 1.49228E-22 which also affirms the rejection of the null hypothesis. However, a T-Test conducted for experimental groups two and three yielded a result of 0.9894375 which is greater than 0.05. There was overall statistical difference, but between experimental groups 2 and 3 there wasn't a significant statistical difference.

Botany B (HS BOT-B)

Honorable Mention

Lichen Abundance and Diversity in Cemetery Environments

Abby Madson *Chesapeake Bay Governor's School*

In the 21st century, 55% of the world's population lives in urban areas, and air pollution is at an all-time high. The lichen, a living mutualistic symbiosis between a fungus and an alga or cyanobacteria, although small and unassuming to the human eye, serves its environment as both a pioneer species and as an environmental indicator of air pollution. The focus of this study is on the presence of lichen species in the cemetery environment. This study aims to test the view that cemeteries are relatively undisturbed environments, and to determine whether or not cemeteries are true ecological safe havens by studying the abundance of lichen growth and the richness of species present within high population density areas. Samples were gathered in 5 cemeteries and pictures were taken of the front and back of the stones, as well as a picture of its surrounding area; the age of the stone was recorded as well, this data was then used to determine percent coverage and species richness. A total of 8 different species were observed and identified between the 5 sites. It was found that a direct correlation exists between the average age of the stone and the average number of species present on it, with p= 0.041 using ANOVA test. This study was significant in proving the common idea that cemeteries are undisturbed natural areas hidden amongst large expanses of urban areas, a sanctuary for species such as the lichen. The results of this study provided useful insight into regionally understudied organisms in an often-overlooked environment.

Investigating Sound on the Effect of Music Genres on Growth of *Vigna radiata* and *Solanum lycopersicum*

Anika Makarla *Mills E. Godwin High School*

The purpose of this experiment was to investigate sound through the effect of music genres on tomato and mung bean growth. Recently, sound treatment was introduced as a new approach to enhance the growth of mung beans and tomatoes. Both plant types were grown in 120 mL of garden soil with exposure to classical and rock music at sound frequency of 440 Hz. The plants grew for thirty-one days, and their height was then measured. Mung beans and tomatoes that were exposed to neither classical nor rock music were the controls of the experiment. It was hypothesized that mung beans treated with classical music at 440 Hz would result in the tallest plants. The results, however, revealed that mung beans treated with no music grew the tallest, on average, 6 cm more than when treated with classical music. T-tests were performed on the data and showed that tomatoes exposed to classical music vs. rock music (2.868), mung beans exposed to classical music vs. control (3.967), and mung beans exposed to classical music vs. rock music (2.727) were significant. However, tomatoes exposed to classical music vs. control (1.030), mung beans exposed to rock music vs. control (1.045), and tomatoes exposed to rock music vs. control (1.670) were not significant. The results did not support the research hypothesis because mung beans grew worse when exposed to classical music, as it slowed protein production and nutrient absorption in plant cells, reducing their growth.

Honorable Mention

The Effectiveness of Natural Medicinal Essential Oils as Cleaning Products

Ankita Mandal *Mills E. Godwin High School*

Pandemics and widespread disease have become seemingly unsurmountable threats – an unwanted aftermath of enormous societal and technological advancements. One way to protect oneself from bacteria and viruses is using cleaning products, which have skyrocketed in price and plummeted in availability. The purpose of this experiment was to explore cleaning effectiveness of widely available essential oils.

Lavender, tea tree, peppermint and nutmeg essential oils were tested on simulated bacterial surfaces of UV-reactive pigment applied to plates. The level being tested was spread in an identical manner. Every trial was ranked on a scale of increasing effectiveness from 1 to 5 by how much pigment remained. A negative control, water, and a positive control, Clorox wipes, were tested to gain perspective on how essential oils compared to trusted brands. The hypothesis of this project was if four different essential oils were tested for their cleaning properties, peppermint essential oil would be the most effective disinfectant.

With a degree of freedom of 5 and a p-value of 3.213, the calculated chi-square was 0.667, thereby accepting the null hypothesis of a unique ratio of median rankings. Peppermint and Clorox prevailed as the best options, closely followed by tea tree. Lavender and nutmeg came next respectively, and water ranked the least effective of all. This supported the hypothesis and demonstrated essential oils' potential to be cleaning agents in the foreseeable future. Further experimentation could be conducted to identify other value propositions that cater to customer needs, such as aroma and antioxidant amounts.

The Effect of Different Pesticides Containing Heavy Metals on the Transpiration Rate of *Vigna unguiculata*

Nishaanth Mulpuru *Mills E. Godwin High School*

The purpose of this experiment is to investigate the effect of different pesticides containing heavy metals on the transpiration rate of bean plants. Pesticides and fertilizers like insecticides and herbicides containing heavy metals are extensively used around the world, and as a result, agricultural soils are becoming heavily contaminated with heavy metals. Traces of heavy metals are required for plant metabolism, growth, and development, but excessive concentrations of heavy metals result in a decrease in root and plant growth and plant performance (Clemens, 2006). Bean plant seeds were treated with either the control (distilled water), Demon WP Insecticide solution, or Roundup solution. The transpiration rate of bean plants was measured. It was hypothesized that the transpiration rate of bean plants given the control will be greater than the bean plants given the insecticide or herbicide. The results revealed that the transpiration rate of bean plants given the control was greater than the Demon WP Insecticide and Roundup solutions. A t-test revealed that the data was statistically significant, and that the results supported the research hypothesis and are due to the independent variable. Since the Roundup solution contained higher concentrations of heavy metals than the Demon WP Insecticide, the Roundup solution negatively affected the bean plants more. A defense mechanism activates in plants when given heavy metals, increasing the concentration of various enzymes and peroxidase (Verma et al., 2011). Further studies like the effect of heavy metals and pesticides containing heavy metals on specific plant enzymes and processes could be investigated.

Third Place

The Effect of Different Antioxidants on the Protection of Free Radicals in *Vigna radiata* Seed Germination

Angela Nguyen *Mills E. Godwin High School*

The purpose of this experiment was to find the effects of different antioxidants on the protection of free radicals in *Vigna radiata* seed germination. Plants naturally generate free radicals, but when the concentration of reactive oxygen species overwhelms the antioxidant defense system, oxidative stress occurs, causing damage to lipids, proteins, and nucleic acids. Gloves were worn as a precaution from the vitamins and hydrogen peroxide to prevent skin irritation. *Vigna radiata* seeds were soaked in a diluted solution of hydrogen peroxide and water and were drained. The seeds were then soaked in mixtures of the antioxidants vitamin A, C, and E with water for four hours, drained, allowed to grow for five additional days, and the height of each sprout was measured. The control used in this experiment was a hydrogen peroxide and water solution as a source of free radicals without any antioxidants. It was hypothesized that if *Vigna radiata* seeds were treated with vitamin C supplements, then the seeds would grow the tallest. The results revealed that the seeds in vitamin C (105.4 mm), on average, grew more than seeds in vitamin E (91.8 mm), A (75.3 mm), and no antioxidant (17.7 mm). Multiple t-tests were performed on the data, which revealed that the data was statistically significant. It is believed that vitamin C was able to enhance *Vigna radiata* growth because the antioxidant enzymes reduced oxidative stress and damage to the plant cells and aided cell proliferation, while vitamin E and A were insoluble in water while may have resulted in less antioxidant absorption by the seeds.

The Effect of Temperature of Water on Capillarity

Hemanth Nimmagadda *Mills E. Godwin High School*

The experiment's purpose was to research the effects that changing the temperature of water had on its capillarity. This was an important topic to study because capillarity is the main driving factor of water transport through the stem of plants, and the research could allow many people to find the proper temperature at which their plants should be watered. A research hypothesis was formulated that if the temperature of water was decreased, then its capillarity in a tulip stem would be increased. An experiment was then conducted by conditioning water to different temperatures and then testing its capillarity in a tulip stem. The capillarity was measured by recording the time it took for the water to travel to the top of the stem. Appropriate safety precautions were taken when conducting the experiment. The temperature values were selected by taking average temperatures in Richmond, Virginia during different months. One temperature value was not a naturally occurring average temperature in Richmond and was set as the control as a result of being the unknown variable. T-tests which were performed to determine the significance of the data showed that it was statistically significant. The research hypothesis was supported because the water at lower temperatures took less time to travel through the tulip stem than the water at higher temperatures. This occurred due to liquid water having stronger cohesive forces at lower temperatures and weaker cohesive forces at higher temperatures.

First Place

The Synergistic Allelopathic Effects of Extracts from Two Invasive Species on Germination and Growth of *R. sativus*

Carson Ray & Daniel Han *Roanoke Valley Governor's School*

Allelopathy, or the use of secondary metabolites to inhibit or benefit other plants, could be one mechanism by which invasive species dominate native species and produce monocultures. However, allelopathic plant species coexisting with invasive species in their natural range may have developed allelopathic resistance to them, meaning that extracts from two such plants may neutralize each other. This experiment analyzed the synergistic effects of total plant matter filtrates from *L. leucocephala* and *L. japonica* on the germination and growth of *R. sativus*. A Chi-Squared test was conducted on germination data at 156 hours and significance was found (p = 3.96E-10). The *L. japonica* and *L. leucocephala extracts* had the smallest germination (~53% and ~39% of the control). The 3:1 and 1:3 ratios of *L. japonica* to *L. leucocephala* had significantly more germination (~84% and ~76%). The 1:1 ratio had approximately the same germination as the control. Growth measurements were collected at 216 hours and analyzed with a One-Way ANOVA and Tukey post-toc analysis: wet mass (p = 5.57E-13), radicle length (p = 1.69E-6) and shoot length (p =1.44E-10). The 3:1, 1:1, and 1:3 groups had significantly more mass than the 1:0 filtrate groups (average of ~89% of the control). The 1:1 group had significantly more shoot length than all the other groups and ~38% more than the control. These results provide strong evidence to support the hypothesis that the combined filtrates would have less inhibition, meaning this technique could be applied to protect native species from invasive allelochemicals.

The Effect of Different Soil and Bean Combinations on Electricity Production

Sriharsha Sambangi *Mills E. Godwin High School*

The purpose of this experiment was to find the effect of different soil and kidney and lima bean combinations on the amount of electricity produced. Recently, more and more people are becoming knowledgeable about climate change and the negative effects it brings. To combat the negative effects of renewable energy sources, need to be used and bioenergy is one such source. Kidney beans and lima beans were grown in compost, topsoil, and potting soil. They were given four weeks to grow, and the voltage was measured using a multimeter. There was no control as no common soil and bean combination is being grown. A research hypothesis was formulated that if kidney beans are grown in compost soil, then it will result in the highest electricity output. Results revealed that, on average, compost with kidney beans produced more electricity than topsoil with lima beans and potting soil with kidney beans but produced less electricity than Topsoil with kidney beans, Potting soil with lima beans, and Compost with lima beans. A t-test was done, and the data was revealed to not be significant and that the results did not support the research hypothesis. This experiment and its research can help future studies that will investigate the optimum growing time for kidney and lima beans and whether kidney and lima beans are the legumes that produce the most electricity in compost, potting soil, and topsoil.

The Effect of Using Black Soldier Fly Larvae in Composting on Resulting Plant Height

Benjamin Schneider *Clover Hill High School*

The purpose of this experiment is to determine the effect of the addition of black soldier fly larvae to compost production on the height of plants grown with the compost. Improvement of compost could provide a boost in agricultural production to aid in crop growth and quality for a continually expanding population. The hypothesis was that if black soldier fly larvae, *Hermetia illucens*, were used to produce compost, the plants grown in that compost would grow taller. The control group was a compost developed without the larvae. Two equal compost bins were created, and both were filled with organic materials such as food scraps and leaves. 5,000 black soldier fly larvae were ordered, and they were released into one of the bins. At the beginning, the insects were in the early larval stage. Each compost was given 1 month to finish and was then distributed to 10 pots. The growing period occurred from October to September, and the temperature was not sufficient to support the plants. For this reason, the experiment was relocated indoors and the plants were developed using grow lights. 4 green bean seeds were planted in every pot, but only the strongest sprout was kept for the duration of the six-week growing period. The plants were measured at the same time each week of the experiment. The final height of the plants at the end of the experiment was recorded. The plants grown in the larvae compost had a mean height 36.840 cm, while the control compost produced plants with a mean height of 41.248 cm. Following the experiment, a t test was conducted to determine the significance of the results. The t test found that there was a significant difference between the two levels of the independent variable. Therefore, the null hypothesis of no significant difference was rejected. The compost produced without black soldier fly larvae resulted in taller plants, so the experimental hypothesis was not supported.

The Effect of Climate Change on Seed Germination

Meyyammai Subramanian Periyakaruppan *Mills E. Godwin High School*

The purpose of this experiment was to find the effects of heat and humidity on pea plants and bean plants. Recently, climate change has affected agriculture with positive results in some conditions and negative in other conditions. The pea plants and bean plants were subjected to room temperature, extra heat, and heat and humidity. The plants grew for ten days and then the length that they had sprouted was measured. The control that was used in the experiment was pea and bean plants at room temperature. It was hypothesized that if the humidity and temperature levels are changed from the optimum temperature, then the length of the sprouts will be shorter. The results revealed that pea plants given extra heat, grew on average, 2.8 cm more that pea seeds in room temperature and 3.4 cm more than pea plants with heat and humidity. It also revealed that bean seeds with extra heat and humidity grew, on average, 1.4 cm more than bean seeds at room temperature and 0.6 cm more that bean seeds with extra heat. Nine t-test were done with six t-tests being significant and three tests not significant. Since the majority of the t-tests was significant, the data is also significant. The results supported the research hypothesis. This research could lead further studies that investigate the effect of extra heat on different species of plants.

The Effects of Electricity at Different Voltages on Growth of Ambrosia Hybrid Corn Plant (*Zea mays* var. *rugosa*)

Imaan Syed *Central Virginia Governor's School*

The purpose of this study was to find a faster and more effective way to grow crops, which will help agricultural producers competently grow food to meet the demand of the rapidly growing population. This experiment was done by creating three groups of plants with different electrical flow: a control group, a two-volt group, and a four-volt group. Each pot contained about five inches of soil with one metal rod on each side of the seed, which had the electrical flow going through it. The electricity came through copper wires which were attached to the rods on one end and a power source (which let out the appropriate amount of electricity) on the other. Each week, the height of each plant in each group was measured and recorded. An ANOVA data analysis was performed after three weeks of growth. The data was not statistically significant because the p-value, .23, was not less than the alpha, .05. The data did not support the research hypothesis, although, the data trends towards the research hypothesis, which was that the lowest voltage group would grow the highest, following the control group and then the four-volt group. The final height averages for each group: the control group was 17.30 centimeters, the 4-volt group was 13.13 centimeters, and the 2-volt group was 18.93 centimeters. Additional experimentation and research would need to be done to further analyze this study to see exactly what these trends suggest.

The Effect of Various Hygroscopic Humectants on Seed Germination Day

Aquib Syed *Mills E. Godwin High School*

The purpose of this experiment was to determine the effects of different hygroscopic humectants on the seed germination day. Hygroscopic humectants are substances known for increasing moisture due to their hydroxyl groups, but recently, they have been found to decrease seed germination times. Humectants come in multiple varieties, each having its own unique properties and applications. The rationale of this experiment was to determine which hygroscopic humectant results in the earliest seed germination day. This experiment may benefit scientists, agriculturists, horticulturists, and gardeners as they all wish for faster seed germination. The hypothesis was that if the hygroscopic humectant Epsom salt is used, then the seed germination day will be the earliest.

Appropriate safety protocols were followed. Marigold seeds were soaked in the different humectants, which were glycerin, propylene glycol, Aloe vera gel, and Epsom salt. Soil was put into pots, and the seeds were planted and watered until germination. The seed germination days were recorded and converted to a rank system. There was no control because no unchanged hygroscopic humectant could be used.

The data showed that propylene glycol resulted in the latest seed germination day, whereas Aloe vera gel resulted in the earliest seed germination day. Chi-square tests were performed, and the calculated values were greater than the table values. The null hypothesis was rejected, the probability of error was less than 0.05, and the data was statistically significant. Since Aloe vera gel contained beneficial vitamins, enzymes, and hormones, it resulted in the fastest seed germination time.

The Effect of Aqueous Calcium Concentrations on the Germination of *Pisum sativum*

Ryan Taylor *Mills E. Godwin High School*

The concentrations of minerals dictate cellular function and intracellular signaling and responses. Plants depend on calcium as a critical mineral for cell organization and processing, and the concentration of calcium controls the health of the entire organism. In tap water across the county, calcium concentration varies greatly, with some areas electing to purify water while others preserve the high mineral concentrations. While a range of anthropic advantages and disadvantages exists for varying calcium concentrations in water, the botanical effects of calcium concentrations must be considered, too. An experimental design was formulated to study the effects of various aqueous calcium concentrations on *Pisum sativum* germination. The highest concentration (180mg/L) was hypothesized to benefit the *Pisum sativum* germination the most.

Pisum sativum germination was tested through incremental concentrations of aqueous calcium supplements: 0, 60, 120, and 180mg/L to represent pure, soft, moderately hard, and very hard water, respectively. 0mg/L represented the control as it contained no calcium supplement. For nine days, 25 seeds for each independent variable were placed in petri dishes and watered daily with the designated calcium concentrations. Afterwards, the length of the root was measured (in centimeters) to determine the germination of the *Pisum sativum*. Proper safety attire was worn for the entire experiment and proper disposal of equipment was utilized.

The 180mg/L concentration revealed the highest germination (7.680cm), supporting the research hypothesis. However, a t-test showed much of the data was not statistically significant, with only 120mg/L vs. 180mg/L showing statistical significance. The results were likely because high levels of calcium enable optimal cellular function and intracellular response. For future experimentation, more extreme ranges of calcium concentrations should be tested.

The Effect of Magnetism on Crop Survival During a Simulated Drought

Diana Trutia *Mills E. Godwin High School*

In this study, low levels of magnetism were tested on two crops, *Zea mays var. indentata* (dent corn) and *Brassica rapa* (common turnip), to determine if their health, germination rate, and growth would be sustained during a simulated drought. Many countries have seen an increase in drought due to climate change; thus, helping crops that are useful to feeding humans and livestock, as well as industrial processes, is essential. This study was conducted to determine if low levels of magnetism provided by N35 magnets, which are relatively inexpensive and therefore more accessible compared to stronger magnets, can be a feasible way to improve plant growth in locations where droughts occur.

It was hypothesized that if *Zea mays var. indentata* was exposed to two magnets, then the plants in that group would be healthier, have a higher germination rate, and grow taller. The control for each species was the group not exposed to any magnets. To conduct the experiment, zero, one, or two magnets were placed at the bottom of containers where the plants were grown for five weeks. All plants were watered only once, at the beginning of the study, to simulate the progress of a drought. Statistical tests determined that all results of the experiment were insignificant. It is likely that the results were insignificant because of the low magnetic strengths studied, and therefore, higher levels of magnetism should continue to be focused on as a solution to aiding farmers during droughts.

Honorable Mention

The Effect of Magnesium Sulfate on *Epipremnum aureum's* Radicle Growth

Nivriti Vanga *Mills E. Godwin High School*

The purpose of this experiment was to find out how magnesium sulfate, Epsom Salt, effects ***Epipremnum Aureum's***, Pothos, radicle growth when propagated using the water culture method. Since Epsom salt has a positive impact on many outdoor plants, it may also be beneficial to indoor plants when mixed in water used to propagate cuttings. This could lead to a faster way of propagating Pothos. Gloves, goggles, and proper clothing were worn when dealing with Epsom salt. Nothing was eaten or drunk while experiment was being performed. Pothos cuttings were placed in a solution with a concentration of 0, 7.1, 14.2, 28.4, or 42.6 grams of Epsom salt per 3.8 liters. After 26 days, change in length of radicle was measured in millimeters. The control used in the experiment was 0 grams of Epsom salt because Epsom salt is not commonly given to Pothos plants. It was hypothesized that if 14.2 grams of Epsom salt is added to 3.8 liters of water, and 250 mL of this water is given to a Pothos cutting, then the radicle will grow the longest. The results revealed that the 42.6-gram trials had the smallest mean, and the 0-gram trials had the highest mean. Ten t-tests were done on the data and six of the t-tests showed significant results. The results did not support the research hypothesis. It is believed that the results are because the cuttings already had enough magnesium sulfate. This most likely caused the cuttings to go through osmotic stress. This research could lead to studies of Epsom salts effects on various indoor plants.

Second Place

The Effect of UV-B Intensity on the Floral Pigmentation of *Brassica rapa*

Arleigh Wagoner *Central Virginia Governor's School.*

The purpose of this study was to determine the effects of varying levels of UV-B intensity on the floral pigmentation of *Brassica rapa*. The hypothesis was that if *Brassica rapa* was exposed to a 10.0 UV-B intensity bulb, a 5.0 UV-B intensity bulb, and a control group representing negligible UV-B presence, then it would grow to be the most vibrant under the 5.0 UV-B intensity light. Three groups of ten plants were planted under each UV-B intensity group and grew until fully matured after two months. After growth, the plants were photographed under the same lighting conditions to capture the floral pigmentation. The *Brassica rapa's* floral pigmentation was then quantified using the eyedropper tool in Microsoft PowerPoint on an RGB scale, ranging from 0-255. After organizing and averaging the red, green, and blue values, three separate single ANOVA tests were conducted to determine if there was any statistical significance between the recorded data. The tests determined there was no significance between groups with p-values of .354, .659, and .056 compared to an alpha value of .05. The research hypothesis was not supported. Overall, the experiment suggested that varying levels of UV-B intensity have little to no effect on the floral pigmentation of *Brassica rapa*, and ultimately that dioecious organisms do not rely on exposure to UV-B light for reproduction.

Chemistry A (HS CHM-A)

The Effect of Mordant on the Weight of Yarn

Haley Baasansukh *Washington-Liberty High School*

The purpose of this experiment was to test if various mordants would have an effect on the weight of yarn trials. Mordants are chemicals that are used to help bond the natural dye molecules to the yarn that is being dyed on to form an insoluble compound. A mordant would aid the dye in attaching itself to yarn fibers. It was hypothesized that if the iron mordant is tested, then the yarn will weigh the most. The iron would have caused the dyed yarn's color to be darker because of its reaction with tannin-rich dyes. The null hypothesis for this experiment is that if the mordants are tested, then there is no effect on the weight of the yarn.

Three levels were tested: no mordant, alum power along with a Cream of Tartar fixative, and an iron mordant. The hypothesis was tested through dyeing 10g yarn trials from three yarn skeins. Yellow onion skins were boiled to create a dye. Two different mordants simmered with their respective skein. Both the alum and iron mordant consisted of a 1:2 ratio.

From the data collected, it was concluded that the iron mordant had the highest mean of 13.6g and the control had the lowest mean of 10.9g. The data supports the hypothesis that was tested. Statistical tests were done to determine the statistical significance of the data, with both an analysis of variance (ANOVA) test and one T-test on all experimental groups yielding p-values of less than the critical value of 0.05.

The Effect of pH on the Solubility of Acetaminophen

Olivia Bartrum *Wakefield High School*

The purpose of the experiment was to test the effect of pH of different substances on the solubility of acetaminophen. The project analyzed the intersection of gastroenterology, drug absorption, and pH. The hypothesis was if acetaminophen was placed in lemon juice, it would dissolve more quickly than all other substances. It was believed that lemon juice, which has a similar pH compared to gastric acid, an important substance in the process of digestion, and stimulates the production of hydrochloric acid, would break down the acetaminophen the quickest. Substances were chosen to represent the pH of areas of the gastrointestinal system. The substances tested included Lemon Juice (gastric antrum), Black Coffee (fundus), Water (blood), Milk (small intestine), and a Baking Soda-Water Solution (duodenum). The dependent variable was the time taken for acetaminophen to dissolve and the independent variable was pH. The experiment was conducted by placing a 325mg tablet of acetaminophen into 200mL of each substance tested, with 20 trials of each substance performed. The acetaminophen was evaluated for solubility at least every hour for six hours, and once at 24 hours. The results of the experiment showed the hypothesis was rejected; none of the acetaminophen tablets in any of the substances had completely dissolved. However, the time for acetaminophen to break down significantly was recorded (with the average in parentheses) and is what is represented in the data. Black Coffee was able to break down acetaminophen the quickest (5 minutes 39 seconds), followed by Water (6 minutes 53 seconds), Lemon Juice (78 minutes 11 seconds), Baking Soda-Water Solution (144 minutes 46 seconds), and Milk (244 minutes). Future iterations of this project may be improved by accounting for other factors (enzymatic, chemical, physical) not considered in this project.

The Effect of Different Types of Wood on Maximum Temperature Yield

Raneem Basir *Clover Hill High School*

The question that was addressed in this experiment was which type of wood released the most heat. Knowing what kind of wood releases the most heat allows for people to use the best firewood for heating or cooking purposes. The purpose of this experiment was to determine the effect of different types of wood on maximum temperature yield. The hypothesis was that if tulip poplar, pine, red oak, and cedar wood were burned, red oak would give off the highest temperature. One piece of wood was placed into a circular fire pit with seven pieces of charcoal and was lit on fire. A temperature gun was used to scan the surface of the wood every minute to find the highest temperature. This process was done until the timer reached three minutes. Ten trials were conducted for each species of wood. Each temperature found was recorded into a data table. The highest mean temperature was red oak, which was 493.8 degrees Celsius, while the lowest was pine, which was 408 degrees Celsius. Cedar and tulip poplar were rather in the middle, cedar having 459.8 ℃ and tulip poplar having 479 ℃. Red oak overall gave off the highest temperature, which shows that the experimental hypothesis was supported. The null hypothesis of no significant difference was tested using an ANOVA test, and the null hypothesis was rejected.

Third Place

The Effect of Different Levels of Ammonia on Absorption of Hair Color During the Dyeing Process

Cherish Bland *Clover Hill High School*

The goal was to understand how ammonia affects the saturation of dye in the hair to help beauticians and people at home that dye hair, have the optimum amount of color saturation resulting in long-lasting color. The hypothesis stated that if 5ml of ammonia is added into ammonia-free hair dye, then the hair will have the optimal amount of saturation compared to other levels. The experiment was carried with three variables. 2mL, 5mL, and 10mL of ammonia. Each amount of ammonia was mixed up into its respective bowl of dye, and then the dye was placed onto one inch of 30 strips of hair. Once the strips were dyed, they sat for the amount of time on the box, were dried, and then measured. Each strip was measured five times and the value of the R, G, and B values of each strip were averaged. The results showed that increasing the amount of ammonia decreased the color saturation for the R, G, and B, values. The data did not support the research hypothesis and the null hypothesis was rejected.

First Place

Optimization of an Electrocoagulation System for the Removal of Polyatomic Ions from Water

Julia Brodsky *H.B. Woodlawn*

Electrocoagulation (EC) is a water purification method that uses electricity to induce a reduction-oxidation reaction between electrodes and water. It is largely used in industrial settings to remove heavy metals, emulsified oils, and dyes from wastewater. This experiment aimed to optimize a battery-operated, household-sized EC system for the removal of polyatomic ions from water. The operational parameters altered were electrode material (aluminum, bronze, copper), inter-electrode distance (IED) (1, 2, 3, 4cm), and number of electrodes (2, 4). The experiments were conducted in water that contained NaH2PO4, MgSO4, or NaNO3. There were 72 different combinations of the conditions tested. Data were collected with a total-dissolved-solids meter to determine the amount of dissolved solid in the water before and after EC. Copper electrodes were found to be the most effective at removing all three polyatomic salts. Bronze electrodes removed a higher percentage of monosodium phosphate and magnesium sulfate than aluminum electrodes but was least effective at removing sodium nitrate. The average optimal IED differed between the three pollutants: 2.3cm for monosodium phosphate; 3.2cm for sodium nitrate; 1.3cm for magnesium sulfate. EC with 4 electrodes was more effective than with 2 electrodes. Percent removal ranged from 18.2% to 63.5%; the most effective combination of conditions was 4 copper electrodes with an IED of 1cm in water containing magnesium sulfate. ANOVA tests found all data comparing inter-electrode distances to be significant (p-value = <.05), so the null hypothesis was rejected.

The Effect of Active Ingredient on Ultraviolet Radiation Protection

Victoria Bui *Mills E. Godwin High School*

In 2018, a ban on the sale of two types of active ingredients commonly used in sunscreens, oxybenzone and octinoxate, was initiated in Hawaii, which was taken into effect on January 1, 2021. The purpose of this initiative was to reduce damage to coral reefs, as these compounds have been linked to coral bleaching. Alternatives such as zinc oxide and titanium dioxide exist, but if these ingredients have a lower efficacy against ultraviolet (UV) radiation, the recent ban may sacrifice human health for the wellbeing of coral reefs. The purpose of this study was to determine the efficacy of different active ingredients of sunscreen in relation to their environmental impact. The hypothesis was that if different UV protective substances were tested on strength, then, of the active ingredients, titanium dioxide will perform the worst in protection against UV A/B light due to the mineral component of the sunscreen. The independent variable groups were oxybenzone, titanium dioxide, zinc oxide, and none, with no active ingredient being the control. This was to compare the effectiveness of these active ingredients based on the UV intensity before and after application. A permission form was signed by a parent that indicated they had read and understood the risks and possible dangers involved in the research and consented to their child participating in this research. A sunscreen made by heating a combination of coconut oil, shea butter, and aloe vera gel and allowing the mixture to set. Then, the active ingredient was thoroughly combined into the lotion in the corresponding container. The difference of UV intensity was measured in microwatts per square centimeter, using a UV monitor. The mean intensity deflected or absorbed was 0.92 for the control, 2.96 for titanium dioxide, 4.84 for zinc oxide, and 3.16 for oxybenzone. The t-tests performed showed the data to be significant, except for the comparison between oxybenzone and titanium dioxide, so there is a low possibility that the results were due to chance.

Honorable Mention

The Effects of Antifungal Agents on the CO2 Production of Baker's Yeast

Richard Chen *Washington-Liberty High School*

The purpose of this experiment was to study the effect of certain antifungal agents on the CO2 production of baker's yeast. Fungal infections are a problem across the entire globe, and very common at that. The aim of this experiment was to determine which antifungal agent would be best at inhibiting the growth of fungal infections in the real world. It was hypothesized that the growth of the yeast would be best stopped by terbinafine, because this agent interferes with squalene epoxidase, the first enzyme used by a fungus in the process of making a cell membrane. Four antifungal agents were tested: no agent, clotrimazole, terbinafine, and undecylenic acid. To test the antifungal agents, the agents were mixed into a warm sugar water yeast solution to stimulate the yeast's growth, like in baking. The yeast's growth was best inhibited by the undecylenic acid, which had the lowest mean volume of CO2 production. Thus, the data did not support the research hypothesis. Statistical testing was done to determine the statistical significance of the data, with both an analysis of variance (ANOVA) test and six T-tests on all experimental groups yielding p-values of less than the critical value of 0.05. This experiment provided a beginning understanding of the effectiveness of the tested antifungal agents. With the proper information, people will be able to make better decisions regarding their own lives and healthcare. It also allows for future in-depth study on the wide variety and capabilities of antifungal agents.

The Effect of Cleaning Solution on Rust on Nails

Misthi Choksi *Mills E. Godwin High School*

The purpose of this experiment was to determine the effects of different cleaning solutions on the amount of rust removed from nails. Phosphoric acid, citric acid, and baking soda claim to remove rust and get rid of the flaky, orange color that sits on iron. Rust can also transfer onto the skin if not cleaned off, showing that removing rust from jewelry is important. Rusted nails were treated with four levels: phosphoric acid, citric acid, baking soda, and no solution. The nails were submerged in water for two weeks and then the mass was measured. After the nails sat in a solution for one day, the mass was measured again and the difference between before solution and after the solution was calculated. The control that was used in the experiment was no solution. It was hypothesized that if phosphoric acid is used on the rusted nail, then it will remove the most amount of rust. The results revealed that rusted nails treated with phosphoric acid had a greater difference, on average 24.8 mg, 3.2 mg more than citric acid, and 6 mg more than baking soda. A t-test was done on the data, and it revealed that the data was significant for all levels vs. control. The results supported the research hypothesis. The conclusion proves that phosphoric acid was able to remove rust effectively because it converted the rust into an easier form to remove. The other two acids relied on removing dirt and grime and were used as abrasives. All safety measures were met.

Honorable Mention

The Effect of Genetic Pool Testing on Result Reliability

Sydney Coffman *Mills E. Godwin High School*

Reliable testing results are necessary in situations such as virus testing. Therefore, it is important to determine which testing procedures lead to optimal results. Pool testing is a procedure in which multiple test samples are combined, helping to save money and effectively decrease resource consumption. The purpose of this project was to determine if using a pool testing decreases test reliability.

For this experiment, PCR and electrophoresis were completed to determine the reliability of pool testing. Two different samples were created for electrophoresis; one sample contained DNA with a known positive GMO presence while the other contained 1/4 DNA with known positive GMO presence and 3/4 DNA with known negative GMO presence. After electrophoresis, the pigmentation of the bands was determined to show the resolution of the bands. The darker bands (highly concentrated DNA) had higher resolutions/reliability. For this experiment, safety gloves and goggles were worn.

After completing 25 trials, the data was analyzed. The mean Delta E value for band color change was calculated as 11.8151 for the pool tested trials and 12.3906 for the non-pool tested trials. The higher mean calculated Delta E color change shows that the resolutions of the non-pool tested electrophoresis bands were higher, supporting the hypothesis. However, the null hypothesis could not be rejected based on a completed t-test.

Previous research supports the results obtained in this experiment. According to both the CDC and the FDA, pool testing decreases result reliability by diluting positive testing DNA. This supported the findings of the project, showing a slight decrease in band resolution.

Second Place

Optimizing Direct Air Capture Through Using Infrared-Promoted Vibrational Behaviors of Greenhouse Gases: A Computationally assisted Analysis

Zaid Contractor *Mills E. Godwin High School*

With upcoming years showing potential for growth in innovative carbon capture technologies, it remains vital for all current scientific findings to align properly with the policies set for achieving net zero and negative emissions. This computationally assisted study investigated the vibrational excitation of four greenhouse gases. The study provides a theoretical basis on the use of chemical behaviors upon infrared (IR) absorption for cost reduction in the adsorption/desorption process of direct air capture (DAC). The studied molecules were carbon dioxide, methane, nitrous oxide, and water vapor, all of which continuously contribute to a detrimental *positive feedback loop* of emissions: A mechanism responsible for the global temperature increase projections to go well over the Paris Agreement's two degrees Celsius limit. No control group was present for an appropriate distinction between the greenhouse gases to be made due to their chemical structure distinctions. The semiempirical program MOPAC was utilized with the Avogadro GUI to gather data on the vibrational spectroscopies and the chemical changes that occur in the selected gases for study of a hypothesis. The hypothesis being tested claimed that the high energy requirement for gas desorption can be eliminated and that the combined adsorption of multiple species – including particulate matter – can be achieved through the adapted use of IR vibrations of gases. Calculated data indicates that N2O and CO2 have high transition dipole moments and infrared intensities. Statistical analyses, however, show an inconsistency in those values whose variations can be explained through their quantum chemical analyses for analyzing IR-mediated chemical changes at various frequencies. As for further research, using machine learning for high-throughput screenings of adsorbent databases and advanced computational simulations or empirical studies for more realistic environments is encouraged. The latter can allow for an accelerated transition to an optimal global commercialization of negative emission technologies. Moreover, eye protection through blue light shielding glasses was maintained at all times during this research that was conducted digitally.

The Effect of Fruit on the Alcohol level of Kombucha

Ramon Dayan *Washington-Liberty High School*

Kombucha has been gaining popularity worldwide. Sugar is one of the commonly known ingredients of Kombucha to increase its alcohol level. Fruit contains sugar that is called fructose. The purpose of this experiment was to test the effects of different types of fruits on the alcohol level of Kombucha. The research hypothesis stated that if sweeter fruits were added to the kombucha, then the alcohol level of the Kombucha will increase because sweeter fruit has more sugar and fruits with higher fructose content will generate a higher alcohol content after fermentation. To begin this experiment, fermentation must start a Kombucha. In this experiment, no fruit, strawberry, banana, and mango will be tested to determine the effect of different types of fruits to the alcohol level of Kombucha. Since each group has different fruits, the concentrations of alcohol of each group are different. A hydrometer was used to measure the alcohol level by measuring the specific gravity. The equation for calculating the alcohol level was “Starting Gravity-Final Gravity” which means that the tea was measured with the use of a hydrometer before adding the fruits to the Kombucha. It took approximately seven days to finish the second fermentation. After the second fermentation, the final gravity was measured. The average alcohol level of the control group (no fruit) was 2.3%, strawberries were 2.6%, bananas were 3.0%, and mangos were 2.8%. Therefore, the hypothesis was supported because bananas contain the most fructose among the experimental group and according to the data, the banana group had the highest alcohol level concentration. The p-value of my data was 3.402E-14 which makes it significant because it’s less than 0.05. A T-test was also done to compare two levels of the experiment.

The Illumination of Different Chemical Additives on Road Markings

Logan Dwyer, Jack Pierce & Rajitha Anbu *Governor's School@Innovation Park*

Decreased night vision is a prominent issue causing automobile accidents and deaths across the world. There are many instances in which it is difficult to sight the markings in nighttime due to decreased light sources and the dull appearance of the markings. Unfortunately, there have not been any technological advancements to help solve this problem, besides little metal reflectors on highways that are placed far apart for detection of limits of the road. The purpose of our research is to determine a way for road markings to be bright and visible while not blinding the driver's eyes. The research we gathered about road markings suggests that combining a glowing chemical additive with a strong resin could allow street markings to illuminate all on their own. The resin is to help withstand various weather conditions, acting as a protective paint material. The resin and additive mixture are heavily tested through both indoor and outdoor conditions in order to determine the most effective mixture that could withstand the wear of the road and keep its illumination for the longest. Through the research we determined that the crystalline strontium aluminate was the best chemical to use for the road markings. Even though the illumination of this chemical did not last overnight like we had hoped, we see this as an opportunity to create something that has yet to exist. When we can create a chemical for our vision, it will profoundly change safety behind driving and hopefully inspire more safety driven innovations.

Chemistry B (HS CHM-B)

Honorable Mention

The Effect of Ripening on Ascorbic Acid in *Capsicum annuum*

Laken Evans *Mills E. Godwin High School*

This experiment was conducted to determine which storage location allowed *Capsicum annuum* to retain the most ascorbic acid. Ascorbic acid, also known as vitamin C, is a nutrient that is integral to many bodily functions. 100 grams of *Capsicum annuum*, jalapeño pepper, has more than double the ascorbic acid that is found in 100 grams of navel orange, a fruit that is commonly consumed to prevent or combat vitamin C deficiencies. It was hypothesized that if *C. annuum* is kept in the refrigerator, then it will retain the most ascorbic acid. The refrigerator also served as the control in the experiment because it is the most common storage location for produce. Three sets of 26 *C. annuum* were allowed to ripen for 14 days, with one set exposed to natural light a room temperature, one set left in darkness at room temperature, and one set kept in a refrigerator. An HI3580 Ascorbic Acid Test Kit was used to determine the amount of ascorbic acid in each sample, measured in mg/100g. Three t-tests showed that there was a statistical difference in the ascorbic acid quantities of the refrigerated peppers vs. the peppers kept in natural light and in the peppers kept in natural light vs. those kept in darkness, but not in the peppers kept in darkness vs. the refrigerated peppers. The peppers kept in natural light retained the most vitamin C. The increased ascorbic acid levels in *C. annuum*, coupled with exposure to light and heat to speed up ripening explain this result.

The Effect of Color on Levels of Vitamin C in Bell Peppers

Heera Rajiv *Mills E. Godwin High School*

This project was conducted in order to determine the effect of different growth stages of bell pepper on its concentration of vitamin C. Vitamin C is a micronutrient that is required to synthesize collagen, which is vital to wound healing, and create certain neurotransmitters. A vitamin C deficiency causes scurvy, which leads to fatigue and can be deadly. Some studies show that the levels of various nutrients in produce are affected by maturation, so it was hypothesized that if red, yellow, and green bell peppers are tested for vitamin C, then the red bell peppers will contain the most vitamin C. 10 grams of bell peppers were blended with 100 mL of water, and five mL of starch solution was added. The solution was strained into a cup and iodine was added gradually until it became a solid dark color. The control that was used in the experiment was green bell peppers. The results revealed that red bell peppers had, on average, 0.2 more mg of vitamin C per gram of bell pepper than yellow bell peppers and 0.7 more mg of vitamin C per gram of bell pepper than green bell peppers. A t-test was conducted and showed that the data was significant for all the independent variables and thus supported the research hypothesis. It is assumed that the results are due to bell peppers going through chemical changes that produce more micronutrients like ascorbic acid while they develop.

The Effect of Making Ice Cream with Dairy Products of Various Butterfat Percentages on the Melting Time of Ice Cream

Macy Kin *Clover Hill High School*

The purpose of this experiment was to determine the effect of butterfat percentage in ice cream on the melting time of the ice cream. The hypothesis was that if the butterfat percentage was increased, the ice cream would take longer to melt. Two batches of ice cream per level of independent variable were made using dairy products of various butterfat percentages. Once made, each batch of ice cream was divided into portion cups and put in the freezer for 36-48 hours. The portions of ice cream were then taken out of the freezer, five at a time, and placed in sieves resting overtop of Mason jars. The melting times were measured using the stopwatch in the iPhone “clock” app and recorded on the data table. Five levels of the independent variable were tested: 36% (control), 18%, 9%, 2%, and 0.5% butterfat; and 30 trials were performed for each level. The ice cream made with heavy cream (36% butterfat) had the highest mean melting time of 13,974 seconds (s), which was over twice the time of any other level. Following heavy cream, ice cream made with 2% milk (2% butterfat) had a mean melting time of 4,827 s. Ice cream made with light cream (18% butterfat) had a mean melting time of 3,654 s, which was only 199 seconds higher than the mean melting time of ice cream made with skim milk (0.5% butterfat), 3,455 s. Ice cream made with sweetened condensed milk (9% butterfat) had the shortest mean melting time of 1,858 seconds. After the data collection, an ANOVA test was conducted to test if the results were statistically significant. Based on the results, the null hypothesis was rejected, and the data supported the research hypothesis.

Honorable Mention

The Effect of Different Types of Sugar on the Vitamin C Concentration of Fresh-Squeezed Orange Juice

Naomi Lindsay *Wakefield High School*

The purpose of this study was to determine the effect of different types of sugars (reducing and non-reducing) on the vitamin C concentration of fresh-squeezed orange juice. The independent variable was the type of sugar added to the fresh-squeezed orange juice, with the levels; maltose, lactose, dextrose, sucrose, and no sugar (the control). The dependent variable was the average percent change in the volume of iodine solution needed to titrate 100 mL of orange juice. The hypothesis was that if sucrose is added to fresh-squeezed orange juice, then the percent decrease in iodine solution will be the greatest, because sucrose is a non-reducing sugar. 50 fresh navel oranges were sliced and juiced--1000 mL for each level of the independent variable. Ten oxidation-reduction (redox) titrations were then conducted for each level of the independent variable, in which 100 mL of fresh-squeezed orange juice was titrated using 2% iodine solution and a 0.5% soluble starch indicator solution. The initial and final volumes of iodine solution were recorded for each titration, and pictures of the initial and final titrated orange juice mixtures were taken. Each fresh-squeezed orange juice sample was treated with the same quantity of sugar. Once all the initial and final volumes of iodine solution for each trial were recorded, the average percent change in the volume of iodine solution needed to titrate 100 mL of fresh-squeezed orange juice was calculated, using percent increase and decrease formulas. The results from the experiment showed that the mixture of fresh-squeezed orange juice and sucrose yielded the highest percent increase in the average iodine solution volume needed to titrate 100 mL of orange juice. This result showed that sucrose, a non-reducing sugar, was the least effective in preserving vitamin C. Additionally, the mixture of fresh-squeezed orange juice and maltose yielded the highest percent decrease in the average volume of iodine solution needed to titrate 100 mL of orange juice, showing that maltose, a reducing sugar, had the greatest effectiveness in the preservation of vitamin C. This project can be improved by including a vitamin C standard solution in order to determine the concentration of vitamin C with greater accuracy for each level of the independent variable.

The Effect of Different Pill Capsules on Capsule Opening Time

Abhilash Mangamuri *Mills E. Godwin High School*

The purpose of this experiment was to identify the type of medicinal capsule that was the fastest to open. Different types of capsules have different opening speeds, which affects how quickly the antibiotics in the capsule can be released and absorbed by the body. The research hypothesis in this experiment was: If the enteric capsule is placed in vinegar, then it will take the longest to open. Vegetarian, gelatin, delayed release, and enteric coated pharmaceutical capsules were filled with iodized salt and placed in 5% vinegar. A timer was started as they were placed in the vinegar and was stopped when there was a noticeable hole in the capsule and the time was recorded. Appropriate safety protocols were followed. There was no control in this experiment because there is no common ground between these types of capsules. Based on the results of the experiment, vegetarian capsules were the earliest to open, followed by gelatin, followed by delayed release, and enteric capsules took the longest to open. T-tests were conducted at a significance of 0.05 and showed that overall, the results were statistically supported. The results proved that the research hypothesis was supported. Because the enteric capsules were coated with more acid resistant coating than the other capsules, it was believed to have allowed them to last longer in the vinegar. This experiment could lead to further research studying different types of enteric capsules placed in basic conditions to stimulate the small intestine and then see which one dissolved the fastest.

Honorable Mention

The Effect of Various Household Remedies on Neutralizing Stomach Acid

Arjun Modi *Mills E. Godwin High School*

The purpose of this project was to investigate the effects of various household remedies on neutralizing stomach acid with the goal of finding out which substance can make the vinegar the least acidic. This would show which is the most beneficial for stomach acid reflux, gastroesophageal reflux disease, and/or heartburn. The consumption of a variety of day-to-day substances have become popularized to bring relief to the body from those stomach issues and milk, green tea, baking soda water, aloe vera juice, and Pepto Bismol were put into vinegar, a substance with a similar pH to stomach acid, and pH was investigated to see how much it increased.

The hypothesis formulated was if green tea is inserted into vinegar, then the pH of vinegar will be neutralized the most, due to high pH level. 20mL of each independent variable was inserted into 20mL of vinegar while being mixed and the pH of the solution was measured using a pH probe. The control was Pepto Bismol since it's commonly consumed for high stomach pH. Appropriate safety protocols were taken by the experimenter.

The results indicated that baking soda water made the solution the least acidic and green tea made it the most acidic showing the hypothesis was insignificant; the t-tests were significant. The results are based upon pH of the solution with baking soda being the most basic item increasing the pH of vinegar the most. The research could lead to studies on substances to avoid consuming for a neutralized stomach pH.

First Place

The Effect of the Form of Heat Resistant Product on the Heat Damage of the Hair.

Thanvi Parupati *Mills E. Godwin High School*

The purpose of this experiment was to determine whether different forms of heat resistant products influenced the tensile strength in heat-treated hair. Thermal treatment in hair has become more popular. As a result, the need for an efficient heat protectant product has grown. It was hypothesized that if heat resistant spray was used, then the tensile strength in hair would be the highest. Hair strands were treated with leave-in conditioner, heat-resistant spray, and coconut oil for one hour. Then the heat was applied to the hair strand with a hair straightener and the tensile strength of the hair was measured. The control in the experiment was that no product was used in the hair. The results revealed that hair strands with coconut oil had the highest tensile strength with an average of 127.40 grams. A t-test was done on the data, and it revealed that the data was mainly significant except for Heat Resistant Spray vs. Coconut Oil. The results did not support the research hypothesis. It is believed that the results are due to fact of the characteristics coconut oil has. Coconut Oil helps retain moisture in the hair and it is made up of lauric acid which allowed it to be easily absorbed into the hair shaft when compared to other oils. This research could lead to further studies that investigate the amount of time the coconut oil was in the hair before heat as it could change its ability to protect hair from heat damage.

The Effect of Type of Catalyst on Efficiency of Water-Splitting with an Application Towards Solar Energy

Daniel Philip *Mills E. Godwin High School*

The purpose of the experiment was to determine the effect that various forms of transition metal-based catalysts had upon the efficiency of the electrolysis of water. This project proposes combining hydrogen fuel cells with solar panels to effectively harness solar energy during bursts of sunlight, while still ensuring that energy is available during periods lacking sunlight. This would help combat the growing threat of running out of fossil fuels. It was hypothesized that if cobalt chloride, manganese sulfate, iron sulfate, and nickel sulfate were used as catalysts in the electrolysis of water, then cobalt chloride would yield the greatest increase in efficiency of the reaction. A solution containing deionized water was introduced to an electrical current with a voltmeter attached. The voltage was recorded, a catalyst was introduced, and the change in voltage was recorded. No control catalyst was used, as in nature, electrolysis would not have a catalyst. The absence of a catalyst would make the reaction inefficient. Nickel sulfate ultimately yielded the largest mean increase in efficiency of the electrolysis of water.

An ANOVA test demonstrated that the results obtained were statistically significant, rejecting the null hypothesis. The research hypothesis was not supported by the data collected. It is believed that the results obtained were due to the size of the molecules of the catalyst after various calculations were performed. The results of this project demonstrated that nickel-based catalysts perform better than other transition metal-based catalysts, and also gave insight into why iron sulfate is not a proper catalyst.

Second Place

The Effect of Cooking on Vitamin C Concentration

Hannah Kim *Central Virginia Governor's School*

The purpose of this study was to determine whether dry heat or moist heat cooking method had an effect on vitamin C concentration. Sweet potatoes were peeled, cubed, and then roasted at 400°F for 30 minutes (dry heat) or steamed at 212°F for 10 minutes (moist heat). These samples, along with uncooked samples (control), were ground into a paste and swirled with 5% metaphosphoric-10% acetic acid solution. Afterwards, they were treated with DNPH solution and were kept at 37°C for three hours for coupling reactions to occur, resulting in a colored solution for spectrophotometric analysis. The absorbances were collected at a wavelength of 521 nm and compared to a standard curve in order to obtain vitamin C concentrations. A one-way ANOVA test determined a statistically significant difference, as the p-value of 3.73x10-23 was greater than an alpha of .05. A Tukey test, with a Dmin value of 1.97, revealed that the uncooked, roasted, and steamed samples were all significantly different. The mean concentrations for the uncooked, roasted, and steamed samples were 33.08 ppm, 19.75 ppm, and 5.46 ppm, respectively. The research hypothesis, that steamed samples would maintain more vitamin C, was not supported. In conclusion, cooking methods do have an effect on the vitamin C concentration in vegetables. This knowledge is most applicable to meal preparation and ensuring optimum vitamin consumption.

First Place

A New Treatment? An Analysis of the Effect of Known Phytochemicals on SARS-CoV-2 Pathogenesis

Aatish Sethi & Jasmine Agyepong *Governor's School@Innovation Park*

In late 2019, Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) was discovered in Wuhan, Hubei Province, China, and has since infected more than 115 million people and caused over 2.5 million deaths. While few studies have been conducted on the pathogenic entity, the basis of infection and viral make-up are both known. Specifically, the receptor-binding domain of the SARS-CoV-2 S Spike Protein binds to the angiotensin-converting enzyme 2 (ACE2) to "hijack" human cells. This study aims to further elucidate the biological pathways utilized by SARS-CoV-2 to bind to the ACE2 receptor, and analyze if, and which, phytochemicals can competitively inhibit the S Spike Protein-ACE2 interactions using the in-silico program Maestro 12. After conducting preliminary research on possible inhibitors, a total of nine phytochemicals were short-listed for experimentation using Glide XP Ligand Docking to both ACE2 and the S Spike Protein. The results show that Streptomycin and Hesperidin are front-runners to bind to ACE2, with binding-energies of -7.193 kcal/mol and -7.169 kcal/mol, respectively. Additionally, the efficacy of both phytochemicals proves to be statistically significant ($p < 1 -17$). Similarly, in binding to SARS-CoV-2, Streptomycin, Hesperidin, Phytic Acid, and Glycyrrhizic Acid are capable of inhibiting pathogenesis, with the results being statistically significant ($p < 1 -24$). The study, in short-listing four main chemical compounds, hopes to inspire further in vitro analysis of how each of the phytochemicals could decrease the severity or likelihood of SARS-CoV-2 infection.

The Effect of Different Levels of Oxygen on the Exothermic Oxidation of Iron Powder

Trisha Taparia *Mills E. Godwin High School*

The purpose of this experiment was to find the effects of different levels of oxygen on the exothermic oxidation of iron powder. 0% surface area of the hand warmer covered with black construction paper, 50% surface area of the hand warmer covered with black construction paper, and 100% surface area of the hand warmer covered with black construction paper were used to observe the exothermic oxidation of iron powder and fuel mechanics. Hand warmers with 0% covered, 50% covered, and 100% covered were exposed to an air canister for thirty seconds. The control in this experiment was 0% surface area covered. The experimenter followed all safety guidelines necessary, such as wearing gloves and tying back hair, as well as all COVID-19 restrictions. It was hypothesized that if 50% surface area of the hand warmer was covered, it would have a higher exothermic oxidation compared to 0% covered and 100% covered. The results showed that 100% covered, on average, had temperatures that were 2.8℃ and 1.0℃ higher than 0% covered and 50% covered respectively. Three t-tests were performed on the data, showing that the data was significant for all three: 0% surface area covered vs. 50% surface area covered, 0% surface area covered vs. 100% surface area covered, and 50% surface area covered vs. 100% surface area covered. Based on the results, the research hypothesis was not supported. The results are due to the fact that lower levels of oxygen limit the exothermic reaction of the active functional groups of oxygen. These results can lead to further research on how different powdered metals affect the exothermic oxidation of iron powder.

The Effect of Water pH on Copper Oxidization Using Pennies

Christina Wen *Mills E. Godwin High School*

The purpose of this experiment was to find the effects of different pH levels on copper corrosion. Copper plumbing has been used in homes since the 1930s, however, more recent studies have shown that these pipes may corrode more easily due to pH changes in the water. Pennies were treated with either 20 mL of a vinegar solution or 20 mL of soap solution. The pennies then sat in the solution for a week and then their oxidation level was observed and recorded. All safety precautions were maintained during the experiment. The control that was used in the experiment was water. It was hypothesized that pennies treated with a vinegar solution would produce shiner and less oxidized pennies than water and soap solution. The results revealed that pennies treated with either solution was less oxidized than the pennies treated with water. A chi-square test was done on the data, and it revealed that the data was significant. The results did not support the research hypothesis. It is believed that the results are because any drastic change in pH from neutral can cause copper to corrode. This research could lead to further studies that investigate the better alternatives for home plumbing and therefore keep drinking water safer.

Engineering A (HS EGR-A)

Second Place

An Indoor Farm Scouter Through Time-Based Imaging

Naman Agarwal *Patriot High School*

As indoor farming becomes critical to our food chain, there is a need for a cost-effective scout system to continuously monitor plant health. Current methods employ human scouts which have limitations and are not cost effective. Outdoor farms can employ drone based hyperspectral imagery, but such a system is not feasible in an indoor farm. The current project develops a machine learning based system for indoor farms that identifies stressed plants with an inexpensive RGB camera. The machine learning system achieves effective performance with a unique 3D-convolutional time-based imaging technique. The project offers two solutions: a robot that autonomously navigates greenhouses to scan areas and a static system with cameras placed above the plants. Using safety glasses and constantly checking for damage, the prediction pipeline was tested through two phases: in-lab testing and real-world testing. In-lab testing consisted of training, validating, and testing the models on a dataset of several thousand images. Real-world testing consisted of deploying the final system to an indoor farm, setting the camera above stressed plants, and recording its performance across several days. In the first phase, the pipeline achieved 0.99, 0.99, 0.99, 0.99 for the accuracy, specificity, recall, and balanced accuracies respectively. In the real-world phase, the pipeline achieved the 0.95, 0.93, 0.95, 0.94 for the accuracy, specificity, recall, and balanced accuracies respectively. The data suggest the system is effective and scalable in indoor farms, preventing catastrophic failures and helping to improve yield.

Validation of Semi-automatic Computational Methods for the Assessment of Stiffness and Deformation of the Thoracic Aorta from Magnetic Resonance Imaging

Joshua Alexander *Deep Run High School*

An aneurysm, a specific type of cardiovascular complication, is defined to be when the peak inflation of an artery is 1.5 times greater than its original size and, most notably, they are caused by the stiffening of the aorta, or atherosclerosis. Because they are asymptomatic, it has become vital for doctors and researchers to accurately measure and track cardiac motion and deformation. The goals of this research were to compare the DENSE magnetic resonance imaging (MRI) technique to a manual segmentation process and to determine the effect of patient age and aortic location on the inflation of the aorta. It was predicted that the inflation calculation from the DENSE segmentations would not be statistically different from the manual segmentation and that age and location would significantly impact percent inflation. In this study, diastole (deflated state) and systole (inflated state) segmentations of the aorta were produced from MRIs of 19 patients. Corresponding DENSE data was also utilized in this study to interpolate systole segmentations from a manually segmented diastole segmentation. The segmentations produced manually and from DENSE were used to find the inflation of the aorta. An ANOVA effect test was used to determine the effect of location and age on percent inflation and a paired student t-test was used to compare the DENSE and manual techniques. The ANOVA effect test confirmed that age impacts the percent inflation with a p-value of 0.0067, while the paired student t-test result demonstrated that the difference between the area calculated from the manual segmentation and DENSE was statistically significant with a p-value of 0.0204. With a difference of approximately 7% between measurement techniques, it is likely that there were some interobserver differences and inconsistencies related to precision of the DENSE technique. The data suggests age was a significant factor on percent inflation of the aorta, but there was not enough evidence to claim the same for location as well. Because of MRIs capabilities and benefits as a non-invasive tool, the further development of its associated imaging and processing techniques are vital for improving patient diagnosis.

Honorable Mention

The Effect of 3D Printing Material on 3D Print Strength

Eyuel Berhanu *Washington-Liberty High School*

The purpose of this study was to determine the effect of 3D printing materials on their maximum tensile strength. The independent variable was 3D printing material (PLA, ABS, PETG). There was no control group. The dependent variable was the maximum tensile strength in newtons. The constants were, test sample design, infill percentage, perimeters, testing procedure. The hypothesis was if 3D printed materials are tested for strength, then ABS will withstand the most load. 30 3D printed test samples per trial were designed in Autodesk Fusion 360 and printed on the Creality Ender 5 PLUS 3D printer. 10 samples were printed for each material. These test samples were then pulled apart with an electric winch and the averages were calculated. An ANOVA test was also performed to determine statistical significance. The results showed that ABS had the highest average maximum load. These results supported the hypothesis. In conclusion, the study suggests that ABS has the highest average maximum load.

Honorable Mention

The Effect of Varying the Thickness-to-Chord Ratio of an Airfoil and the Pitch of the Blades on a Wind Turbine on the Turbine's Electrical Output

Zachary Burgess *Clover Hill High School*

This experiment was designed to address the issue of developing renewable and sustainable energy sources by investigating how changing different aspects of a wind turbine's blades can improve their efficiency. Specifically, to discover a link between the thickness of an airfoil to the blade's optimal pitch. The research hypothesis was that the control turbine, which had blades with a 21% thickness-to-chord ratio and angled by 7 degrees, would produce the highest amperage out of all other groups. Three sets of three identical blades were 3D printed: one set with 16% thick blades, one with a 21% thickness, and one with a 26% thickness. A hub was then printed with holes allowing the blades to be set at pitches of 1, 4, 7, 10, and 13. This, in combination with the 3 blade types, allowed for the one hub to be able to form 15 unique rotors, all with 3 matching blades set at the same pitch. All 15 rotors, across 12 trials, were exposed to a fan's wind for 10 seconds and the average amperes produced over that time was recorded. Overall, the turbines with 21% thickness blades performed the best, followed by the 26%, then the 16%: and each increased across higher pitches. A Two-Way ANOVA test was conducted on the data and the null hypothesis was rejected. The research hypothesis was also rejected as the most efficient turbine was not the control, but instead the 21% thickness turbine set at a 13 pitch.

Honorable Mention

Small Scale Vertical Farming

Mia Constantin & Elizabeth Quimby *Harrisonburg High School*

This project presents research and experimentation of ways to build a vertical farm that would be accessible to low-income households and would produce 75% more food per acre than a traditional farm of the same size. Our investigations focused on reducing the overall cost of building such structures by using non-recyclable materials. We assessed the growth for four different types of plants, in comparison to that achieved by typical farms with the same availability of surface area and found that our vertical farm produced close to or more than what the traditional farming techniques usually yield. Nevertheless, our method proves to be significantly more environmentally friendly: the usage of soil and water was more than 90% reduced, while it was constructed using solely recycled materials. We also assess that while the vertical farm design we implemented here might not be feasible for commercial use, it would work well for home gardens.

Simulating the Feasibility of a Chlorophyll-Based Photovoltaic Cell Design

Samuel Cutler *Ocean Lakes High School Mathematics and Science Academy*

This project seeks to prove the feasibility of a new type of photovoltaic cell to use for harnessing energy from sunlight. Based on previously conducted scientific literature on chlorophyll b, it was hypothesized that a solar cell design utilizing its natural light absorption properties could compete and outmatch the current industry standard silicon-based design under ideal conditions. Simulation software was constructed and utilized to test this hypothesis, using ideal climate conditions to determine the maximum reasonable output of both types of solar cell and comparing the results. It was determined that, at a depth of approximately 250 micrometers and a concentration of 10% chlorophyll by weight, a chlorophyll-based solar cell had the potential to outperform a silicon-based solar cell using standard manufacturing conditions. This project involved testing the chlorophyll solution at various depths to determine a relationship between its depth and current output in order to achieve the data points shown above. While many other factors must be considered and implemented before any manufacturing can begin, this idea has the potential to bring about great change in the industry of solar panels and solar energy as a whole.

First Place

Whitewater Helmet STAR: Evaluating the Biomechanical Performance and Risk of Head Injury for Whitewater Helmets

Brock Duma *Blacksburg High School*

There are more than 6 million people who participate in whitewater kayaking and rafting in the United States each year. Of these 6 million participants, there are over 50 whitewater related deaths each year, which makes it have one of the highest fatality risks of all sports. As the popularity in whitewater activities grows, the number of injuries, including concussions, also increases. The objective of this study was to create a rating system for whitewater helmets by evaluating the biomechanical performance and risk of head injury of whitewater helmets using the Summation of Tests for the Analysis of Risk (STAR) system. All watersport helmets that passed the EN: 1385: 2012 standard, and that were clearly marketed for whitewater use were selected for this study. A total of 21 helmets were found, and 2 models of each helmet were tested. A custom pendulum impactor was used to test the helmets under conditions which are known to be associated with the highest risk of head injury and death. The struck head consisted of a NOCSAE head and Hybrid III 50th percentile neck, with the head form instrumented with three linear accelerometers, and a triaxial angular rate sensor. For this study, 126 tests were performed at six different configurations. The helmets were tested at 3.1 m/s and 4.9 m/s with impacts to the front, rear, and side for each speed. The velocities were chosen given that the highest recorded flow rate in a whitewater river is 5 m/s, which implies that it is very unlikely that any underwater head impact will have a head impact speed greater than 5 m/s. Each helmet's STAR value was calculated using the combination of exposure and injury risk that was determined by the linear and rotational accelerations. The resulting head impact accelerations predicted a very high risk of concussion for all impact locations with the 4.9 m/s impact speed. The STAR values varied between helmets, indicating that some helmets provide better protection than others. Overall, these results show a clear need for improvement in whitewater helmets, and the methodologies developed in this research project should provide manufacturers a path to improving their products.

IntelliCure: A Novel Deep Learning Platform to Distinguish Morphological Features from Malignant and Benign Endometrial Carcinoma

Khushi Garg *Thomas Jefferson High School for Science and Technology*

Endometrial carcinoma is the cancer of the endometrium lining the uterus caused by DNA mutations in endometrial cells. This aggressive cancer is the sixth most commonly occurring cancer in women and the most common occurring cancer of the female reproductive organs. According to the American Cancer Society, 65,620 new cases were diagnosed in 2020 and 12,590 women died because of this cancer. Diagnosis of endometrial carcinoma is a resource and time intensive effort, but, due to the intricate features present, obtain at best, a mere 88% binary classification accuracy and a lower positive predictive rate (PPV). Artificial intelligence (AI) algorithms, specifically convoluted neural networks (CNN), have been employed to combat over and under diagnosis. However, these too fail to provide adequate accuracies that can be clinically utilized. The aim of this experiment is to increase accuracy rates of algorithms to identify endometrial carcinoma. The binary classification accuracy is improved without overfitting because of the utilization of a large database, manipulation of hyperparameter values, and optimal selection of a classifier. To measure the performance of the model, a benchmark pathologists' accuracy (89%; 95% CI of .81-.97) of diagnosing endometrial carcinoma images was used to compare to the accuracy of the novel artificial intelligence model, IntelliCure which achieved 93% (95% CI of .88-.99) accuracy. Furthermore, the PPV, negative predictive value (NPV), sensitivity, and specificity achieved 100%, 87%, 85%, and 100% accuracy ratings, respectively. IntelliCure is substantially less aggressive than a pathologist, as there is a marked difference in d' values and it obtains an under the curve (AUC) value of 0.9. The diagnosis platform outperforms pathologists and other diagnostic algorithms in terms of higher binary classification accuracy, which can be attributed to the optimization of variables within the network. As a pathological diagnosis tool, IntelliCure offers a potential use in endometrial cancer diagnostic technology. All safety precautions were taken into consideration while conducting the experiment.

Using AI to Detect and Deter Telemarketers

Max Gordon *T C Williams High School*

Telemarketers and phone scams are the biggest source of complaints to the FCC, swindling nearly $40 billion from phone users. While much of this is illegal, it is impossible to enforce American laws, such as the Do Not Call Registry with telemarketers based in India and China. This project explores the possibility of using a recurrent neural network (RNN) to identify telemarketers through natural language processing (NLP) classification. The goal is an 80% success rate at identifying telemarketers with less than a 5% rate of false positives. In addition, computational simplicity is critical so it can run on a Raspberry Pi, making it accessible to everyone. The system will answer calls to the user's smartphone and begin to talk to the caller. Speech from the caller is classified into six possible categories: information, question, command, conditional (if … then …), general exchange (banter and greetings), and persuasion. A telemarketer will be identified by persuasion; if greater than 30% of the caller's sentences are persuasive, the program will flag them as a telemarketer. To engage the caller in conversation, another RNN (chatbot) will generate responses. During the conversation, the language classifier will continue classifying while the chatbot tries to keep the telemarketing talking for as long as possible. If the language classifier does determine the caller is a telemarketer, it will stop analyzing the telemarketer's speech while the chatbot continues to loop until the telemarketer hangs up. Otherwise, the system will forward the caller back to the user.

The Effect of Parabolic Reflectors Constructed of Household Materials on the Signal Strength of a Router

Will Gregory *Central Virginia Governor's School*

The purpose of this study was to determine whether parabolic reflectors constructed of household materials have any effect on the signal strength of a router. This study was conducted at a local household in November of 2020. Two different reflectors were used for this experiment, one made of Mylar and the other Aluminum Foil, along with a control group of a router by itself. Each group was tested once a day for a 17-day period. Both reflectors were placed around the router for an average of 125 seconds and the received signal strength was recorded, this was also done for the control group. The signal strength was recorded in decibels (dBm). A one-way ANOVA test determined that there was statistical significance, with a p-value of 2.12x10-7 and an alpha value of .05. A follow-up Tukey test with a Dmin value of 3.18 determined between which groups there was statistical significance. The difference was shown to be between the control group and both of the parabolic reflectors (with a difference at/above 7.19 dBm for both). This finding did not support the hypothesis that a parabolic reflector constructed of Aluminum Foil would have the greatest effect on the signal strength, because there was no statistical significance between the reflectors themselves. To conclude, parabolic reflectors constructed of household materials have the ability to increase the signal strength of a router which can be beneficial to the average person by allowing a simple and effective solution to common connectivity problems.

Effect of Varying Temperatures on The Performance of a Passive Suspension System with a Nonlinear Air Spring in a Seismic System

Grant Helm *Central Virginia Governor's School*

The purpose of my study was to determine how changing temperature affects the forks spring rate and consequently the suspension's performance at absorbing shock. Tests were run on a mountain bike suspension fork in a test apparatus that replicated a seismic system. Repeated impact was enacted to the fork's axle while data was recorded from two accelerometers, measuring input acceleration and the acceleration of the sprung mass. A heat gun was used to increase the temperature inside the fork, as measured by a thermocouple threaded into the fork's air chamber. This test was run at 88 degrees and 120 degrees Fahrenheit. Shock absorption was defined as the percentage difference between the peaks of two acceleration measurements. An ANOVA test was conducted on these percentages from each temperature. Using an alpha value of .05, the ANOVA gave a p-value of .4, showing that there was no significant difference between the shock absorption performance at different temperatures. Another experiment, intended to identify any change in spring rate due to temperature, also supported this conclusion. A pressure sensor was used to plot pressure versus displacement graphs at 88, 120, and 200 degrees. This data (which followed an inverse graph) was linearized; the resulting slopes showed no linear relationship with temperature. Both of the tests rejected the research hypothesis, "If the air temperature inside a nonlinear, air sprung suspension system is increased, then the spring will become stiffer and the suspension will be less effective at absorbing impacts."

The Effect of the Front Angle of a Carbon Dioxide Powered Car (degrees) on the Speed of the Car(m/s)

Michael Hunter *Clover Hill High School*

The question this experiment addressed was what the optimal front angle would be for a car to achieve maximum speed. The purpose of this experiment was to determine the optimal front angle of a car to achieve maximum speed. The research hypothesis stated that if carbon dioxide powered cars with the front angles of 30o, 35o, 40o, 60o and 90o raced to 10m 30 times, a car with a 30o front angle would reach 10m the fastest. The procedure for the experiment was conducted as follows. Six carbon dioxide powered cars were assembled per provided instructions. Five pieces of cardboard were cut with scissors, and then using a protractor and a hot glue gun, the pieces of cardboard were placed on the cars at 35o, 40o, 45o, 60o, and 90o on the front end of the car, leaving one car with no cardboard to be the control for the experiment (30o). Ten meters were then marked out, and at the end of the course, a slow-motion camera was placed. To conduct the actual experiment, a carbon dioxide launcher was used to race the cars down the track. All the trials for the same car were held back-to-back, replacing the carbon dioxide cartridge every trial. The trials were recorded using a stopwatch along with a slow-motion camera in order to have two ways to accurately measure the times. The results found that the cars with a smaller front angle had a higher speed. This is shown by the car with a front angle of 30o had the highest speed at 6.87 m/s, and the slowest car, which raced at 4.88 m/s, had a front angle of 90o, the largest angle tested. The research hypothesis stated that a car with the smallest front angle (in degrees) would have the highest speed. Since the car with the highest speed was the car with the smallest front angle, the research hypothesis was supported. The null hypothesis stated that the front angle of the cars would have no effect on the speed of the cars, and due to the fact that calculated F-value was 312.06146, and the F-critical value was 1.607, the null hypothesis was rejected, and the findings can be seen as significant.

The Effect of Wingspan Length on Distance a Balsa Wood Glider Travels

John Jensen *Clover Hill High School*

The purpose of this experiment was to determine the most efficient wing aspect ratio that would allow gliders and planes to fly the farthest with the lead thrust needed. The research hypothesis for this experiment was that if the wingspan was 28 cm long, then the glider would fly the farthest. The experiment began with building a launching platform and enclosure for windless and consistent testing. The distances were measured using a measuring tape. The five independent variable levels were the control of 20 cm wingspan, 36 cm, 30 cm, 28 cm, 25 cm, and 15 cm. After the wingspan length was cut, it was then placed on the launch pad, released from the rubber band, and its distance travelled was recorded. This process was repeated 25 times for each independent variable level. The 5results were then collected and the mean average was calculated. The average distance flown for a 36 cm wingspan was 4.496 m. The 30 cm wingspan had a mean distance flown of 5.030 m. The 28 cm wingspan flew 5.570 m on average. A wingspan with a 25 cm length flew on average 5.652 m. The 20 cm control wingspan flew 5.573 m on average. The 15 cm wingspan had a mean distance flown of 6.062 m. An ANOVA test was conducted after the data was collected to determine the statistical significance of the results. The ANOVA test stated that the null hypothesis was rejected according to the F statistic. The experimental hypothesis of a 28 cm wingspan flying the farthest was not supported.

Honorable Mention

The Effect of Anti-aliasing Method Used on Speed of Video Output

Richard Jones *Clover Hill High School*

The experiment sought to answer the question of what impact various anti-aliasing methods have on video render speed. The time cost associated with rendering video hurts the ability of film companies and scientific projects that rely on 3D models in a virtual workspace by increasing the required processing power to export a video. With shortened render times, a greater portion of the budget can be focused on the project itself rather than the expensive process of exporting a video. For the experiment, the research hypothesis was that the 2x MSAA anti-aliasing method would render the video in the shortest time. The experiment was carried out by applying the different independent variable levels to a sample video within a video editing perk. The video was then exported, and a specialized script recorded the amount of time taken from the start of the render to the end. Each independent variable level was tested 30 times. Generally, the 2x MSAA had the shortest average time at 84.652 seconds, followed by the 4x MSAA method at 89.941 seconds, the 2x SSAA method at 94.750 seconds, the 8x MSAA method at 102.443 seconds, and finally the 4x SSAA method at 115.682 seconds. The control group had an average time of 77.222 seconds. From statistical analysis through an ANOVA test, The null hypothesis was successfully rejected, and the data collected supported the research hypothesis.

Third Place

Trainable WEKA Segmentation Tool Machine Learning-Enabled Segmentation on Features of Orthopantomograms

Nitin Kanuri *Mills E. Godwin High School*

Segmentation of dental x-rays is a comprehensive subject in oral care with various research in algorithms that effectively segment an x-ray. This paper will provide an in-depth analysis of the latest benchmarks in oral imaging by studying the segmentation of x-rays using Trainable Weka Segmentation. Precise segmentation is a stepping-stone in the delineation of anatomical structures in order to provide the best course of treatment. The aim of this research is to accurately automate segmentation where it can be implemented on a large scale of clients in order to simplify radiological diagnosis. This technology is especially valuable in telemedicine where patients are treated remotely. The experimentation was conducted by modifying open-source x-rays from UFBA_UESC_DENTAL_IMAGES dataset. In order to simulate realistic conditions such as noise affecting regions of interest, panoramic x-rays were degraded and blurred with Gaussian noise. Accuracy was quantified by measuring the difference between the automated x-ray and the dentist annotated image using MorphoLibJ. To ensure the precision in results, automated predicted segmentations were verified by two Oral & Maxillofacial Radiologist and compared with the dentist-renditioning annotations of the panoramic x-rays. The TWS classifier on x-rays with an average of 32 teeth and greater (Dice value of 0.66) and an average of less than 32 teeth (F1 score of 0.59) was significant. The calculated t-value for the Jaccard index is 2.78 and the t-value for the Dice score is 2.81. The results, considering the statistical scores, were due to the IV. The x-rays with 32 teeth and greater had higher IoU scores and F1 scores is because there is less of a discrepancy in tooth alignment.

Engineering B (HS EGR-B)

Second Place

A Novel Integrative WSI-Based Framework for Breast Cancer Molecular Classification

Laasya Konidala *Mills E. Godwin High School*

Breast cancer is the most prevalent cancer in women globally, with incidence rates projected to escalate. Advanced diagnosis of intrinsic molecular subtype is key to evaluating intermediate survival risk: however, biological variance and staining inconsistencies make the standard manual analyses of H&E-stained images a challenging task. Recent advancements in deep neural network architecture introduce a robust mechanism to address this task through recursive learning. A state-of-the-art paradigm (M-BC) using multiscale patch representations of cancer-rich clusters was developed for the classification task among Luminal A, Luminal B, HER2-enriched, and Basal-like subtypes. After WSI pre-processing, the concatenated dense clusters were assessed for tumor-positive patches. At the final layer of the architecture, a one-versus-all SVM generated true labels. To minimize eye strain, breaks from conducting data analysis were taken every sixty minutes. The performance was evaluated against local-based classifiers (L-BC), analyzing cancer-rich clusters, and global-based classifiers (G-BC), analyzing the tissue structure interactions. A five-fold cross-validation metric indicated the statistically significant high-performing average f1-score of the M-BC, supporting the research hypothesis. The M-BC model had superior performance because it analyzed the interdependencies between cellular structures on varying spatial levels of information, allowing the aggregation of the patch representations to extract key features of the WSI in detecting heterogeneity. The sensitivity to sub clonal diversity in cancer cell localities, a strong indicator of intratumoral heterogeneity, denotes the novel application for breast cancer intrinsic molecular subtype classification. With further work mapping molecular expression to the multiscale patch representations, the high feature extraction, low computational cost, and robust applicability of the M-BC model accelerates the application to standard biomarker prognostic procedures.

The Effect of Different Sorting Algorithms on Program Runtime

Devesh Kumar *Maggie L. Walker Governor's School*

As the world becomes more and more dependent upon technological tools, the importance of the efficiency of the algorithms used within these tools become all the more important. Sorting algorithms sort a set of elements based upon a key and can do so in a variety of ways. The performance of each algorithm was measured by recording the runtime of each algorithm. The purpose of the experiment was to find which sorting algorithm is the most efficient, so that processes reliant on sorting can create a better user experience, use less hardware, and less electricity. The research hypothesis was “If merge sort is used, then the runtime would be the lowest (fastest).” To test the hypothesis, a python file with implementations of bubble sort, merge sort, quick sort, and heap sort was created in Visual Studio Code using online resources. The results, with a p-value well under 0.05%, showed that merge sort was the fastest, followed by heap sort, quick sort, and bubble sort respectively, consistent with research by Taiwo et. Al in 2020. Merge sort and heap sort did the best because they are recursive algorithms, and merge sort specifically did well because of its divide-and conquer nature. Bubble sort was slow because of how inefficient it was with its O(n^2) worst case. Quick sort did poorly because it is not efficient in large data sets and could not use tail recursion in Python. This research will help power a new wave of technological progress and innovation by making fundamental tools more efficient.

Honorable Mention

Cost Effective Setup for Testing Mask Efficacy

Teddy Liu *Central Virginia Governor's School*

The purpose of this study was to find a simple, inexpensive setup to test the efficacy of face masks. The system consisted of a smoke machine connected to a mannequin head with a mask through silicone tubing, and multiple PVC parts for connection. The average percent change of humidity near the mask was recorded with ten trials per each of the six masks and a one-way Anova test was used to analyze the data. There was also a control group of 10 trials with the setup without any masks. Using the obtained p-value of 1.1301x10^-47 and an alpha of 0.05 and rejected the null hypothesis that there would be no significant difference between each mask and the control. A post hoc Tukey test showed that all masks (N95, surgical, Olsen style two-layer cloth, pleated two-layer cloth, neoprene, and gaiter) were significantly different from the control, however some masks (such as the gaiter, being the worst, and the neoprene mask the next worse) performed poorly as they were significantly different from the best performing mask, the N95, which had the lowest percent change humidity. This supported the research hypothesis of "If the efficacy of blocking particles of 6 different masks is tested, then the N95 mask will be the most effective and the polyester gaiter will be the least". In conclusion, the setup could be feasible in order to test masks in the future.

Third Place

Non-Invasive Enhancement of Bionic Vision for Patients of Photoreceptor Degeneration through Computer Vision Techniques

Gwyneth Liu *Mills E. Godwin High School*

This project investigated a non-invasive method of improving the performance of retinal prostheses by using computer vision techniques. Millions of people suffer from photoreceptor degeneration (PD). PD is an irreversible eye condition caused by progressive deterioration and death of retinal photoreceptor cells, and it is a leading cause of low vision and blindness worldwide. To restore the vision for blind patients with PD, subretinal prostheses, a type of bionic eye, have recently been developed to replicate the function of photoreceptor cells, and encouraging results have demonstrated partial visual restoration. Unfortunately, the artificial vison produced by a subretinal prosthesis is often affected by the spatiotemporal distortions that render the vision blurry. Targeting this shortcoming in a non-invasive manner, images at the input of a subretinal prosthesis in the video processing unit were preprocessed to reduce the spatiotemporal distortions of the stimulated image while keeping its implanted electrode array intact. Two image processing algorithms were tested. One was a structured forest-based edge detection algorithm, and the other was a manifold-ranking saliency algorithm. The two algorithms were also compared with no image processing. The effectiveness of the two algorithms were evaluated by computing the correct classification rates (CCRs) of image sets at two ends of a prosthesis. To make CCR computation feasible, convolutional neural networks (CNNs) were used, which also accounted for the learning curve that goes into the use of prostheses. It was shown that applying edge detection achieves the highest CCR. The results were found to be significant via a t-test. It could be concluded that with proper preprocessing of input images, the object-recognition accuracy and the feature-retention capability of an existing prosthesis could be improved significantly without requiring any invasive surgeries.

Honorable Mention

Automobile Window Tinting on the Transmission of Ultraviolet-A Radiation and Laterality of Skin Cancer Analysis

Grace Loos *Mills E. Godwin High School*

The purpose of this experiment was to evaluate the relationship between skin cancer laterality and country driving patterns and ascertain which type of window tinting transmitted the least amount of ultraviolet-A radiation. Incidences of cutaneous melanoma, basal cell carcinoma, and squamous cell carcinoma are increasing internationally, and thousands of people die each year from skin cancer. The research hypothesis formulated was that if ultraviolet-A radiation is shone through ceramic window tinting adhered to tempered glass, then ultraviolet-A radiation transmission out of all of the window tints will be the least. To test the hypothesis, ceramic, crystalline, carbon, metalized, hybrid, and dyed window tinting were adhered to tempered glass samples and placed individually on a stand. Thick safety gloves, sunglasses with ultraviolet-A radiation protection, a long-sleeve shirt, close-toed shoes, an apron, and long pants were worn throughout the experiment. An ultraviolet-A monitor measured the transmission of ultraviolet-A radiation, the dependent variable, in microwatts per square centimeter through the glass samples. The positive control, tempered glass, and the negative control, laminated glass, provided an analysis of various window tinting's' effects on ultraviolet-A radiation transmission. The research hypothesis was supported by the data because ceramic window tinting had the lowest average ultraviolet-A radiation transmission ($1uW/cm^2$); dyed window tinting was least effective at reflecting ultraviolet-A radiation because it had the highest average ultraviolet-A radiation transmission ($33uW/cm^2$). The differences between all of the levels of independent variables were statistically significant, except for the difference between hybrid and metalized window tinting. The differences in ultraviolet-A radiation transmission were attributed to the differing compositions and additives of the window tinting.

Honorable Mention

Comparing Sustainable Materials as Filters for Aqueous Dye Solution

Ina Lynch *Central Virginia Governor's School*

The purpose of this study was to compare the feasibility of using sawdust, bamboo charcoal, and activated carbon as absorbents for the removal of methylene blue dye from water. Five to 200 ml of aqueous methylene blue solution was pumped at 100 ml/min into a packed vertical column. The column was packed with a starting layer of 10 ml of fiberglass for stability and a top layer of absorbent. The aqueous solution filtered through the layers and drained into a lower container. In addition to the three tested absorbents, a control was tested using only fiberglass. A sample of the starting and ending solutions were taken and measured in AU at 664 nm. A one-way ANOVA test resulted in a p-value of 1.136x10-23 which, compared to the accepted alpha value of .05, indicated that there was a statistically significant difference between at least two groups. A post-hoc Tukey test revealed that there was significance between the control and independent variables, sawdust and bamboo charcoal, sawdust and activated carbon, and lastly bamboo charcoal and activated carbon. The results of this study partially supported the research hypothesis that bamboo charcoal would perform better than other groups. Although bamboo charcoal did perform better than sawdust, activated carbon outperformed both groups. In conclusion, sawdust, bamboo charcoal, and activated carbon can all be used as absorbents to remove dissolved dye from water, with activated carbon being the most effective. With pollution on the rise, it is essential to study sustainable methods to prevent detrimental waste.

A Comparison of Different Percent’s of Ethanol Mixed with Different Octanes on Small Combustion Engine Run Times.

Hunter Maul *Chesapeake Bay Governor's School*

Most every gas station in the country provides gas to consumers that has a premixed rate of ethanol in their fuel. This study investigated whether mixing different percent’s of ethanol with different octanes could provide alternate mixtures that could be more efficient. There are two main things that are observed that determine efficiency, the miles per gallon and CO2 emissions. This study observed run times, since miles per gallon is unrealistic to measure in a small combustion engine. This study was conducted using three different ethanol free octane ratings of 87, 89, and 93, and mixing them with different ratios of ethanol. The results of this study were that as ethanol increased in 87, so did the run time. But in 93 as the ethanol rate increased, the run times decreased. And for 89 as the ethanol rate increased, the run times stayed around the same. Ethanol does have an environmental benefit which is not releasing any new CO2 into the atmosphere. But it is a tradeoff as adding more ethanol could decrease performance.

The Effect of Different Wavelengths on the Photovoltaic Electricity Produced

Ella McNally *Washington-Liberty High School*

Climate change is a rising concern, causing the usage of renewable resources to increase. This project relates to solar panels. By using more renewable resources, the amount of carbon dioxide in Earth's atmosphere would decrease. The independent variable was the different wavelengths the solar cell is exposed to. The experimental group included red, orange, yellow, green, blue, indigo, and violet. The control group was white. The dependent variable was the amount of photovoltaic electricity produced by a solar cell (volts, current). The constants were the amount of time the solar cells were exposed to wavelengths, type of solar cell, and the position of the solar cell. The hypothesis was if a solar cell is exposed to different wavelengths of light, then the photovoltaic electricity produced will not be constant. The null hypothesis was if a solar cell is exposed to different wavelengths of light, then the photovoltaic electricity produced will stay constant. In a room with ambient light, a solar cell stand was created that connected the solar cell and multimeter. A 500-watt halogen lamp was set at a constant distance of 2'4" from the stand. Each color sheet was held up to the solar cell. For each experimental variable, the number of milliamps and volts was recorded 10 times. The results showed orange, yellow and violet are ideal, while green, blue, and indigo are not ideal to produce power. This was also true for the volts and milliwatts produced. White produced the most power. These results confirm the hypothesis.

The Effect of Hair Conditioner on Cheerleading Bow Dimensions and Rate of Color Fading Based on UV Index

Katelynn Menjivar *Clover Hill High School*

The purpose of this experiment was to determine which amount of hair conditioner combined with the bows would have the most impact on the rate of color fading and bow dimensions of cheerleading bows. The hypothesis was that if hair conditioner and sunlight were combined with the cheerleading bows, then the bows would have the most change in the rate of color fading and the dimensions of the bow. To determine which amount of hair conditioner would have the greatest impact on the cheerleading bows different amounts of hair conditioner were set upon ten different bows. One set of ten cheerleading bows was the control and had 0 mL of hair conditioner added. Another set of ten cheerleading bows were given 10 mL of hair conditioner, the third set containing ten cheerleading bows were given 50 mL of hair conditioner. The fourth set of ten cheerleading bows were given 75 mL of hair conditioner and the last set of ten cheerleading bows were given 100 mL of hair conditioner. All of the bows were set out in the sunlight for a total of two hours and were washed and dried after the two hours finished. The data regarding the change in circumference and color change of the cheerleading bows were measured in percentages and centimeters (cm). After the data was collected an ANOVA test was conducted in order to determine if the data was statistically significant. The results from the ANOVA test rejected the null hypothesis. The research hypothesis stated, if hair conditioner and sunlight are combined with the bow, then the bow would have the most color fading and would shrink the most. The data from this experiment did support the research hypothesis.

Finding a Correlation Between Temperature and Melt Pool Size in Laser Additive Manufacturing

Victoria Midkiff *Blacksburg High School*

Laser additive manufacturing is a technique that has the capability to build three-dimensional components using metal. The process is done by using a laser to melt and fuse powdered metal. The laser melts the solid, powdered, metal in a particular pattern, and the technique has the potential to produce any three-dimensional shape. During the process, the melted metal forms a melt pool in the powder bed. The melt pool formed has several measurable characteristics. One of these characteristics is the average temperature of the melt pool at a given time. This is found using thermal imaging, which captures the thermal profile of the melt pool during the manufacturing process. Simultaneously, the exact shape of the melt pool can be examined using synchrotron X-ray imaging. During the additive manufacturing process, the melt pool first enlarges, then shrinks. Using X-ray video taken of this phenomenon and data showing the average temperature of the melt pool over time, an investigation into the correlation between these two variables can be made. In this study, the depth and width and varying depths of a melt pool were compared to the temperature at the same time. In order to find these dimensions, the X-ray video frames were examined using the software Image J, which allowed for accurate measuring of the melt pools. The resulting analysis indicates that a positive, linear, correlation exists between the average temperature and size over time. Based on these findings, the laser additive manufacturing process can be observed with more detail when X-ray imaging is not available, using the prediction of the melt pool shape based on the average temperature and that temperature's correlation to shape.

The Effect of Car Seat Safety Devices on Body Pressure

Namit Nallapaneni *Mills E. Godwin High School*

The overall purpose of this experiment is to design a cheap, comfortable, and safe car seat attachment for the weak and debilitated. Driving can be a fateful danger. In Virgina, during 2019 alone, there were 128,172 crashes and 927 fatalities (Department of Motor Vehicles, 2020). Today, there are no relatively cheap, efficient, and practical options to help increase safety significantly for frail individuals. With a economical, ergonomic, and protective car seat attachment for these individuals, car rides can be made safer and more enjoyable during their common use. The independent variable present in this experiment is the design of a car safety device; the levels include an original design and the control, no device. The dependent variable for this experiment is the amount of g-force at two different locations: the chest and waist. A research hypothesis was formulated that the original design will result in less pressure onto the body, at the measured locations, than a standard car seat setup. During construction and experimentation, caution was greatly exercised by the experimenter. Two t-tests were performed on the data at a level of significance of .05 with the degrees of freedom of 48. The data pertaining to the difference between the body pressure at the chest of the two designs did not prove to be significant, while the data pertaining to the difference between the body pressure at the waist of the two designs did prove to be significant. For continued study, the feasibility and usability of the original design compared to various car safety devices could be studied.

The Effect of Fiber Orientation on the Flexural Properties of Carbon Fiber Reinforced Polymer

Jarred Newcomb *Central Virginia Governor's School*

The purpose of this experiment was to determine if the fiber angle of carbon fiber reinforced polymer tubes would affect their flexural properties. These tubes were manufactured and tested at a local engineering firm from October to December of 2020. A total of 14 coupons were manufactured and put into groups according to their angle: 45º, 55º, 65º, and 75º. These coupons were then subjected to a three-point bend test. From the raw data output, a stress-strain function was created to evaluate the structural stiffness and flexural yield strength at a .2% offset. Using a single-factor ANOVA test, the resulting structural stiffness and flexural yield strength datasets were both determined to be significant based on their respective p-values of 2.24 × 10-6 and .043 compared with the alpha value of .05. Next, post hoc Tukey tests were performed for each dataset. For the structural stiffness dataset, significance was found between groups 45º and 65º, 45º and 75º, 55º and 65º, and 55º and 75º since all of these shared a higher difference than the D-min value of 258.14. For the flexural yield stress dataset, significance was found between group 55º and 75º since the difference between the means was closest to the D-min value of 4.00. These findings supported the research hypothesis, that the carbon fiber tubes constructed at greater angles would have the strongest flexural properties. Overall, the results suggested that the fiber angle of carbon fiber reinforced polymer tubes has a significant effect on their flexural properties.

First Place

The Effect of Rat Brain Phantom Construction on Mimicry of the True Brain Model

Chirayu Nimonkar *Mills E. Godwin High School*

In the field of neuroscience, rat brain models are crucial for research and experimental testing. One of the leading solutions for animal and human experimentation is using phantoms: functionally accurate replicas of live tissue. The purpose of this investigation was to determine the effects of rat brain phantom construction on its ability to mimic the real tissue during brain stimulation. A tissue-separated model was developed and hypothesized to yield a magnetic flux density closest to the true brain.

After skull-stripping a rat brain MRI, one construction was segmented into grey and white matter while another remained as one whole brain. A spherical model was created as a control for comparison with the other constructions. Each construction was stimulated using a transcranial magnetic stimulation procedure in ANSYS Maxwell. The computer hardware and software were checked for damage before experimentation to ensure safety.

The tissue-segmented model had the closest magnetic flux density (0.6036 T) to the real brain (0.6 T) followed by the whole brain and then spherical constructions. The observed results supported the hypothesis that the tissue-segmented model would most closely mimic the true rat brain. Multiple t-tests showed that each comparison was statistically significant; therefore, phantom construction does have an effect on the mimicry of the true brain.

The findings from this experiment resemble other studies that found similar patterns in the stimulated region. The tissue-segmented model most closely mimicked the true brain likely from the combination of accurate geometric and dielectric properties. To improve the phantom, further research into creating a physical model and adapting results to human models is needed.

Effect of Aspect Ratio of Aerofoil on Downforce Produced by Aerofoil

Andrew Orndorff *Clover Hill High School*

The purpose of this experiment was to determine the relation between the aspect ratio of an aero foil and the downforce it produces. The hypothesis was that lower aspect ratio aero foils would produce greater downforce. 4 aero foils were constructed out of foam board with aspect ratios of 60:8, 40:12, 30:16, and 24:20. Also constructed out of foam board was a platform with a column glued to the center, with 4 toothpicks inserted into the top of the column. The first aero foil was attached to the column through the toothpicks. The foam board platform was placed onto the scale and the tare function was used to cancel out the weight. The fan was blown over the aero foil for 2 minutes and the highest value to register on the scale over that period was recorded as the downforce after being converted from grams to Newtons. The aero foil was then removed, and the process was repeated with the next one, each aero foil design was tested 10 times. The mean downforce for the aero foils in Newtons were: 0.78 1.13, 1.12, and 1.00 for the aero foils with aspect ratios of 60:8, 40:12, 20:16, and 24:20, respectively. The median downforce for the aero foils in Newtons was 0.7, 1.11, 1.14, and 1.01 for the aero foils with aspect ratios of 60:8, 40:12, 20:16, and 24:20, respectively. The correlation between aspect ratio and downforce was nonlinear. The null hypothesis that all 4 aero foils would produce the same downforce was rejected. Additionally, the research hypothesis that the aero foil with an aspect ratio of 24:20 would produce the greatest downforce, followed by the aero foils with aspect ratios of 30:16, 40:12, and 60:8 respectively, was also rejected.

The Effect of Various Earthquake Resistance Methods on Reducing Movement of a Wooden Structure During a Simulated Earthquake

Ishita Patel *Clover Hill High School*

The purpose of this experiment was to determine which of the three chosen earthquake resistant systems best affect the reduction of movement of a wooden building during an earthquake. The research hypothesis was that if three earthquake resistant systems were tested, pendulum power, base isolation, and rocking wall-core, using earthquake simulations on wooden models, then base isolation would be the most effective method of reducing movement. Thirty trials were conducted for each level of independent variable: no method, base isolation, pendulum power, and rocking core-wall. Each method was constructed using specific materials and equipment. The system was attached to the wooden structure one at a time, which was then placed on top of a graphed wooden platform. The platform hung between two columns by embroidery floss wrapped twice around the columns. Each trial was conducted for a minute and was filmed for data accuracy. Observations were made and written down during the simulations. After reviewing the videos and observations, the data was organized into a data table. Using the data table, an ANOVA test was conducted to determine whether the results were significant or not. Based on the results of the ANOVA test, it was concluded that the null hypothesis was not rejected. For complete certainty of the results of the experimental hypothesis, more research is required through a repeated experiment with the suggested adjustments. .

The Effect of Lining a Sound Box with Various Materials on the Intensity and Duration of the Sound Created

Caleb Peake *Clover Hill High School*

The purpose of this experiment was to determine the effect of lining a sound box with various materials on the intensity and duration of the sound created. The experimental hypothesis was that if a sound box was lined with materials of no lining (control), foam, cork, plastic, plywood, and hardwood, and a consistent sound was projected through each sound box, then the hardwood would produce the highest decibels of sound and the longest duration of sound. Sound is present throughout everyday life everywhere. Attaining a greater understanding of how sound can be affected, especially by materials, would allow for the development of new technologies which reduce or strengthen the output of sound. Finding materials that effectively and cheaply reduce sound would greatly benefit places filled with noise pollution such as cities. A sound box was created, and a consistent sound was projected through the sound box for five seconds and recorded on the other side. The intensity and duration of the sound was recorded across thirty trials for materials of foam, cork, plastic, plywood, and hardwood with a basic sound box without a lining as a control. For the materials no lining, foam, cork, plastic, plywood, and hardwood the mean intensities (dBA) were 116.55, 115.24, 117.38, 119.05, 120.63, and 115.29 and the durations (s) were 6.51, 6.4, 6.52, 6.5, 6.43, and 6.28 respectively. The null hypothesis was rejected as well as the experimental hypothesis.

Engineering C (HS EGR-C)

Third Place

Using Piezoelectricity to Create a Self-Powered Calculator

Jade Personna *Central Virginia Governor's School*

The purpose of this study was to determine the feasibility of using piezoelectricity to create a self-powered calculator. A solar-powered scientific calculator was disassembled for this study. A piezoelectric disk was inserted under one of the calculator's keys and the solar panel was removed from the calculator. The voltage produced by the solar panel and the voltage produced by the piezoelectric disk were measured as keystrokes were being simulated on the disk by a mechanical actuator. The solar panel produced an average magnitude of 2.77 V while the piezoelectric disk produced an average magnitude of 5.21 V. A two-sample t-test with an alpha value of .05 used to analyze this data produced a p-value of about 1.911x10-7, indicating that there was a statistically significant difference in the voltage produced by the solar panel and piezoelectric disk. The results of this study found that the piezoelectric disk produced enough energy to completely power the calculator, which partially supported the research hypothesis that the piezoelectric disk would be able to offset some, but not all of the energy required to power a calculator. In conclusion, it would be feasible to use piezoelectricity to design a calculator that is powered by the force used to press its keys.

The Effect of Ultraviolet Light on Thermoplastic Tensile Strength

Annabel Puritz *Mills E. Godwin High School*

When plastic is not properly recycled, it can end up in the environment. Rather than decomposing like other materials, plastic breaks down into increasingly smaller pieces of plastic that can cause harm to animals that ingest it. An experiment was designed to observe how ultraviolet (UV) light affects a plastic's strength properties. It was hypothesized that if various types of thermoplastics were exposed to UV light, then polypropylene plastic will present the least amount of damage afterward.

A device was used to measure the tensile strength of three different plastics: polyethylene terephthalate, low-density polyethylene, and polypropylene. Then, the tensile strengths of these plastics were measured again after exposure to UV light to determine how this factor might affect the strength of plastic in the environment.

The data from this experiment showed that high-density polyethylene was damaged the least by UV light, and polypropylene had a significant decrease in tensile strength. The results also showed that polyethylene terephthalate plastic significantly increased in tensile strength after UV light exposure. While performing the experiment, safety precautions were taken, and a parent signed a permission form indicating that they understood the risks associated with their child doing this research.

Each of the three plastics had completely different results from the exposure to UV light. These results could have been caused by differences in the manufacturing process of the single-use plastic items, which caused them to present damage to the plastic in different ways. However, the results may have also been from human error during the tensile strength testing process since each level of the independent variable had differing amounts of outliers in the data.

Honorable Mention

DORC: Dynamic Operating Room Companion for Surgical Workflow Recognition

Pravalika Putalapattu *Thomas Jefferson High School for Science and Technology*

Every year, 4000 human errors occur in the operating room. Surgical workflow recognition is a burgeoning field of study that aims to combat this problem by analyzing medical video and identifying tool presence and surgical action in each frame. This project uses the Cholec80 dataset, which contains 80 full-length gallbladder removal surgery videos with frame-by-frame annotations. Our goal of live surgical action recognition is split into two tasks: (1) identifying the tools in each frame and (2) analyzing patterns and time-dependencies within tool presence to deduce current phase. (1) For tool identification, I created an algorithm that improves upon the standard approach of convolutional neural networks using image segmentation and an optimized region proposal network. I attained an 89% tool accuracy compared to a 90% state-of-the-art but gained an advantage in runtime of 60ms/frame compared to 300ms/frame. This allows my method to be used on live video with a higher frame count, making it more useful in a real-world hospital scenario. (2) To analyze tool patterns and temporal dependencies, I combined two methods: hidden Markov model (HMM) and linear temporal logic (LTL). LTL is traditionally hard-coded, but to maximize efficacy, I created a program to extract LTL rules from the training dataset. My algorithm successfully mapped between tool presence and phase labels for 93.5% of all frames in the testing dataset, beating state-of-the-art performance achieved by a recurrent neural network for this task. These results indicate that my system and methodology are sound with strong potential to be used for live surgery in the future.

The Effect of Various Concrete Additives on the Structural Integrity of Concrete

Carter Ramkey *Clover Hill High School*

The purpose of this experiment was to find the best eco-friendly recyclable concrete aggregate to add to concrete in order to create the strongest concrete possible. By knowing which eco-friendly concrete aggregate creates the strongest concrete, engineers and consumers can cut costs along with keeping the environment clean. The original experimental hypothesis was that if reused concrete, glass, and crumb rubber were added to a concrete mixture, then glass would make the concrete more structurally sound. The structural integrity of concrete was measured via a break machine, which broke concrete molds consisting of concrete mixed with each respective aggregate. The outcome of this experiment resulted in the glass aggregate performing the best at 7695.5 kilopascals (kPa) compression strength, followed by recycled concrete with a 6430.5 kPa compressive strength, and finally rubber with a 2264.1 kPa compressive strength. However, the control group exceeded each of the independent variables with a mean compressive strength of 7905.8 kPa. After the data was collected, an ANOVA test was conducted to determine if the data was statistically significant. The results of the ANOVA test concluded that the results of the experiment were statistically significant. The null hypothesis was rejected, and the original research hypothesis was supported.

Honorable Mention

The Effect of Different Cooling Systems on the Voltage Generated of a Fixed Angle Solar Panel

Taryk Saidou *Central Virginia Governor's School*

The purpose of this research was to determine the effectiveness of different cooling systems on the amount of voltage generated from solar panels. Three data groups were used: a solar panel with a system that utilized water convection, a panel that used the heat transfer components of antifreeze, and a standard panel. A Feit Electric 250W incandescent heat lamp was also used to provide a consistent heat and light source. Over the course of three weeks, three measurements of the voltage produced, and the surface temperature of each panel were taken daily. A single-factor ANOVA test determined significance in the data, with a p-value of 5.69x10-95 and an alpha value of .05. A post-hoc Tukey test was then used to determine that there was a statistically significant difference between all data groups, using the Dmin value of .06. This statistical analysis revealed that the data collected was significant. Therefore, the original hypothesis, which stated that if the electricity produced from each of these panels were measured, then the panel with the water pump would generate the greatest amount, was supported. In conclusion, while each of these cooling methods proved to be beneficial compared to the control group, the water-based cooling system showed the most significant effect on the amount of voltage generated.

Effect of Number of Symptoms on the Accuracy of the Na-ve Bayes Classifier for Diagnosis of Heart Disease

Roshan Sarangi *Mills E. Godwin High School*

This experiment was conducted in order to determine how a patient's number of relevant symptoms affect the accuracy of the Naïve Bayes classifier when predicting the presence of heart disease in the patient. Disease predictions by the Naïve Bayes classifier can mitigate a common problem in modern-day medical diagnoses: a lack of evidence suggesting that a given patient either has or does not have a particular disease. Research regarding the diagnosis of heart disease is relevant as the disease is the number one killer of men, women, and children in the United States; insight on the improved diagnosis of this disease has the potential to provide more accurate heart disease diagnosis for the millions of people in America and around the world who may suffer from it. The research hypothesis stated that if a patient had four symptoms of heart disease, then the Naïve Bayes classifier would have the greatest accuracy in predicting that the patient suffered from heart disease. The experiment did not use a control because no level of the independent variable served as an appropriate benchmark with which to compare the other levels. Prior to commencing the experiment, a data bank of symptoms and their classifications were supplied to the classifier. Then, the experiment could commence, and the symptoms of the example patients were supplied to the classifier. The output from the classifier was its prediction regarding whether each patient had heart disease. The t-test conducted on the collected data showed that all data was statistically significant. Results showed that the classifier was most accurate at predicting heart disease in patients with four relevant symptoms and least accurate at predicting heart disease in patients with one relevant symptom.

The Effect of CPU and GPU Based Parallel Processing on the Execution Time of Different Types of Computational Workloads

Rishav Sen *Mills E. Godwin High School*

All modern computers come with powerful graphics processing units (GPUs), separate, or integrated, but most programs do not take advantage of them. As a result, those programs do not use the full potential of the computer. This study's purpose was to determine the effectiveness of using the GPU compared to just using the CPU to perform different computational workloads – light and heavy. Programs calculating a fixed number of decimal points of π (Pi) using two different formulas - Nilakantha (light) and Leibniz (heavy) - were chosen to be the workloads. It was hypothesized that utilizing the GPU and the CPU would be significantly faster than just utilizing the CPU for both the workloads. Three programs were written for each workload with the controls being the programs computing sequentially on the CPU (single-threaded). For the heavy workload, the results supported the hypothesis. A t-test performed on the data found it significant. However, for the light workload, using just the CPU was faster than the combination of the GPU and the CPU. The results for the light workload are explained by the time taken to break the work into smaller chunks and send those to the GPU exceeding the time taken by the CPU to complete the work, hence, outweighing the benefits of the GPU's parallel processing capabilities. On the other hand, for the heavy workload, the processing time for the CPU is much longer, reducing the impact of the GPU communication overhead on the overall performance.

People Spotter

Sejal Sharma, Jennine Faruque & Kalea Wen *Governor's School@Innovation Park*

The accuracy of a novel infrared human sensing system was investigated through its ability to detect, count, and confirm social distancing between individuals in a public environment. Different from previous detection systems, this implementation responds to the COVID-19 pandemic as an ambient, non-intrusive, and low-resolution application. A Flir infrared camera was used to take images of people in four varying crowd densities: touching, stretching, and being close and six feet apart. Images were taken in two different locations: a deck area and a store. The image processing algorithm included preprocessing, thresholding, Connected Components algorithm, postprocessing, and distance calculation methods examining the temperature values in each captured image. The total number of humans exposed to the algorithm over multiple images was 408 in the deck and 320 in the store. This was expressed as percentages of the correct number of humans detected. The algorithm averaged 88-100% accuracy in all crowd densities excluding humans strictly touching, averaging an accuracy of 50-64%. Using a t test, the significance level was 0.044 overall in both locations and the crowd densities combined, statistically proving significance. When analyzing the separate densities, touching and stretching had significance levels of 0.007 and 0.015, while densities of close and six feet distance were statistically insignificant due to lack of samples. Future statistical significance warrants a larger sample size and inclusion of crowd density testing using covariance.

First Place

Investigation of the Tumoricidal Effects of Sonodynamic Therapy in Malignant Glioblastoma Brain Tumors

Kimball Sheehan & Darrah Sheehan *Western Albemarle High School*

Objective: Glioblastoma is the most common primary brain tumor; survival is typically 12-18 months after diagnosis. We studied the effects of sonodynamic therapy (SDT) using 5-Aminolevulinic acid hydrochloride (5-ALA) and high frequency focused ultrasound (FUS) on 2 glioblastoma cell lines.
Material and Methods: Rat C6 and human U87 glioblastoma cells were studied under the following conditions: 1mM 5-ALA (5-ALA); Focused ultrasound (FUS); 5-ALA and focused ultrasound (SDT); control. Studied responses included cell viability using an MTT assay, microscopic changes using phase contrast microscopy, caspase-3 assay apoptotic induction, and apoptosis staining to quantify cell death. A CAD designed and 3-D printed device was engineered to deliver FUS to in vitro glioma models. UVA biosafety approval was obtained, and guidelines were followed for all tissue culture and reagents.
Results: SDT led to a marked decrease in cell extension and a reduction in cell size. For C6, the MTT assay showed reductions in cell viability for 5-ALA, FUS, and SDT groups of 5%, 16%, and 47%, respectively compared to control ($p<0.05$). Caspase 3 induction in C6 cells relative to control showed increases of 109%, 110%, and 278% for 5-ALA, FUS, and SDT groups, respectively ($p<0.05$). For the C6 cells, caspase 3 staining positivity was 2.1%, 6.7%, 11.2%, and 39.8% for control, 5-ALA, FUS, and SDT groups, respectively. C6 Parp-1 staining positivity was 1.9%, 6.5%, 9.0%, and 37.8% for control, 5-ALA, FUS, and SDT groups, respectively. U87 cells showed similar responses to the treatments.
Conclusions: Sonodynamic therapy resulted in appreciable glioblastoma cell death as compared to 5-ALA or FUS alone. The engineering and biological based approach couples two already FDA approved techniques in a novel way to treat the most aggressive and malignant brain tumors.

Second Place

ELMOPP: An Application of Graph Theory and Machine Learning to Traffic Light Coordination

Fareed Sheriff *Mills E. Godwin High School*

Traffic light management is a broad subject with various papers published that put forth algorithms to efficiently manage traffic using traffic lights. Two such algorithms were the OAF (oldest arrival first) and ITLC (intelligent traffic light controller) algorithms. However, many traffic light algorithms have not considered future traffic flow and therefore cannot mitigate traffic in such a way as to reduce future traffic in the present. This paper presented the Edge Load Management and Optimization through Pseudo-flow Prediction (ELMOPP) algorithm, which aimed to solve problems detailed in previous algorithms; through machine learning using nested long short-term memory (NLSTM) modules and graph theory, the algorithm attempted to predict the near future using past data and traffic patterns to inform its real-time decisions and better mitigate traffic by predicting future traffic flow based on past flow and using those predictions to both maximize traffic flow in the present and decrease future traffic congestion. Furthermore, while ITLC and OAF required the use of GPS transponders and GPS, speed sensors, and radio, respectively, ELMOPP only used traffic light camera footage, often more readily available than GPS and speed sensors. ELMOPP was tested against the ITLC and OAF traffic management algorithms using a single-intersection simulation, and the collected data supported the conclusion that ELMOPP statistically significantly outperformed both algorithms in throughput rate, a measure of how many vehicles were able to exit inroads every second.

The Effect of Flaps on Aircraft Landing Distance

Ardenne Sklavos *Mills E. Godwin High School*

The purpose of this experiment was to find the effect of the degree of flaps on the amount of runway required for landing. The pilot and the co-pilot conducted seventy-five landings with three different degrees of flaps: 0°, 15°, and 35°. For each landing, the same checklist was followed. Prepare the plane from run-up procedures to following the traffic pattern. When reaching the abeam point for landing put in the first notch of flaps if flaps are to be used, if not skip this step. Continue proper protocol to the base leg and put in the second notch of flaps if used. On final approach, put in the remaining flaps and land. The control was full flaps or 35°, as this is the standard procedure for normal landings as provided by the Federal Aviation Administration (FAA). To maintain safe protocol, pilots completed frequent check-ins, radio calls that established position, and followed FAA regulations. It was hypothesized that if there are no flaps used during landing, then it will require the longest average distance to land. The results revealed that the 0° or no flaps independent variable level did have the longest average required distance. A chi-square test was done on the data and it revealed that the data was significant, and the results supported the research hypothesis. It is believed that the results are caused by the drag being reduced as the degree of flaps decreases. This research could lead to further studies that investigate other types of effects that drag has on an aircraft as well as how airflow and various factors such as weather conditions affect aircraft landings.

Honorable Mention

The Effect of Various Sleeve Materials on the Force Exerted and Percent Contraction of Pneumatic Artificial Muscles

Andrew Tabor *Central Virginia Governor's School*

The purpose of this study was to determine the optimal sleeve material of pneumatic artificial muscles (PAMs) for force exerted and percent contraction. To collect data on force exerted by the PAMs, a testing frame was constructed, and a load cell was used to measure force at 25 and 35 psi. The percent contraction data was calculated using the initial and the contracted length of the PAMs for both of the pressures. A two-way ANOVA test with replication was performed on both the force and percent contraction data sets. The ANOVA on the force data set yielded an interaction p-value of 3.49×1_0_$^{-51}$, _ _and the ANOVA on the percent contraction data set yielded an interaction p-value of 1.93×1_0_$^{-8}$. These p-values were then compared to the alpha value of .05, which determined that there was significance in both data groups. Four post-hoc Tukey tests were conducted to determine that there was significance between all of the groups. Neither of the research hypotheses were supported, it was predicted that the PAM with carbon fiber sleeving would generate the most force and that the PAM with the Stainless-steel sleeving would have the greatest percent contraction. However, the results suggest that the Stainless-steel sleeving was able to generate the most force at both pressures. The carbon fiber sleeving had the greatest percent contraction at 25 psi, and the nylon sleeving had the greatest percent contraction at 35 psi. These results could aid in deciding what sleeve material is best depending on the situation.

Modeling the Effect of Environment on Collision Detection Runtime

Josh Tomiak *Southwest Virginia Governor's School*

Collision detection (CD) is the digital process of finding and reporting intersections between objects. CD is a fundamental problem in computer physics and is employed in a wide variety of applications; however, it is a time-consuming process often involving complex data structures and algorithms. Although many broad phase CD algorithms have been developed, they are difficult to compare and analyze because their performance is tied to the digital environment in question. This research parameterized seven aspects of the environment and modeled their effect on broad phase CD runtime. Two broad phase algorithms each ran for 2,187 simulations of varying parameter settings, and a multiple regression model was constructed for each algorithm using the average runtime over 1,000 cycles and parameter settings of each simulation. Partial R2 model statistics quantified the effect of each parameter, showing that total objects had the greatest effect for both the axis-aligned bounding box tree (0.986) and incremental sweep and prune (0.897) algorithms, but that some other parameters had effects to a lesser degree, as related to the operation of the algorithm: linear velocity (0.186) and aspect ratio (0.117) for the axis-aligned bounding box tree algorithm and density (0.173) and linear velocity (0.103) for the incremental sweep and prune algorithm. The results provide insight into the effect of environment on broad phase CD runtime, facilitating the development, benchmarking, and implementation of algorithms. Future work could improve the models, collect similar data for more algorithms, or investigate the observed relationship between total objects and the effects of other parameters.

Risk-Adjusted Return Analysis of Asset Allocation Strategies for Retirement Savings

Carson Wang *Maggie L. Walker Governor's School*

These days, Americans are living longer, and most are concerned with outliving their assets. The purpose of this project was to use ex-post testing to determine which combinations of asset classes yielded the highest risk-adjusted returns through the Sharpe ratio. It was hypothesized that the S&P 500/corporate bonds 50-50 split would have the highest Sharpe ratio. Data for S&P 500, U.S. small-caps, corporate bonds, commodities, U.S. REITs, and other developed countries' equities were used to create multiple 1/N portfolios, where asset classes in each portfolio were equally weighted. The Sharpe and Sortino ratios were calculated for 1981-2020and the four economic cycles within, using monthly returns and volatilities. There was no control because a risk-free asset was not considered. The results showed that the S&P 500/corporate bonds split was the winning portfolio with the highest Sharpe ratio, followed by the S&P 500/corporate bonds/REIT split. For total returns, the S&P 500/small cap was the highest of all portfolios. The favorable risk-adjusted returns for the winning portfolio and similar combinations made them desirable options for long-horizon investors in the past 40 years. Further research can be conducted to predict the performance of these asset classes over the next 40 years due to factors such as the FAI framework and credit spread tightening.

The Effect of Various Existing Algorithms on Success at Correctly Identifying Emotions by Facial Expressions

Sarah Wilms *Clover Hill High School*

The purpose of the experiment was to determine the effect of various existing algorithms on their ability to successfully identify emotions through facial expressions. Many software companies make image identification programs with the hope to have the program with the most accuracy and speed. Comparing the performance of four well known classification algorithms allows for both companies to build off of the most accurate model and smaller programmers to understand and use the most accurate model. The hypothesis stated that if the models InceptionV3, VGG16, VGG19, and InceptionResNetV2 were used to identify emotions, then the model InceptionV3 will show the highest accuracy with identifying emotions. 15 people were put against a blank background and 9 pictures were taken of each individual: three portraying happy, three portraying angry, and three portraying surprise. Each image was copied 9 times, and each copy was altered slightly, resulting in pictures that were zoomed in, mirrored vertically and horizontally, etc. After being sorted into the folders training, validation, and testing, each image classification model was uploaded to the Jupyter Notebook application, and the models were given access to the training image folder. After the models were trained, each model was given access to the validation and testing folders, and the results of that round of training was recorded in a data table. The nine copied images were slightly altered, and the same process was repeated two more times, for a total of 3 rounds of training each model. The mean accuracy at the end of each round for the models InceptionV3, InceptionResNetV2, VGG16 and VGG19 were 63.70%, 70.74%, 76.05%, and 72.10%, respectively. The experimental hypothesis was not supported, as VGG16 had the highest accuracy with 76.05%. An ANOVA test was conducted and concluded that the results were statistically significant, rejecting the null hypothesis.

Effect of Pelletized Plastic on Asphalt Compressive Strength

Frank Wright *Central Virginia Governor's School*

The purpose of this research was to explore the feasibility and effects of integrating plastic into asphalt as an additive in order to improve strength. In this experiment, plastic was integrated into samples of asphalt in pelletized form during the mixing process in varying concentrations, and then subjected to tests and analysis in order to determine the average maximum compressive strength of each test group, as well as a control. The data was then subjected to a single-factor ANOVA test and a post-hoc Tukey test to determine significance. With an alpha value set at .05, the p-value was 4.98×10^{-22}, showing a significant difference between groups. The post-hoc Tukey test found significant differences between all groups except for between 3% and 4% concentrations. This data generally supports the research hypothesis, that if pelletized plastic-modified asphalt is subjected to compressive testing, then the maximum compressive strength will decrease as the plastic concentration increases. However, this data shows an unexpected “plateau” effect in asphalt quality at higher plastic concentrations after a large drop from the control asphalt, a phenomenon which could be worth further study. Although our research did not find improvements with the addition of plastic to asphalt, we cannot rule out the idea that other production methods such as melting into the bitumen may prove more effective in improving the quality of asphalt through plastic additives.

Environmental & Earth Science A (HS ENV-A)

Third Place

Modeling *Oncorhynchus nerka* Populations Near Pebble Mine, Alaska

Thomas Ackleson *Washington-Liberty High School*

The proposed pit mine in Pebble Bay, Alaska is predicted to displace up to 8.4 million tons of mine rock waste for every year it will be in use. This waste contains highly acidic chemical compounds, namely sulfide acid and copper nitrate. Mineral waste like this will increase pH levels in the surrounding water system and Bristol Bay. Responsible for 46% of the world's sockeye salmon (*Oncorhynchus nerka*) production, this water system is also an important cultural and spiritual hub. The predicted impacts of rising pH from rock waste on O. nerka reproduction has been researched, but not modeled over time. This project's purpose was to conduct that modeling, taking various pH estimates into account. Python simulation software was programmed, which used an iterative formula to calculate Bristol Bay salmon spawning statistics at various pH levels for the next 40 years. It was found that any pH levels less than normal conditions (7.0 - 7.9) would slow the rate of reproduction significantly, and any pH level less than 5.0 would lead to negative growth. The pH environment most likely to arise from Pebble Mine waste displacement, pH 5.0 - 6.9, saw a nearly 68% slower population growth rate than normal levels. It was concluded that, given the many assumptions and generalizations the model took, the precise numbers calculated by the model were largely inaccurate, however the trends they show likely are. If the mine is approved, salmon populations and their economic and social values will be put into jeopardy.

The Effect of Crumb Rubber on the Height of Tall Fescue Grass

Elizabeth Adams *Washington-Liberty High School*

Do artificial turf fields contribute to the deterioration of plant life? Crumb rubber is the name for the small rubber pellets which are commonly used as infill in artificial turf fields. The use of crumb rubber is widespread, therefore emphasizing the importance of ensuring its safety to both humans and the environment. This experiment sought to find the impact of crumb rubber on the height of tall fescue grass. This could have widespread impacts, as crumb rubber is relatively common and could easily enter an ecosystem from attachment to clothing, bags, or hair and runoff. Tall fescue grass seed was planted in cups with differing amounts of crumb rubber. Per experimental level, 20 trials were performed. The experimental levels of this project included a control group containing no crumb rubber, a group with 1 gram, one group with 3 grams, and lastly, a group with 5 grams of crumb rubber. After 20 days, the height of the grass was measured and recorded. The hypothesis for this experiment was: if tall fescue grass was exposed to different amounts of crumb rubber, then the growth of the grass would be highest at 1 gram of crumb rubber, because the possible aeration and water retention benefits could occur, though the concentration could be too low as to negatively impact plant growth through chemical leaching. This hypothesis was not supported, as the results of this experiment were not statistically significant and failed to reject the null hypothesis.

The Effect of Different Types of Fertilizers on the Regeneration of *Lumbriculus variegatus*

Sujhan Alwin *Clover Hill High School*

The purpose of this experiment was to determine which type of fertilizer was the most detrimental to the regeneration of Lumbriculus variegatus. Fertilizers have acted as major water pollutants and are used both commercially and non-commercially. By testing different types of fertilizers on Blackworm regeneration, it will become possible to determine which type of fertilizer is the most hazardous and should be limited. The research hypothesis stated that if the *Lumbriculus variegatus* were exposed to 2 grams of nitrogen-based fertilizer, 2 grams of potassium-based fertilizer, or 2 grams of phosphate-based fertilizer during the period of their segmental regeneration, then the blackworms would regenerate the least amount of length in the nitrogen-based fertilizer because of the increase in ammonia content which decreased water quality. The experiment was conducted by first setting up four small containers with a small amount of water and a piece of an organic paper towel. Three of these containers then received fertilizer, with one having 2 grams of Nitrogen-based fertilizer, one with 2 grams of Potassium-based fertilizer, and one with 2 grams Phosphate-based fertilizer. The fourth container remained a control. This process was repeated 9 more times, with a cumulative 40 containers. Then, 80 blackworms were cut to 12 millimeters in length and placed inside the containers. Each container held two black worms and were monitored for a period of three weeks. At the end of the three weeks, the worms' length regenerated was recorded and the experiment was repeated. The results exhibited high regeneration lengths in worms of the control group, while the worms in each of the experimental groups exhibited roughly similar, comparably low lengths regenerated. The null hypothesis that stated that there would be no significant difference in the lengths regenerated was rejected but the research hypothesis was not supported by the results.

The Effect of Aquatic Plants on Nitrate Reduction in Ecosystems.

Nikhil Amin *Mills E. Godwin High School*

The purpose of this study was to determine how various aquatic plants affected the denitrification process and which freshwater plants were most effective at reducing nitrate levels for the maintenance of the ecosystem. The research hypothesis stated that if various aquatic plants were used to reduce nitrate levels in model freshwater environments, then the *Lemna minor* species would decrease the nitrate concentration the most. The experimental procedure began with the set-up of three tanks containing *Lemna minor, Limnobium laevigatum*, and the control of no aquatic plants. An API nitrate test kit was utilized to determine the nitrate concentration in parts per million (ppm) from zero to 160, and the nitrate levels were then recorded in a laboratory notebook. Safety was ensured throughout the experiment as every possible safety precaution and protocol was followed under the direct supervision of the designated supervisor. The research data was statistically analyzed, and the descriptive statistics indicated that *Lemna minor* was most successful in reducing nitrate concentration as the mean was 3.74 ppm. The standard deviations were low, implying that the data was precise with little variation. Furthermore, three t-tests were conducted at a level of significance of 0.05, and these calculations resulted in values larger than the critical value of 2.012. The results indicate that the data was statistically significant and the probability of error in the experiment was less than 5%. Ultimately, it was believed that *Lemna minor* was most effective due to its ability to absorb nitrogen and phosphorus in a short time span; however, further research must be conducted before its effectiveness can be concluded.

First Place

Baby Got Leatherback! Anthropogenic Effects on Sea Turtle Nesting and Reproduction in North Carolina

Sydney Bakir *Chesapeake Bay Governor's School*

Sea Turtles have been around for more than a hundred million years. Anthropogenic climate change has caused drastic weather conditions which harm the turtles and their nests. Along with that, vast amounts of development, pollution, and artificial lighting have put multiple species of sea turtles on the endangered species list. When humans started to notice the downfall of sea turtles, countless protection programs began to form. Most incubating nests are now protected from predators and hatchlings are now guided. This study compared anthropogenic impacts to sea turtle data in North Carolina to see the effect of humans on sea turtles. This study used data collected from 25 beaches along the coast of North Carolina from 2009-2020. The five species involved in this study were the loggerhead, green, kemp's ridley, leatherback, and hawksbill sea turtles. To measure levels of development, google satellite images were analyzed for building density and sorted into the two categories: low development and high development. Northern vs. Southern Beaches were split to evenly distribute oceanfront mileage and the average nests on each of the beaches were averaged together and analyzed against each other. To analyze relocated nests vs. incubation periods, relocated nest percentages were ordered from least to greatest and the corresponding incubation was matched with each. Nests per year and false crawls per year data was gathered and analyzed in chronological order. Finally, storm and research data were analyzed against false crawls and nests to find a possible correlation. Development vs. average nests had a p-value of 0.03 showing that there is a higher average of nests on beaches with less development. Latitude vs. average nests had a p-value of 0.10 meaning the data proved to be insignificant with a p-value trending towards significance. Relocated nests vs. incubation periods had a p-value of 0.39 proving the data to be insignificant. Average nests vs. year had a p-value of 0.04 which proves to be significant and false crawls vs. year had a p-value of 0.04 which also proves to be significant. Sea turtles take around 30 years to reach sexual maturity and around 40 years ago, sea turtle protection programs began to sprout everywhere. So, it can be assumed that the sea turtle population is increasing with the help of these programs to protect them from predators. Therefore, if humans were to decrease development and increase turtle protection, we should see the Sea Turtle population double within the next 40 years.

Atlantic, Caribbean and Great Barrier Reef Coral Bleaching as a Function of SST

Isaac Barber *Chesapeake Bay Governor's School*

Coral bleaching is cause for immediate attention and solutions to be put in place. Locating and assessing each bleaching location is crucial in explaining the phenomena and combating its effects. Overfishing, pollution, and climate change are the cause for the majority of coral deaths. Statistical data were taken from NOAA Coastwatch, ERDDAP GRIDDAP, a NOAA data software package that generates buoy data. The grid variables that were selected were sea surface temperature (SST) and coral bleaching alert area (BAA). For the SST data, ANOVA, much less than p=0.05 suggests that Keys is significantly different. For the BAA data, ANOVA, p-value=0.53 from 2-4 across sites suggests no statistical change. Since coral reefs are keystone species, when they are threatened by external sources, so is their entire habitat. By preventing and controlling climate change, bleaching events can be minimized when also paired with methods that increase resilience such as herbivore management areas.

The Effect of Water Source on the Number of Microplastic Particles in the Water

Anita Bennett *Clover Hill High School*

The question addressed in this experiment was which location on the James River in Virginia had the greatest number of microplastic particles. The purpose of this experiment was to determine which location had the most microplastic particles and is therefore least safe to drink. The hypothesis stated that the more urbanized area, Newport News, would have the greatest number of microplastics. During the experiment, 8 water samples were collected via plankton net from Newport News, Richmond, and Buchanen. Samples were also taken from tap water as a control. Of the 8 samples taken from each location, only 5 were tested, and the other 3 remained in storage as backup samples. The samples were sieved using a No. 3.5 stacked on a No. 50 sieve. Anything on the sieves was discarded and the sieved sample was kept for wet peroxide oxidation. The process of wet peroxide oxidation involved adding 20 mL of pre-prepared aqueous 0.05 M Fe(II) solution and 20 mL of 30% hydrogen peroxide. The solution was heated at 75 C for thirty minutes, adding more hydrogen peroxide at regular intervals until there was no remaining organic matter. Salt dissolved in the sample, and the sample was left to cool and settle in a funnel separator for 12 hours. The excess solids were drained, and the sample was sieved through the No. 50 sieve. The sieve was left to dry and was later examined under a microscope. Any microplastic particles visible under the microscope were counted and recorded. The mean number of microplastic particles for Newport News, Richmond, Buchanan, and tap water was 2.2, 1.8, 1.2, and 0.2 respectively. The data supported the experimental hypothesis that Newport News would have the highest number of microplastic particles. The null hypothesis that there would be no difference between locations was rejected using an ANOVA test.

Third Place

Can 3D Printed Substrates Provide a Suitable Substrate for Fouling Organisms in the Lower Chesapeake Bay Estuary?

Kylie Berry *Chesapeake Bay Governor's School*

Eastern Oysters, *Crassostrea virginica*, are considered the keystone species of the Chesapeake Bay because of their important roles as a biofilter and multidimensional hard substrate for other organisms to use for shelter and habitat. The decline in Eastern Oysters is attributed to overfishing, disease, sedimentation, and eutrophication causing the population to decline to less than 1% of its historic size. This study explores the potential for 3D printed structures to attract and support estuarine fouling organisms as a substitute for lost oyster reef substrate in a Chesapeake Bay tributary. Six plastic 3D printed substrates of two colors, red and purple, were dropped in shallow water of 0.5m, and another set of six with both colors was dropped in 1.5m deep water in the East River, Mathews, Virginia. After 6 weeks of deployment, substrate baskets were observed, and fouling organisms counted using a grid quadrat method. The percent coverage of fouling organisms was estimated, and the invertebrate fouling species were identified. There was an abundance of Chesapeake Bay fouling organisms that attached to the 3D printed structures. The shallow substrates at 0.5 m were preferred over the deeper substrates of 1.5 meters. The shallow red and purple were not different, $p=0.613$, nor were deeper substrates, $p=0.867$. The purple structures showed statistical difference between shallow and deep $p=0.013$, but the red structures were not statistically different, $p=0.152$. This experiment helps to establish new opportunities for restoration environments for the Chesapeake Bay.

A Preliminary Assessment of the Recovery of Stony Creek from Pollution Using Aquatic Macroinvertebrates

Jenna Beville *Dinwiddie High School*

Pollution in waterways is a major issue for wildlife conservation as well as human wellbeing. The goal of this study was to determine whether the tributary, Stony Creek, had since recovered from a pollution event occurred in 2015. To do this, two sites, one upstream and one downstream, compared to the pollution source location were assessed using aquatic macroinvertebrates. Aquatic macroinvertebrates are a reliable source of information about water quality due to differing levels of tolerance to pollution. We used abundance, number of families, overall diversity estimated by Shannon-Wiener Index and the Family-Level Biotic Index (FBI) to assess the water quality. On average, the upstream site and downstream site had the same number of macroinvertebrate families. However, the average abundance of macroinvertebrates in the downstream site was two-times higher than that of the upstream site. The average FBI for the upstream site was 4.68 which indicates “Good” water quality with some organic pollution probable. In contrast, the average FBI for the downstream site was 3.20 which indicates “Excellent water quality” with organic pollution unlikely. This may suggest that Stony Creek is recovering from the water pollution that occurred in July of 2015.

The Effect of Weather Patterns on the Spread of Airborne Plastic

Kathryn Boerckel & Allison Grove *Washington-Liberty High School*

The purpose of this experiment was to discover the effects of weather patterns on how microplastics travel from urban to national park locations through the air. This experiment also observed weather patterns in specific regions of the United States and if they had an effect on the transmission of airborne plastics from an urban to rural location. Over the span of seven days, the original (urban) locations of microplastic filled air masses found in national park locations were recorded. Microplastics in the atmosphere are becoming an issue in the world, due to extensive amounts of plastics in the environment and have many negative effects on the health of the earth. Based on the data collected, the hypothesis (If high concentrations of airborne plastics are found in urban areas, then they will travel and affect ecosystems in less populated areas such as national parks because of weather patterns) was accepted as airborne plastics were found constantly traveling long distances to national park locations. The result of an ANOVA test also supported this hypothesis because it validated the data to be statistically and significantly different. As a result of this data, the null hypothesis (If high concentrations of airborne plastics are found in urban areas, then they will not travel or affect the levels of airborne plastics and ecosystems in less populated areas because of weather patterns) was rejected.

The Effect of Water Turbulence on Microalgae Growth

Nelson Bonilla *Chesapeake Bay Governor's School*

The growing of algae is affected by various variables; the purpose of the study is to analyze if water turbulence is also one of these factors. The algae *Chlorella vulgaris* under different treatments, different quantities of turbulence, was grown over a period of two weeks. The results suggested that a high and medium amount of turbulence would create a higher yield of algae. This concluded that, under limits, increasing the amount of water turbulence does increase the concentration/yield of algae in a given volume. The possible uses of the data may include biofuel optimization and enhancement to mitigate carbon dioxide emissions.

An Analysis of Fire Call Frequencies During Severe Storm Events in a Rural Area

Olivia Brocklebank *Chesapeake Bay Governor's School*

Severe weather events can create a plethora of damage to an area, in which the people that first respond to the scene are first responders. This includes EMT, law enforcement, and the fire department. Many different types of incidences can happen during these weather events, including structural damage, flooding, and downed trees. This study was broken into two parts. The first part compared the type of call to the Frequency (F) of each type, while the second part compared the Frequency of three different types of calls to three different road classifications. The data received from the Sherriff's Department, consisting of roughly two years of reports during severe weather events, was sorted by type of call. The first data table showed the data sorted by type of call. An ANOVA test comparing the Frequency (F) to type of incident showed significance, so a Tukey's Post-hoc Test was also used, displaying a significant difference only when comparing the group between Trees Down to the following: High-Water Events, Car Accidents, and Structural Damage. The second data table was sorted by road type (Main Road (M), Backroad (B), and Dead-end Road (D)) with the frequency of the three main types of calls to the corresponding road they occurred on. The graph showed that backroads had the most calls, as well as most trees down, whereas dead-end roads had the most power lines down and main roads the most flooding. However, an ANOVA test displayed no significance, to no further tests were applied. This statistical data could be explained by the unfavorably small data set used for this experiment. These results show that there is a difference in frequency of each incident, which could aid in First Responder preparation. This could also incentivize tree-removal companies to clear out older trees, fallen limbs, or trees surrounding power lines.

Salinity and Temperature Effects on the Growth of Diploid Oysters in the Lower Rappahannock River

Katherine Brooke *Chesapeake Bay Governor's School*

Oyster restoration in the Chesapeake Bay is critical because oysters provide ecosystem services such as building reef habitat for commercially important blue crabs and striped bass. Today, the oyster population in the Chesapeake Bay is approximately 1% of its historical abundance due to overfishing, disease and oyster reef degradation. This study seeks to determine if water quality parameters of salinity and temperature affect the growth of diploid oysters over time in different locations of the Rappahannock River estuary. Observations of water quality and oyster growth were made on 250 juvenile oysters spread over five sites in the Rappahannock River: Parrotts Creek, Urbanna Creek, Locklies Creek, Meachim Creek, and Sturgeon Creek. To analyze the growth of the oysters, the shell height of individual oysters was measured in mm with calipers, and pictures were taken to document their growth over time. Across all sites, oyster growth was not statistically different, ANOVA, $p=0.6508$, but salinity did vary statistically across sites, ANOVA, $p= 0.0207$, while the temperature was relatively similar. From these results, it can be inferred that oysters can grow successfully in many locations of the lower Rappahannock River, since they are highly adaptable to changes in water conditions. As the Earth continues to warm at an increasing rate, the oyster population will most likely be able to survive due to their adaptability to wide ranges of conditions observed. Restoring Eastern Oysters will be critical for improving water quality as climate changes, protecting from the effects of increasing runoff and turbidity.

Honorable Mention

The Effect of Air Pollution on the Efficiency of Solar Panels

Isla Carlson *Wakefield High School*

The purpose of this experiment was to see if air pollution affected the efficiency of solar panels. Air pollution was simulated using a varying number of translucent sheets that covered the solar panel. Sunlight was simulated using a light positioned above the solar panel. The levels of the independent variable were, 1 sheet, 3 sheets, 5 sheets, 7 sheets, and 9 sheets, with no sheets being the control. The dependent variable measured the current (microamps), voltage (volts), and power (microwatts). The hypothesis was, if there is low air pollution (1 translucent sheet), then the solar panel will produce the most volts, microamps, and microwatts because the less simulated air pollution there is, the more light reaches the solar panel.

To collect data, the correct number of translucent sheets were placed over the solar panel, the light above the solar panel was turned on, and after 30 seconds data was recorded. Ten trials were conducted for each level of the independent variable, the current and voltage were measured on the multimeters and multiplied together to calculate the power. Photos were taken of the light bulb through trials to compare the brightness.

The results were, when pollution increased (as simulated with translucent sheets), the amount of microamps, volts, and microwatts decreased. The level of the independent variable with the 1 sheet had the most electricity measured and brightest light bulb. The level of the independent variable with the most pollution, 9 translucent sheets, had the least amount of measured electricity and the least bright light bulb.

Second Place

A Study on the Changes in Pollution and Turbidity Affected by Riparian Buffers of Local Lakes after Three Years

Amulya Chowdhory *Mills E. Godwin High School*

In 2017, a study was conducted to test the effectiveness of riparian buffers by measuring the turbidity of local lakes. This project was a continuation project, and the purpose of this experimentation was not only to study the use of riparian buffers but also to study the pollution trends in Henrico County. Riparian buffers are strips of vegetation that line bodies of water that prevent flooding, protect wildlife, and improve water quality. Turbidity is the measure of cloudiness caused by suspended particles and is influenced by location, vegetation, and pollution (Kitchener et.al 2017). The research hypothesis was if four lakes have their turbidity tested after a period of three years, the turbidity of the lakes will increase due to an increase in population. The levels were four lakes, each representing a different riparian zone by length, measured in meters, and the control was the lake with no buffer. The experimenter addressed all safety precautions by wearing closed-toe shoes and protective clothing as well as a face mask to follow COVID-19 restrictions. Using a Secchi Disc, the turbidity of these four lakes were measured and a t-test was conducted to measure the significance of the data, all the data was found significant. In 2017, Lake C (2.03 m) had the best turbidity with a mean of 10 NTU. In 2020, Lake D (2.43 m) had the best turbidity with a mean of 6.3 NTU. Overall, riparian buffers were found effective, the turbidity of the lakes had improved with only Lake C as the exception because more regulation was enforced at these parks, and the research hypothesis was not supported.

Honorable Mention

A Comparison of *Littoraria irrorata* Populations Along the Rappahannock River

Margaret Collins *Chesapeake Bay Governor's School*

The periwinkle snail, *Littoraria irrorata*, is a staple species of shoreline ecosystems along the Rappahannock River and throughout the Chesapeake Bay. They can be found crowded in almost every brackish marsh within the Bay and are usually found in needle rush and cordgrass marshes. This study tested for variation between periwinkle populations in three different marshes along the Rappahannock River. Three different parameters, population density, average shell length, and scar frequency, were tested. Population density was tested by throwing a 1 m2 hula-hoop three places along the shoreline, then counting all periwinkles within the circular quadrant; the average of the three values was used as an estimate of the marsh's density. Scar frequency and shell length were tested by collecting 50 snails in a bucket from around the marsh, then inspecting each snail for scars and measuring its shell in centimeters from the apex to the base of the lip. ANOVA Single Factor tests were run and resulted in p-values of 4.69 x 10-5 for population density, 1.88 x 10-7 for scar frequency and 8.44 x 10-12 for shell length. When comparing tidal range to population density and scar frequency data, it appears that tidal range is inversely related to population density and that tidal range is directly related to scar frequency. Overall, the data confirms the fact that periwinkle populations vary in density, scar frequency, and shell length in different marshes along the Rappahannock River. Seeing as the health of individual populations reflects health of individual marshes, the marsh periwinkle should be considered a very important species. Considering the fact that 50% of the Chesapeake Bay's historic marshes have been lost in the past few decades, marsh conservation is more critical now than ever. Understanding the health and status of marsh periwinkle populations could in turn help scientists better understand the food webs, function, and health of Chesapeake Bay ecosystems, and may even aid in their conservation.

Environmental & Earth Science B (HS ENV-B)

The Effect of Different Plants on the Amount of Soil Eroded

Caroline Colucia & Tessa Muldowney *Washington-Liberty High School*

The purpose of this study was to determine the effects of different plants on the amount of soil eroded (grams). The hypothesis was: If different plants placed in a wired cage are watered then *the Physocarpus opulifolius* will cause the least amount of soil to be eroded because it has the largest bark to support the roots and hold soil in place. The null hypothesis was: If different plants are placed in a wired cage and water is poured on them, then all the plants will cause the same amount of soil to be eroded as the soil without a plant in it (control group). The independent variable was the type of plant. The levels of the independent variable were the *Liatris spicata, Physocarpus opulifolis*, and *Andropogon gerardii*. The dependent variable is the amount of soil that eroded (grams). The control was just soil, no plant. The constants were the amount of water poured onto the plants, the wire cage used to hold the plants, and the place where the experiment is conducted. To complete the experiment, 80 cups were filled with 400ml of soil, 60 of which with three different plants: *Liatris spicata, Physocarpus opulifolis*, and *Andropogon gerardii.* After the plants were fully grown, they were put in a wire cage, made out of galvanized hardware cloth and connected with twine. 50ml of spring water was poured on each sample, falling into a paper bowl. The total amount of soil lost was measured in grams by a scale and recorded in a data table. Results suggested that plants can be used to inhibit soil erosion. The hypothesis was accepted because the *Physocarpus opulifolius* caused the least amount of soil to be eroded. One recommendation for further study would be to perform the same experiment with different plants, all with strong roots. Potential errors, possibly affecting validity were that the same wire cage was used for the duration of the experiment and placing exactly five seeds in each cup was challenging.

The Effect of Fertilizer on Algae and How it Impacts Dissolved Oxygen in Freshwater

Elina Coutlakis-Hixson *Washington-Liberty High School*

Dissolved oxygen is needed for most aquatic animals to survive. When algae decompose, it consumes dissolved oxygen. When there is too much fertilizer, it can lead to an overabundance of algae and oxygen depletion in the water. The Gulf of Mexico hypoxic zone is an extreme example of this. The specific purpose of this study is to determine how varying amounts of fertilizer affect algae growth, based on dissolved oxygen. The hypothesis was, if 25 mL of spring water and 3 mL of Chlorella algae were put into each of the 48, 50-mL test tubes, it was expected that group 2 (0.6 mL fertilizer/ 100 mL spring water) would achieve more growth than the samples in group 1 (0.6 mL of fertilizer) and group 3 (0.6 mL fertilizer/ 300 mL spring water). It was expected that algae in group 1 (0.6 mL) would die quickly because fertilizer decreases the pH of water, making the water too acidic at high concentrations. Also, too much fertilizer would create an overabundance of salt, and because Chlorella is a freshwater organism, this could have made for a smaller number of algae being produced.

The amount of fertilizer in group 3 (0.6 mL fertilizer/ 300 mL spring water) was expected to be insufficient to yield maximum growth. The means from lowest to highest were group 1 (0.6 mL fertilizer), group 4 (control), group 2 (0.6 mL fertilizer / 100 mL water), and lastly, group 4 (0.6 mL fertilizer / 300 mL water). The ANOVA test showed that, overall, the results were not significant because the p-value was 0.121913. However, when a t-test was used between group 1 and 3, the p-value was 0.03558209, yielding significant results between those groups alone.

The Production of Fabric from *Pleurotus eryngii* and *Ganoderma lingzhi* Mycelia

Reesa Taylor and Devers Frazier *Roanoke Valley Governor's School*

The purpose of this project was to compare the properties of mycelium-based fabrics made from *Ganoderma lingzhi* and *Pleurotus eryngii.* The process of creating animal-based leather often includes the use of tanneries that produce waste which pollutes nearby waterways. This experiment was meant to explore the cultivation methods of a biodegradable alternative to animal-based leather. In this project *G. lingzhi* and *P. eryngii* mycelium was grown using two different growing methods: Petri dishes and shaded containers. Once the mycelium was grown, the mats were placed in an oven at 60°C until dry. Once dried, they were cut into samples and flammability, water resistance, density, and tensile strength testing was done. It was hypothesized that the *G. lingzhi* would more closely resemble the bovine leather and that the Petri dish growth method would yield a more leather-like fabric. The results of the tensile test showed that the control of bovine leather was significantly stronger than all made composites and there was no statistical significance between the made composites. The one-way ANOVA tests showed there was a statistically significant difference in the change in mass after burn time, tensile strength, density, time until water permeation, and microliters needed for permeation. The ANOVA also showed there was not a significant statistical difference in the burn time between sample sets. Based on the results, the composites made did not resemble leather, and were weaker than the control. However, the hypothesis was proven correct as the Petri dish and *G. lingzhi* mycelium resembled leather most.

Honorable Mention

Stress Levels of Mummichogs in Response to Noise

Amar Dunham *Chesapeake Bay Governor's School*

Noise pollution is an increasingly problem that causes stress to organisms who cannot adapt to it. Aquatic organisms in closed-system environments are affected by this. This study examined the sound stress that is associated with loud noise levels compared to quiet levels by using dissolved oxygen and ammonia as indicators. The experiment used mummichogs (*Fundulus heteroclitus*), also known as the common killifish, to be randomized into loud treatment vs. quiet and periodically measured for D.O. and NH3 concentration. Analysis concluded that the quiet noise group had lower D.O. indicating more stress while NH3 did not show a difference between the groups with trend changes displaying the depletion of dissolved oxygen and accumulation of ammonia over timed intervals. This study showed that loud noise is not a sound stressor for mummichogs.

The Effect of Conflict on Air Pollution

Andrew Edmondson *Washington-Liberty High School*

This project attempted to investigate the effect conflict might have on the air quality of cities and towns. Specifically, this project sought to categorize the levels of conflict developing cities have endured and compare that to ug/m3 (Micrograms per cubic meter of air) measurements taken in those cities. The hypothesis predicted that cities/towns categorized as having endured military conflict in the past 50 years, would have a higher ug/m3 than those which had endured civil conflict. These cities/towns themselves would have a higher ug/m3 than those which had endured no conflict. Cities/towns that experienced military conflict averaged a ug/m3 measurement higher than those that experienced civil or no conflict, originally a promising result. However, the sheer diversity of size, urbanization, and industrialization in cities analyzed obscured any possibly conclusive results. The null hypothesis was accepted, as there were too many factors left unaccounted for, resulting in inconclusive and inaccurate information. The conclusion admits this fact, while encouraging further investigation as the means did trend in the expected direction.

The Effect of Acidity Level on Paper Degradation

Sarah Eichorn *Washington-Liberty High School*

The purpose of this study was to find out what effect raised acidity level had on paper degradation. The independent variable was pH/acidity level of each tub. The experimental group included: saltwater simulation (distilled water with dissolved salt) with nothing added, saltwater with 1% lemon juice acidity solution, saltwater with 3% lemon juice acidity solution, and saltwater with 5% acidity solution. The control group was plain saltwater to act as a baseline for the ocean. The dependent variable was the degradation occurred in grams. The constants were the amount of time the paper was in the water, amount of water, location, salinity level, substance that was added (lemon juice), and type of paper placed in water. The hypothesis was the tub with the highest acidity level of a 5% solution would cause the most degradation in the papers. The null hypothesis was water acidity will have no effect on paper degradation. For this experiment, 20 pieces of paper were placed into tubs of saltwater with acidities of 0%, 1%, 3%, and 5% and left for one week. They were then taken out and weighed to determine how much weight they lost over the week. This process was repeated to get a total of 40 trials, 10 per each level, and then results were collected. The results showed the 5% acidity solution had the highest degradation over one week. These results accepted the hypothesis. In conclusion, the study suggests that raised acidity levels have an impactful effect.

Honorable Mention

The Effect of Soil Quality on the Viability of Earthworms.

Tamas Gal *Mills E. Godwin High School*

The purpose of this project was to study the effect of soil quality in an urban environment on the viability of its bioindicators, earthworms. Stormwater runoff in Richmond, VA carries chemicals that can adversely affect soil quality and result in decline of worms, resulting in decline of plants and animals that depend on them, disrupting the ecosystem. The hypothesis was that soil from a location unaffected by urban storm water runoff allows greater viability of worms than soil from an urbanized environment. Soil from Pocahontas State Park was the control as it is not affected by urban development. Soil samples representing urban environments were from: Rattlesnake Creek (S) and Reedy Creek ®, which are areas of known storm water runoff, and the Wyndham Golf Course (G), where fertilizer is abundantly used. The worms placed in the soil samples were counted and weighed before and after the 6-week test period. Soil phosphate, nitrogen levels, pH, and moisture content were measured. Contrary to the hypothesis, the number of earthworms increased in S and R soils, but decreased in the control group, P. These changes were not statistically significant, calculated t-values were greater than -2.306 and less than 2.306 (df = 8). Earthworm mass decreased significantly in P compared to R (t = -6.102) and S (t = -2.5070). Soil with known stormwater runoff (with the highest nitrogen and phosphate levels) supported worm growth, however these results don't necessarily indicate good soil health, they might simply mean that worm mass and numbers are not good indicators of soil quality in a short observation period.

Does Our Bay and Surrounding Water Areas Produce Enough Wind Energy that Building Wind Turbines Would be Efficient in Our Area?

Clayton Garrett *Chesapeake Bay Governor's School*

As of 2021 the amount of carbon dioxide in the atmosphere has reached over 415 ppm and this is a huge issue as this is the number one cause of climate change and is making large impacts on Earth's environment. Renewable resources are the way of producing energy and is what will be needed to combat this rising Carbon Dioxide level. Within the Virginia coast, engineers and power companies are getting together to construct wind turbines off the shore of Virginia Beach. 6 buoys were picked to analyze the wind environment of the Chesapeake Bay and the Atlantic coast. An ANOVA was used to determine that there is a statistical difference between the Atlantic buoys and the Chesapeake Bay buoys with a value of p=.0467. The Atlantic coast exhibits more wind average speed than that of the Chesapeake Bay, while at the same time producing more wind efficient days than the Bay. This study is relevant in today's world as there is a huge push to go green and adopt renewable resources. Based on the data the Virginia power company can go ahead with the plan to build offshore wind turbines, as they will be subjected to enough effective wind to produce energy. This giant construction will help reduce the carbon footprint, and pave the way for more renewable resources.

Third Place

A Solution to Plastic Pollution: An Investigation into Microplastic Removal from Water Using Ferrofluid

Madison Goeke *Washington-Liberty High School*

Plastic pollution is one of the most prevalent environmental issues on Earth. Due to their small size, microplastics are able to circulate in oceans and harm marine life both physically and chemically. Currently, there is no feasible large-scale option to remove microplastics from water that is both economical and effective. Ferrofluid has proven effective at removing oil spills from open water and could be used as part of a solution to separate microplastics from water. In this experiment, ferrofluid was tested for its effectiveness at removing six types of plastic: polyethylene terephthalate (PET), high-density polyethylene (HDPE), polyvinyl chloride (PVC), low-density polyethylene (LDPE), polypropylene (PP), and polystyrene (PS). It was hypothesized that ferrofluid would remove at least 80% of microplastic from the water and that it would perform the same with respect to each type of plastic. 5 g/L of microplastics were suspended in twenty-milliliter samples of water. 0.5 g of magnetite and 0.5 mL of vegetable oil were added to each sample and mixed thoroughly. A neodymium magnet was then introduced to remove the oil, magnetite, and plastic. After microplastic removal, the water was analyzed with spectroscopy to determine plastic removal rates. Safety precautions were taken during the sanding and removal process to prevent injuries. The results found that ferrofluid successfully removed on average over 80% of all plastics. It was most effective at removing polyethylene terephthalate (PET) with a removal rate of 92.4% and least effective at removing polystyrene (PS) with a removal rate of 73.7%. This method of microplastic removal shows potential for industrial applications including open water and large-scale water treatment plants.

The Effect of Waxworms on Plastic Decomposition

Vaidehi Goyal *Mills E. Godwin High School*

This project explained the effect of waxworms on plastic decomposition. The research hypothesis was formulated that the waxworms would consume the LDPE (low-density polyethylene) the most, compared to the other two plastics, HDPE (high-density polyethylene), and polystyrene. Previous research has shown that waxworm larvae decompose plastics efficiently and quickly. There has been a growing pollution and contamination problem due to plastics not degrading for thousands of years, and these waxworm larvae showed promising results in consuming PE plastic and PS plastic in this experiment, and they could be a potential solution. Four waxworms were placed with each type of plastic and were given two weeks to consume it. The results of the experiment showed that the waxworms ate equal amounts of LDPE and HDPE, and although a smaller amount, the polystyrene was also consumed. All results for the experiment were significant, which means that there was a 95% chance that the results were due to the independent variables. It was deduced that the waxworms were able to consume the LDPE and HDPE due to having the gut bacteria, *Bacillus sp.* YP1 and *Enterobacter asburiae* YT1. The reason for the polystyrene is not known, but the notion was made that it may have been because the *Bacillus* gut bacterium of the waxworms and the *Exiguobacterium* gut bacterium of the mealworms, larvae who are known for consuming polystyrene, are in the same class and rank of bacteria. The results from this experiment were compared to another experiment conducted by the author of this paper, in which the effect of mealworms on plastic decomposition was studied. A permission form was signed by a parent that indicated that they had read and understood the risks and possible dangers involved in the research and they consented to their child participating in this research.

Honorable Mention

The Effect of Biodiversity on Water and Pollution Retention

Serena Grant *Mills E. Godwin High School*

The purpose of this experiment was to find if there was a significant difference between biodiverse and monoculture in the land mass's ability to retain water and the pollutants it carries. There are large expanses of monoculture land in the United States that have been tied to the decline in fauna diversity and soil deterioration, so the conversion of ecosystems for the purpose of golf courses, housing developments, etc. could affect runoff volume. Four 60x20x15 cm planters totaling in two levels of I.V., a biodiverse and monoculture sample, were watered on an incline of 45° once every 25 days for a total for 100 trials. A control group, no vegetation, was not used on account of the erosion contributing a significant amount of soil to the final runoff product, consequentially providing inaccurate results. It was hypothesized that if a piece of land had a monoculture plant population, then it would retain less runoff, and if a piece of land had a monoculture plant population, then it would retain less pollutants. The results revealed that there was not a significant difference between the pollution retention for the monoculture and biodiverse sample, but there was a significant difference between the runoff volume of the two levels of IV. Therefore, the runoff research hypothesis was supported, and the pollutant null hypothesis was supported. A different mock-pollutant and a larger population could improve further experimentation concerning the relationship between biodiversity and water retention. However, the proven difference between runoff volume could lead to further research involving other "degrees" of biodiversity (i.e. more plant species), larger plots of land, and more sophisticated means of measuring the collected water samples.

The Effect of Human Activity on Biodiversity in a Freshwater Marsh

Cassy Hixson *Chesapeake Bay Governor's School*

The rise of human activity on water sources has grown in the last few decades. In effect, there have been high levels of noise pollution in correlation to the activities. Noise pollution in aquatic environments have been known to cause harm and stress to organisms causing them to flee the area. This study conducted an experiment to review the relationship between human activity and biodiversity. The study consisted of three sites of differing levels of human activity: high, medium, and low. The biodiversity of macroinvertebrates and small fish was examined at each location. It was revealed that the high activity site, compared to the lower activity sites, had smaller values for indices of organism abundance and biodiversity.

First Place

The Effects of Naturally Occurring Acids on *Scenedesmus* sp. Population Growth

Sara Holt *Central Virginia Governor's School*

The purpose of this study was to find certain contributors of pollution and acidification in certain aquatic environments. Nine groups of algae, specifically *Scenedesmus* sp., were split into three groups of three: nothing, sulfuric acid, and nitric acid were added to each one of the three groups. All nine algae populations were put into 500 mL Erlenmeyer flasks, and then filled halfway up with spring water and halfway up with Alga-Gro. When the acids were added, the pH was lowered to around as close to 4.4 as possible. The pH values and absorbance levels were recorded from all nine populations once a week using a pH probe and colorimeter, respectively. After data collection, the data was analyzed through a one-way ANOVA and post hoc Tukey test to look for any significant differences. The ANOVA showed a significant difference among the groups by providing information like how the p-value was 8.78x10-6, much lower than the fixed alpha value of .05. The Tukey test showed between which groups the significant changes had taken place. The research hypothesis stated that if sulfuric acid and nitric acid were added to the populations, then the algae would increase their cellular functions, fluoresce more, and grow more efficiently. This was only partially supported. This study showed promise for expansion on the topics broached and could certainly allow for future research to be done in order to explore more possibilities about what could be done to better understand algae health in response to deterring factors.

Second Place

Eastern Skunk Cabbages: A Natural and Sustainable Solution for Combating Bank Erosion

Chelsea Hu *BASIS Independent McLean*

Due to increased urbanization and climate change, there has been an increase in bank erosion and the destruction of riparian zones. Riparian zones are vegetative areas of land bordering streams that are vital to keeping tributary water systems clean and well-managed. This research assessed the implementation of *Symplocarpus foetidus* (Eastern Skunk Cabbages), a local obligate wetland indicator in the Chesapeake watershed, as a potential sustainable solution for bank erosion in North America. Penetrometer tests were performed to examine whether the contractile Skunk Cabbage roots increased the strength of the surrounding soil. It was found that soil with Eastern Skunk Cabbages exhibited a significantly higher compactness compared to soil without them. Additionally, to assess the effect of Eastern Skunk Cabbages on strengthening banks against erosion, a controlled experiment was performed using two stream models made from the halves of a 20 ft. drainage pipe. One of the stream models had Eastern Skunk Cabbages planted in; the other, acting as a control, contained just soil. The models were placed into streams and a large decanter (31.5 x 31.5 x 8 inch) was attached at the end of the pipe to collect any eroded sediment that may have been the result of the stream water eroding the model. It was observed that the bank model with Eastern Skunk Cabbages collected less soil on average compared to the control model meaning that Eastern Skunk Cabbages helped to mitigate erosion. Finally, it was determined that the Eastern Skunk Cabbages had no adverse effects on water quality. It was concluded that the unique properties of Eastern Skunk Cabbages could help mitigate bank erosion and act as a riparian zone plant without any negative side effects. Future research should focus on implementing and comparing Eastern Skunk Cabbages with existing methods (coir logs, ripraps, Vetiver grass, etc.) as this would provide hope for an entirely new generation of bank erosion prevention that incorporates local vegetation.

The Effect of Organic Compost Tea vs. Chemical Fertilizer on Growth and Fruit Production of Tomatoes

Abigail Hudgins *Chesapeake Bay Governor's School*

Nutrient pollution has a huge impact on the water quality and overall health of the Chesapeake Bay. The primary sources of nutrient rich agricultural runoff and contamination of the Bay are from chemical fertilizers and livestock waste. In recent years, agricultural researchers have tried to solve the problem of agricultural nutrient runoff by replacing the synthetic chemical fertilizers with organic manure-based compost tea. To address the issue, this study seeks to determine the effectiveness of a manure based, organic compost tea fertilizer as an alternative to a common synthetic chemical fertilizer for the growth of tomatoes, an important commercial crop for Virginia. In the late spring 2020, 12 tomato plants of the same origin were planted in 4 treatment groups: Control (C), Low Concentration (LCT) Compost Tea, High Concentration Compost Tea (HCT), and Miracle Gro Chemical fertilizer (MG). Each group was administered a nutrient treatment and their vertical growth and production of fruit were recorded every 2 weeks. The results showed that compost tea treatment groups outperformed the chemical fertilizer treatment group, but not a statistically significant difference. Using Compost Tea as fertilizer minimizes manure entering the Bay and converts the nutrient pollution source into a sustainable organic fertilizer that also has been shown to reduce insect infestations, contribute to soil health, yields a large quantity of produce, and most importantly reverses eutrophication of the Chesapeake Bay. From this study, it can be concluded that compost tea is a sustainable organic fertilizer that could be used in place of synthetic chemical fertilizers permanently, while still meeting crop quotas and adding health benefits to the soil.

The Effect of Conditional Processing on Atlantic Hurricane Prediction Accuracy

Ojas Joshi *Mills E. Godwin High School*

Multiple factors determine whether a simple thunderstorm will dissipate in hours or wind up escalating to a Category 5 hurricane. Whenever a hurricane is formed, it always comes from a preexisting storm; however, it is challenging to predict if a storm has the potential to become a hurricane. In this paper, an experiment is described which involves creating a prediction model that determines whether a storm will turn into a hurricane, along with the category it would be at its peak. For this model, the environmental conditions of one-day air pressure change, water temperature, and maximum wind downdraft were used. For evaluating the performance of the model, 40 individual hurricanes were studied, and their attributes were extracted from satellite databases to create custom thresholds for a multivariable model. This multivariable model showed 96% accuracy, which was significantly higher than the other independent variables, including the control of one-day air pressure change.

Additionally, all safety precautions were taken for the entire duration of the project. Over the course of the research and conducting the experiment, multiple interesting pieces of information and patterns were uncovered. It was established that hurricanes are the earth's natural method of releasing heat, and as such, heat is their driving force. In addition, hurricanes normally form in the tropics, and as the results support, determining hurricane probability by temperature alone provides the highest accuracy when compared to the downdraft and air pressure variables. Additionally, it was also discovered through a logistic regression model that there was a correlation between the environmental conditions, air pressure, and economic loss. The lower the air pressure within each category of hurricane, the higher the damage cost. In summary, the multivariable algorithm accurately modeled the real-world scenarios.

Environmental & Earth Science C (HS ENV-C)

The Effect of Different Locations on Background Radiation

Ishan Joshi *Mills E. Godwin High School*

The purpose of this experiment is to find out if there is harmful radiation that could be affecting us. The experiment is important because it is providing information on the amount of radiation harm based on where someone lives. This project tested the effects of different locations on radiation in the background. There are five different levels: outside, garage, computer, first floor, and second floor. A research hypothesis was proposed that, if the locations of a cloud chamber differ, then the computer will pick up the most background radiation. A clear plastic box with black felt super glued onto the bottom part of the box, was placed on a baking pan upside down with its lid. The felt was soaked with room-temperature isopropyl alcohol and the excess was drained on the lid of the box. Finally, dry ice was placed under the lid of the box and on the baking pan. Safety precautions were taken in this experiment.

The cloud chamber showed the particles of radiation because of the room temperature isopropyl alcohol's molecular formula, reacting with the cold temperature at the bottom creating displacement. The observations were recorded using a Geiger counter which measured the radiation in the localized area. The data was shown to be significant, according to the t-tests, and the outside level had the highest cpm (counts per minutes) mean. This means that the null hypothesis was rejected but that that the research hypothesis was also not accepted since the computer level did not have the highest cpm.

The Effect of Population Density on Soil Quality

Erin Leland *Washington-Liberty High School*

The purpose of this study was to test the effect of the population density of humans in an area on the overall soil quality of the area, measured by NPK, soil salinity, and pH. The independent variable was people per square mile (1103/km^2, 88/km^2, and 9/km^2). There was no control as there is no standard for the “normal or unaffected” amount of people in an area. The constants were time soil samples were taken, amount of soil, number of samples, conditions of soil testing, testing equipment used, and testing location. The dependent variable was soil quality in NPK, salinity, and pH. The hypothesis was: If soil samples from three different areas are taken then the soil quality of the samples from more populated areas will have more negative results than samples taken from less populated areas. This study was important because it potentially helped measure the impact of human presence and pollution on the ability of soil to be viable for life, helping researchers understand what degree of impact that human pollution has on soils. This study was performed by taking samples from three separate counties and testing their soil for salinity, pH, nitrates, potassium, and phosphorus. From each county ten soil samples were collected and the average results for each parameter were recorded. The data showed that while in salinity and pH the lower population density had a significant effect, in the other three there was no significant impact of the population density. The results rejected the null hypothesis, suggesting that the population density of humans has a negative effect on the pH and salinity of soil. Studies that could be done to expand this data might examine the soil quality between geologic regions of the state or a study of the effects of farming methods on the soil quality or yield of a farms soil.

The Effect of Different Nutrients on Plant Growth

Maya Kent *Washington-Liberty High School*

The reason this experiment was conducted was to test the effect of different nutrients on the growth of radish plants. Previous experiments have shown that Nitrogen, Phosphorus, and Potassium are nutrients that have great effect on height and development of plants. Data was taken for this experiment over 20 days, measuring 96 pods (24 pods per experimental group). The research hypothesis stated that if radish seeds are exposed to different nutrients: Nitrogen, Phosphorus, and Potassium, then the seeds exposed to Nitrogen will grow the tallest because Nitrogen helps the leaves on the plants grow which will have an impact on the height. Based on the results of this experiment, the control group (experimental group 1) contained the plants with the tallest measurements. The kelp/Potassium group (experimental group 4) contained the plants with the 2nd tallest measurements. Both the blood/Nitrogen group (experimental group 2) and the bone/Phosphorus group (experimental group 3) had no growth over 20 days, possibly due to multiple factors. Both an ANOVA and t-test were performed. Because the p-values for both tests were less than 0.05, there was a statistical difference between the experimental groups. The null hypothesis stated “If radish seeds are exposed to different nutrients: nitrogen, phosphorus, and potassium, there will be no difference in their growth.” The null hypothesis was accepted because the control grew at a faster rate compared to the tests with added nutrients. The research hypothesis was rejected because the test with the Nitrogen showed no sign of growth.

Third Place

The Effect of Plastic on the Growth of *Raphanus sativus*

Ella Lewis *Central Virginia Governor's School*

The purpose of this study was to assess the effects of plastic beads on the growth of *Raphanus sativus.* Radishes were grown for thirty days with various concentrations of plastic (no plastic as a control, .5%, 1%, and 2% of soil volume). The plastic beads were mixed into the soil of forty pots (ten in each group) and seeds were planted. As the plants grew, their heights were measured weekly in millimeters using a ruler on November 8, 15, 22, 29, and a final height measurement was taken on December 9. This data was averaged and then analyzed using a one-way ANOVA test and post hoc Tukey test via Microsoft Excel to find statistical significance between the groups. The results showed an F-Statistic (14.467) more extreme than the F-Critical of 2.866, and P-value of 1.418x10-06 lower than the alpha of .05. The initial research hypothesis that .5% would grow tallest, no plastic, 1%, then 2% was not supported. Instead, the control grew the most, followed by .5%, 1%, and 2% grew significantly less. This data can be applied on a larger scale as a model for agricultural crops harvested for food. The hope is that this information will bring awareness to people about the harm growing rates of plastic waste will cause to the terrestrial environment and push them to dispose of plastic more thoughtfully.

Honorable Mention

The Effect of Microplastics in the Form of Glitter on Freshwater Chlorella Algae Growth and pH Levels

Eujine Kim *Central Virginia Governor's School*

The purpose of this study was to observe the effects of microplastics, as represented by glitter concentrations on pH and growth of freshwater algae. There were three glitter testing concentration categories: 0% (zero milliliters), .5% (1.25 mL), 2% (five mL). A pH probe was used to measure pH, and a colorimeter measured algae density in mg/L. The average pH of the 0% group was 7.583; the average of the .5% group was 7.673; the average of the 2% group was 7.706. One-way ANOVA tests (alpha = .05) were used to assess pH and density values. The p-value of .601 for the pH levels ANOVA analysis was not significant. The average algae density of the 0% group was .192 mg/L; the average of the .5% group was .095 mg/L; the average of the 2% group was .046 mg/L. The one-way ANOVA for algae density gave a significant p-value of 2.607 x 10-8. A two-way ANOVA resulted in a p-value of .101 and showed there was no significant interaction between the two variables. The research hypothesis was partially supported; an increase in glitter did lead to a decrease in algae growth. However, there was no interaction between pH and algae density, and the pH was not affected by the glitter concentrations. In summary, pH levels and algae density do not affect one another, and glitter concentrations do not impact pH levels; however, glitter concentrations can affect the amount of algae growth. This suggests that microplastic pollution has an effect on the growth and health of freshwater ecosystems.

The Effect of Different Oil Spill Cleanup Methods on the Survival Rate of Brine Shrimp

Rohan Kurup *Mills E. Godwin High School*

The purpose of this experiment was to find the effect of different oil spill cleanup methods on the survival rate of brine shrimp. Every year, tons of oil are leaked into oceans and other bodies of water. These spills have devastating effects that range in severity from simply polluting the water in the ecosystem to hurting marine life and humans in the surrounding area. Not only do these effects have biological impacts, but they also have huge economic consequences as cleaning up these spills require billions of dollars as well as thousands of workers. In this experiment, brine shrimp in oil polluted waters were treated with absorbents, polymers, and microbes to determine the most effective cleanup agent. The control in the experiment was simulated crude oil. All possible safety measures and precautions were taken during the experiment. The amount of living brine shrimp was measured every 12 hours for five days and the average percentage alive was measured. It was hypothesized that if the oil absorbent sheet was used, it would have the highest brine shrimp survival rate. The results revealed that on average, the brine shrimp treated with the oil absorbent sheet had the highest survival rate of 88% while the hydrocarbon encapsulating polymer and oil degrading microbes had similar rates with each other, but less that the oil absorbent sheet. As a result, the data did strongly support the research hypothesis. A t-test was conducted on the data, and it was revealed that every test was statistically significant. It is perceived that the results had this outcome because the oil absorbent sheet had oleophilic and hydrophobic properties, the oil degrading microbes went through aerobic respiration, and the hydrocarbon encapsulating polymer was specifically formulated to bond to the oil's hydrocarbons to form a solid substance. Lastly, further studies could investigate the effects of different oil spill cleanup methods on oil spills in varying types of water.

A Machine Learning Approach to Wildfire Spread Prediction and Risk Assessment

Ethan Ky & Santiago Campos-Merida *Governor's School@Innovation Park*

Wildfires have become increasingly dangerous among natural disasters worldwide. In the US alone, 58.3 thousand wildfires burned over 10.27 million acres in 2020. According to the National Park Service, 85 percent of wildfires are caused by humans. Due to many conditioning factors, wildfires are considerably very difficult to predict and detect. These factors include biomass, surface temperature, topography, wind, precipitation, and soil moisture. The project aims to aid first responders in predicting wildfire spread through machine learning and remote sensing. To do so, three questions are considered: the most effective algorithm for spread prediction, the most significant environmental factors, and the accuracy of a deep neural network driven smoke classification model. MODIS images are most heavily utilized, including NDVI, LST, and Thermal Anomalies. Also utilized are IMERG, SMAP, SRTM, and MERRA-2 images to encompass the remaining variables. ML.NET Model Builder was used to train three regression algorithms with preprocessed data provided by Cadi Ayyad University. Azure Machine Learning Studio will be used to train the SVM and ANN models with a 4-fold cross validation method. Fast Forest obtained the highest r 2 value of 0.118 as well as the highest mean absolute error of 0.39. A micro accuracy and macro accuracy of 0.8889 and 0.75 were received when training a DNN with ResNet-50. Raster images of NDVI and LST were also visualized with digital elevation models built through QGIS to visualize 3D fire spread on natural terrain.

The Effect of the pH of Simulated Acid Rain on Radish Seed Germination

Ava Lansbury *Washington-Liberty High School*

The purpose of this experiment was to study the effect of the pH of simulated acid rain on radish seeds. The hypothesis was if radish seeds are germinated in a simulated acid rain solution with a more acidic pH, then there will be a negative effect on germination because the acidity will prevent the seeds from germinating properly. The four levels of the independent variable were simulated normal rain with a pH of 5.6 (control) and simulated acid rain solutions with pH values of 5.0, 4.0, and 3.0. The simulated rain solutions were put into Petri dishes each containing 10 radish seeds and monitored for germination. The control group had the highest mean number of seeds germinated in a 10-day period at 9.8 seeds, while the group with the lowest mean was pH of 3.0 with 0.6 seeds. The pH of 5.0 and pH of 4.0 groups were in the middle with means of 2.8 and 1.4 respectively. Six t-tests and an ANOVA test were calculated to determine the significance of the data. The p-values of four of the six t-tests and the ANOVA test were less than 0.05, meaning this data was significant. Because of these calculations, the null hypothesis was rejected, and the hypothesis was accepted. It was concluded that this was likely due to the simulated acid rain stunting or slowing the germination process. This study demonstrated that acid rain harmfully impacts the productivity of radish seeds in germination and is a serious concern for agriculture.

Honorable Mention

Effect of Drift of the Herbicide Dicamba on the Health of SAV in the Estuarine Environment

Madelyn Junker *Chesapeake Bay Governor's School*

The Chesapeake Bay is highly susceptible to agricultural pollution containing excess nutrients, chemicals, and sediments that find their way into the watershed. Herbicide drift occurs as a result of aerial application of herbicides which causes the herbicide particles to be captured in the air and dispersed across the landscape. The purpose of this study is to determine the effect of aerial drift and stormwater runoff of the herbicide Dicamba on the health of SAV plants through experimental comparison in a simulated aquatic system. Varying concentrations of Dicamba, from the brand Ortho Weed B Gon Plus Crabgrass Control Concentrate, were prepared in three experimental groups: a control (no added Dicamba), a low Dicamba concentration, and a high Dicamba concentration, each represented in an 8 L experimental pond treatment. Throughout the experiment, several parameters of SAV growth were measured: wet weight, shoot length, and water pH. A t-test between the SAV growth in the runoff control and the high concentration treatment yielded a two-tailed $p = 0.012$, while a t-test between the SAV growth in the drift control and the high concentration treatment yielded a two-tailed $p = 0.18$. The results demonstrate that the influx of Dicamba into aquatic SAV environments, through both stormwater runoff and aerial herbicide drift, has direct implications on SAV growth and health. The close proximity of intense crop agriculture to the Chesapeake Bay submerged aquatic grass habitat causes SAV to be highly susceptible to agricultural herbicides, as has been shown with agricultural nutrient runoff in anthropogenic eutrophication.

The Effect of Different Filtration Methods on the Consistency and Reduction of Water TDS

Fahad Khan *Mills E. Godwin High School*

The purpose of this experiment was to find out which common method of water filtration was the most efficient in terms of TDS. TDS is a measurement of the concentration of dissolved substances in a sample. Due to the prominence of this subject in society, it was thought this research would have some significance on the way different methods of filtration are utilized. It was hypothesized that if water is put through the process of distillation, then the mean TDS and standard deviation of the data would be the lowest. This is because it is a physical change through natural forces, leaving little room for error. Although distillation is known to leave a very low TDS levels, the consistency of the process is not known. In this experiment, tap water was put through two different filtration processes, distillation, and reverse osmosis; these were the two levels of IV. Tap water without having gone through filtration was the control in this experiment. Safety measures (adult supervision and mittens) were used when performing distillation with the stove. Roughly 6 oz of water were gathered of each method and were tested using a purchased TDS meter. This was done 25 times for each level. Tap water had a mean TDS of 90 ppm, distilled water had 5 ppm, and the reverse osmosis membrane had a mean of 49 ppm. Distilled water had the lowest mean TDS. In terms of consistency, tap water had the lowest standard deviation, at 3.346, compared to distillation (3.583) and the RO membrane (15.019). Tap water vs distilled water ($t = 86.693$), tap water vs RO membrane ($t = 13.323$), and distilled water vs RO membrane ($t = 14.248$) were all significant. The null hypothesis was rejected. In conclusion, distilled water provided the purest water in terms of substances in the sample, but the tap water showed the most consistency in the results.

First Place

Analysis of Microbial Diversity in PCB-Contaminated Environments

Eleanor Little *Roanoke Valley Governor's School*

Polychlorinated biphenyl (PCB) pollution is a global issue affecting both the environment and human health. Although industrial PCB manufacturing has been banned, PCBs remain in water, soil, and adipose tissue, resisting degradation as persistent organic pollutants. Humans can experience various harmful health effects from PCB exposure, particularly through the ingestion of affected fish. This study sought to investigate the impact of PCB-impaired waterbodies on surrounding riparian environments through analysis of microbial community diversity in sediment samples. It was hypothesized that PCB-impaired samples would demonstrate lower functional microbial diversity levels than an unimpaired sample. Sediment samples were collected from three PCB-impaired stream sites and one unimpaired site. Sample dilutions were prepared and used to inoculate Biolog Eco Plates, 96-well microplates containing 31 carbon compounds and a control in triplicate. A microbially-diverse sample can metabolize a greater number of compounds. Metabolization causes a redox dye to change color within the utilized wells. Optical density (OD) values were measured with a microplate reader after 46 hrs. Average well color development (AWCD), richness, Shannon evenness index, and Shannon diversity index were calculated from the ODs of each sample. The unimpaired sample demonstrated a significantly higher AWCD (t-Test, p-value=1.43E-30), richness (t-Test, p-value=7.95E-6), Shannon evenness (t-Test, p-value= 4.91E-8), and Shannon diversity (t-Test, p-value=1.24E-15) than the impaired samples demonstrated. There is less functional microbial diversity in these PCB-impaired locations, which may serve as a bioindicator of poor environmental health. Further research could use gas chromatography to test earthworm and fish tissue for PCB bioaccumulation up the food chain.

Second Place

The Effect of Different Bio-compatible Coagulants on Microplastic Extraction from Water

Aryan Mhaskar *Mills E. Godwin High School*

Microplastics are a common pollutant in water and have shown to pose several threats to human health. Many impoverished regions cannot afford the necessary water purification methods to remove microplastics from water, and bio-compatible coagulants are a potential solution to this issue. Bio-compatible coagulants are cheap, non-toxic, and biodegradable. The purpose of the study was to determine which prominent bio-compatible coagulant was the most effective as a means of water purification in areas with limited access to clean water. It was hypothesized that if a blend of 50% *Moringa oleifera* and 50% *Opuntia* spp. Was treated to water, the most microplastics will be extracted.

To measure the effectiveness of different bio-compatible coagulants, microplastic and water mixtures were treated with four different bio-compatible coagulants: no coagulant (control), *Moringa oleifera* seed extract, ground *Opuntia* spp. Pad, and a 50% blend of the two previous coagulants. The mixture was then filtered through a sieve and the amount of microplastics extracted was measured on a scale. It was found that the blend performed best at extracting microplastics from water, followed by *Moringa oleifera* seed extract, ground *Opuntia* spp. Pad, and then no coagulant. An apron and gloves were worn for safety and the experiment was done in a controlled environment. All equipment was washed through a fine cheesecloth to ensure all 0.1 mm plastic beads were caught and not disposed. The differences between the means of each group were statistically significant at a 0.001 level of significance. The effectiveness of the blend is likely due to the multi-stage coagulation process that results in larger final particle size, which can be more easily filtered through a sieve. A potential further study could include how the blend compares to traditional coagulants used in industrial settings.

Honorable Mention

The Effect of Materials in Compost-on-Compost Temperature

Lillian Moo *Washington-Liberty High School*

The purpose of the experiment was to discover whether the materials used in a compost bin would affect the temperature (and therefore effectivity) of the compost. The results could help people running compost within their homes or even industrial compost in order to make the process more effective. The hypothesis was that if four compost bins are set up with different ratios of nitrogenous to carbonous materials, the ones with higher ratios of carbon to nitrogen will be most effective, though too much carbon will cause the temperature to go down. The experiment was run by filling four compost bins with different ratios of nitrogenous to carbonous materials. The temperature of each compost bin was then measured every three days over a period of thirty days.

The results found that the four compost bins had respective mean temperatures of 55.90ºC, 54.40ºC, 55.00ºC, and 53.60ºC. An ANOVA test was conducted on the results, relating a p-value of 0.982, indicating with 99% accuracy that there was no statistical difference between the four experimental groups.

Due to these results, the null hypothesis for the experiment was accepted. This meant that the materials used in compost had no effect on the temperature or effectivity of the compost itself. This differs from other researchers' findings, which could be explained by multiple sources of error within the experiment. However, the study still relates important information on the effect of materials used (nitrogen versus carbon) on the effectiveness of the composting process.

Effect of Glycerol on the Reproduction Rate of *Daphnia magna*

Lauren Noel *Central Virginia Governor's School*

The purpose of this study was to determine the effects of glycerol on aquatic environments. For this experiment, daphnia were placed in groups exposed to water, and two concentrations of glycerol (10% and 20%). The number of live daphnia in each group over 12 days was then recorded. The results of this experiment suggest that glycerol has an effect on the number of surviving daphnia, but not on their reproduction rate. Between the birth and death rates, there were very few differences in both the means and standard deviations. Three different one-way ANOVA inferential tests were used to determine the significance of the results. An alpha value of .05 was used to compare to the p-values of 6.19x10-7, .75, and .29. The p-value from the number of surviving daphnia per group was much lower than the alpha value. A post-hoc Tukey test revealed significant differences in the number of daphnia per group between 20% glycerol and the control, and 10% glycerol and the control. The research hypothesis stated that, If *Daphnia magna* are exposed to 0%, 10%, and 20% glycerol solution, then the group not exposed to glycerol will reproduce the most. This hypothesis was not supported in the sense that glycerol did not affect the reproduction rate in daphnia. Glycerol did, however, affect the number of surviving daphnia in each group, impacting their life spans. These results suggest that glycerol might have an effect on aquatic ecosystems.

Sequencing Analysis of Micobial Abundance and Diversity of Different Shorelines in the Lower Chesapeake Bay

Kathryn Parnell *Chesapeake Bay Governor's School*

Research has shown that living shorelines are more resilient to climate change than constructed bulkheads, specifically with respect to coastal erosion and performing ecological services. Moreover, the total bacterial community composition associated with these shoreline types has not been described. The purpose of this study is to measure and compare microbial diversity in the Chesapeake Bay between contrasting shorelines types: man-made living shorelines, constructed bulkheads and natural areas to serve as a control. A microbiome study was conducted to determine the phylogeny of all bacteria found within samples Next generation sequencing identified the total bacterial community, using the 16S rRNA housekeeping gene present in all bacteria. The DNA from each sample was also processed using the Illumina iSeq next generation sequencer which provides analysis of the types and relative quantities of bacteria found in the microbial community of the sample to assess the total microbial diversity. Total bacterial abundance was high at all locations sampled and there was greater bacterial abundance in the sediment samples than the water samples. There was a trend of higher bacterial concentrations at natural shoreline sites for Total Bacteria, Antibiotic Resistant Bacteria and *E.coli* versus manmade living shorelines or bulkheads for both water and sediment. The species richness was much greater for water than sediment samples, Water $\bar{x} = 28.9$ and Sediment $\bar{x} = 6.9$. Microbial analyses of coastal shoreline environments should be included in research before and after living shorelines are implemented, this knowledge of microbial biomes helps us understand human impacts on shoreline environments.

Effect of Soil Acidity on Rate of Decomposition of Paper

Ellie Potts *Washington-Liberty High School*

This experiment observed the effect of soil acidity on the time it takes to decompose paper. The hypothesis was; If paper is tested for composability at different soil pH's, then the soil that is the most acidic will break it down the fastest because of the higher abundance of micronutrients and soluble minerals that will interact with the processes that effect the breakdown of paper causing it to disintegrate fastest. Soil with lower PH values is more acidic and a neutral soil would be a soil with a pH of 7. In this experiment, soil with 4 different acidities were tested to see which one decomposed paper the fastest. The levels were pH 7 (control), pH 6.7, pH 6.2 and pH 5.8. The size of the paper was measured for each group and after 10 days, the group that decomposed the paper the most was the soil with pH of 5.8. This group had an average of 5.8 cm, followed by pH 6.7 with 5.9 cm, then tied with pH 6.2 and 7 at an average of 6.1 cm. T tests were also run comparing each group and those displayed that all but 2 comparisons were significant with a p value less than 0.05. In the end, the hypothesis was proven correct because soil pH of 5.8 had the highest decomposition rates, however it did not follow the trend of more acidity means faster decomposition, but the soil with the most acidifier did have the largest effect, so in that regard the hypothesis was proven correct.

Environmental & Earth Science D (HS ENV-D)

The Effect of Soil Location on pH

Siddhant Prakash *Mills E. Godwin High School*

The purpose of this study was to investigate how the location from which soil was sampled would affect its pH. Soil is a nonrenewable resource which humans are dependent upon for all agricultural products, primarily for nutritional purposes; however, about a third of it is degraded. The FAO projected that by 2013 the global population will reach 8.5 billion and global food-production must increase by 60% in order to support this. Soil acidity is a measure of fertility and is affected primarily by free ions. Urbanization has been correlated with both soil acidification and alkalinization in the past; however, there is evidence that due to chemical runoff and acid rain, urban soils are likely to be more acidic than rural soils. For this reason, the research hypothesis that if the pH of soil from urban, suburban, and rural sites was tested, the pH of the urban site will be relatively the most acidic, and the pH of the rural site will be the most alkalescent. There was no control level because there wasn't a standard anthropological population level where soil is collected from. All soluble chemicals within the soils were dissolved in water, and the resulting solutions were tested with a pH probe. The means of the urban, suburban, and rural soils were 5.0, 6.8, and 8.1 pH's respectively. Student's t-tests were conducted and showed statistically significant differences between the levels ($p < 0.05$). These results were consistent with other studies also correlating urbanization and acidification.

Catch of the Century!

Lauren Rahn *Chesapeake Bay Governor's School*

Brevoortia tyrannus, or Atlantic Menhaden, is a key factor in the health of the Chesapeake Bay. By having such a low stance on the food chain, menhaden find themselves subject to prey quite often. Not only do menhaden find themselves as energy for predators, but they are also the key to success for local fisheries, the main being Omega Protein. Founded in 1913, Omega Protein is one of the largest and most successful fisheries in Virginia and across the United States. With locations in Virginia, Louisiana, and Texas, the number of fish caught per year can only be imagined. The purpose of this study was to find if there is a difference in the abundance of menhaden fish caught through Omega Protein in varying locations over the past 10 years. Two locations were used, including the fleet in Reedville, Virginia that fished out of the Chesapeake Bay, and the fleet in Abbeville, Louisiana, which fishes out of the Gulf of Mexico. Not only is the location changing throughout this study, yet the type of menhaden as well. *Brevoortia patronus*, or Gulf Menhaden, find themselves to have very similar features to those found in the Bay. They are a pelagic, schooling fish that also finds itself subject to prey. To begin this study, data was collected through a forecast sheet gifted by members of NOAA, where three different areas of study were analyzed. The factors compared included the catch size, catch effort, and average age caught between the two differing locations. Following the collection of data for catch size, a standard T-Test was calculated where a very significant P-value of 7.43x10 -09 was found. For catch effort, the same statistics were applied to receive another significant P-value of 0.001. For average age, only one-year information was applicable, meaning statistics were unable to run. However, conclusions were able to be made for all factors, meaning this study proved there to be a difference in abundance between varying locations.

The Study of Microplastic Concentrations of Soil and Water from Northern Virginia's Freshwater Bodies and their Effect on the Growth of *Persicaria punctata*

Pearl Raichura, Vinay Bhakthan & Mehreen Rahman
Governor's School@Innovation Park

The increasingly high presence of microplastics in soil and water has been noted to affect photosynthetic species. However, the direct quantification of plastics in freshwater and an analysis of their effects on dependent species has yet to be accomplished. This study defines the amount of microplastics in three freshwater bodies: Leopold's Preserve, Occoquan River, and Silver lake. The methodology used to quantify freshwater plastics utilized a fine mesh sieve and filter paper. This was done to isolate particles that were in between 200um and 20um. For the soil samples, the method used to quantify microplastics utilized the hydrophobic properties of oil and plastics to separate them. This was done by vigorously mixing oil, soil, and tap water to define an oil layer that contained the microplastics. The microplastic concentration was determined by filtering the extracted oil layer and examining them visually. Upon finishing sample testing, the Occoquan River had the greatest amount of microplastics in its water and soil, with an average of 24.67 microplastics per 30 milliliters of water and 61 microplastics per 50 mL of soil. Initial data of *Persicaria punctata* growth showed that Leopold's Preserve had the greatest number of sprouts with 5 sprouts and the Occoquan River had the least with 0. *P. punctata*, and many other emergent species, have key roles in the ecosystem as they provide food for animals and conduct photosynthesis. As such the data presented in this study requires further action to eradicate the presence of plastics in freshwater bodies.

The Effect of Concentrations of Herb Mixtures on Memory Retention in *Dugesia tigrina*

Arvind Rajesh *Mills E. Godwin High School*

The main purpose for conducting this experiment is to better understand the effects of herbicide mixtures that contain distinctive intrinsic pharmacological properties that restore the balance between thromboxane A2 and prostacyclin which contribute to improved vasoregulation in those who ingest it. The herbs used in the experiment were ginkgo biloba, ginseng, and hawthorn. Understanding to what extent memory retention is influenced by herbicidal mixtures that contain important chemical properties in planarians will serve as a great model in comparison to other organisms such as humans. The hypothesis prior to experimentation was that if various concentrations of an herbicidal mixture is fed to planarians, then the mixture with 5% concentration will have the greatest improvement in memory retention. The investigation was conducted with five groups based on the concentrations of the herb mixture the planarians were fed: 0% (control), 5%, 15%, 25%, and 35%. The planarians from each group were subjected to a Y maze spontaneous alternation test leading to raw egg yolk. Results were recorded on a computer application and the unit of measure was recorded in seconds spent until the planarians were able to reach the end of the maze. The results from the experiment revealed that the group subjected to 5% concentration outperformed every other group. The 5% concentration group had an average completion time of 636.76 seconds. The other groups, 0%, 5%, 15%, 25%, and 35% had an average completion time of 672.4, 658.92, 664.8, and 640.6 seconds respectively. A t-test was used to determine the statistical significance of the data. The research hypothesis was determined to be not supported by the data. A plausible explanation from a previous study was that organisms without much damage to vasoregulation, similar to cases found in planarians, may have varying results which could have been a possibility with *Dugesia tigrina.*

Honorable Mention

The Effect of Various Colloidal Metals on Nymphaeaceae Phytoextraction Performance

Snehitha Ravilla *Mills E. Godwin High School*

The purpose of this study was to evaluate if the toxicity of various heavy metals affects the phytoextraction abilities of Nymphaeaceae (waterlilies). Heavy metal soil contamination has become a critical environmental concern that requires the use of an inexpensive remediation strategy, such as phytoextraction. Phytoextraction is a specific phase of phytoremediation in which plants are used for the removal of heavy metal from contaminated water and soil. A research hypothesis was formulated that if the effect of various colloidal metals on Nymphaeaceae phytoextraction capabilities is tested then the Nymphaeaceae will decrease the concentration of the colloidal chromium-vanadium solution the most significantly. Safety goggles and gloves were sported throughout the experimentation process. Water lilies were exposed to 4 different levels of the independent variable: no colloidal metal, colloidal silver, colloidal copper, and colloidal chromium-vanadium. The water lilies that did not receive heavy metal treated water solution acted as the control of the experiment. Each water lily sapling was allocated a cup with 100 mL of 28 C water (~180 ppm) and 5mL of a colloidal metal. After a period of six hours, the change in the water's concentration (ppm) was measured. The ppm prior to and directly after experimentation were analyzed against one another. In order to evaluate for statistical significance, a t-test was performed on the data. The results for the colloidal metals having an effect of Nymphaeaceae phytoextraction performance is statistically significant. Copper is the denser metal of the experimental group; therefore it was the most difficult for the water lilies to extract. For a continued study, this experiment should be expanded to greater concentrations of metals.

The Effect of Limonene from Different Extracts of Citrus Fruits on the dissolving Styrofoam

Rithvik Rayala *Mills E. Godwin High School*

The purpose of this experiment was to find the Limonene extracted from which fruit would result in the highest mass lost from Styrofoam. In recent years the amount of trash and pollution on Earth is at a crisis level. Many methods have been used to reduce the amount of trash with this being one of them. D-Limonene an oil that can be extracted from citrus fruits has a property to break the hydrocarbons in polystyrene and dissolve it. The first step to extract the D-Limonene from the citrus fruits was to dry the peels of the fruits in the sunlight for three days. Then the peels of the fruit would be crushed in the blender. Afterword the powder would be mixed with 100ml of vodka and sealed into a jar. The jar was placed into a fridge for two weeks. After the two weeks were completed, the oil was extracted from the jar using a filter. After word the oil would be mixed with 2g of Styrofoam and sealed in a zip log bag. After a week the Styrofoam would be measured. It was hypothesized that if Limonene was extracted from the peels of an orange, then it would result in the most mass lost from the Styrofoam. The results revealed that the D-Limonene extracted from oranges resulted in the most mass lost. A t-test was done on the data, and it revealed that all the data was significant. The results supported the research hypothesis. It is believed that the results are cause by the fact D-Limonene is found in the highest concentration within oranges. This research could lead to further studies that investigate more effective ways in extracting limonene from oranges. Errors in experiment maybe include the fact that the Styrofoam shapes were uneven, and that the D-Limonene might not have spread evenly among the Styrofoam.

Third Place

The Effect of Rising Water Temperature on the Respiration Rate of Mummichogs, *Fundulus heteroclitus*

Taylor Rice *Chesapeake Bay Governor's School*

Studies have been conducted to show that warming water temperatures and depletion of oxygen in the ocean will shrink hundreds of fish species. However, the ocean is saving us from massive warming right now (Free et. al., 2019). Increasing water temperatures were found for more than ninety-two percent of the Chesapeake Bay (Ding & Elmore, 2017). When water temperatures exceeded twenty degrees Celsius (20°C), minimum oxygen concentrations were less than fifty percent of saturation concentrations (Kuo & Neilson, 1987). With the mummichog, *Fundulus heteroclitus*, being an abundant, permanent residence of the Chesapeake Bay, they can tolerate widely varying conditions environmental conditions like larger changes in water temperature, salinity, and pH levels, compared to most other marine species (Weis, 2010). With this information, this experiment determined how the rise in water temperature has an effect on the respiration rate of mummichogs, as well as determining how a short versus long term water temperature change effected the respiration rate of mummichogs. The results of this experiment concluded that as water temperature rises from twenty degrees Celsius (20°C) to twenty-six degrees Celsius (26°C), the number of respirations given off by mummichogs increased as well. However, with the rise of water temperature from twenty degrees Celsius (20°C) to twenty-six degrees Celsius (26°C), respirations produced by mummichogs for a short-term exposure to increasing water temperatures were greater compared to those of a long-term exposure to increasing water temperatures. The results of this experiment indicate that as the water temperatures in the Chesapeake Bay and other aquatic environments continue to rise, the amount of dissolved oxygen decreases, and the respirations of marine species will continue to increase. These stressors can have negative impacts on Bay food webs and ecosystems.

Ash in Alexandria

Reid Ridenhour *T C Williams High School*

The goal of this project was to find if the Emerald Ash Borer (*Agrilus planipennis*) had effects on the population of Ash (*Fraxinus)* trees in Alexandria Virginia. The approach taken in this project since only a year of time was permitted was to use historical data from forest lands in Virginia from before the Emerald Ash Borer arrived to compare samples in Alexandria that were taken in this project. The results that were found were that the ratio of standing to dead trees was much lower in Alexandria today than from before the insect arrived. This would conclude that the population of Ash trees in Alexandria are not healthy and will most likely further decline in the future.

Corrosion of Different Fishhook Coatings Under Estuarine Saltwater Conditions

John Robins *Chesapeake Bay Governor's School*

Catch and release fishing has a long history in the recreational fishing community as a primary way to maintain marine species' stocks over many different ecosystems. Stricter recreational harvest regulations increase the likelihood of regulatory catch-and-release and releasing fish back to the waters assumes that the fish will survive. The purpose of this study is to determine if fish hooks dissolve or corrode enough to disengage from released fish after breaking or cutting the fishing line. Four different hooks were tested in a constant estuarine environment. Among the four different hook coatings, there was a statistical difference between their corrosion times, p=4.25E-07. These results give us important data that can be used for conservation research. This study provides essential information to recreational fishermen by allowing them to avoid certain hooks and rely on cutting the line with deeply embedded hooks.

The Effect of Different Fertilizers on Plant Height

Zachary Roman *Washington-Liberty High School*

The purpose of this experiment: is to find a safe, eco-friendly alternative to toxic fertilizers. The Dependent variable is the height of the plant. The independent variable is the type of fertilizer used. The constants are the species of plant, the amount of fertilizer used, the amount of water used, the type of soil, the amount of sunlight, the type of pot and the environment the plants are kept in. The hypothesis goes as follows: If different fertilizers are applied to Radish Plants, then the Eco-friendly fertilizer will help the plant grow the highest. The null hypothesis is as follows: If organic fertilizer is used on radish seeds, then there will be no difference in height between the plants. After the experiment was concluded, the results showed that the hypothesis was rejected, and the null hypothesis was accepted. The procedure consisted of planting, measuring, and watering the radishes for 2 weeks. They were contained in plastic pots with plastic coverings to create a greenhouse effect. The plant-based group grew the tallest, but the p-value was 0.08 which means the difference isn't significant enough. Therefore, the fertilizer had no effect on the control group. In conclusion, plant-based fertilizers are a great alternative to toxic fertilizers, but they do not affect the plants' health all that much. To save our planet, switching to plant-based fertilizers may not affect the plants in any way, but will start the process to turning the effects of pollution and global warming around, for a better future.

Honorable Mention

Can Man-Made Ponds Serve All of the Ecological Functions of Naturally Formed Ponds?

Kayla Schill *Chesapeake Bay Governor's School*

As the world's population steadily increases, urbanization overtakes rural ecosystems containing a plethora of biodiversity. Due to a proportional relationship between species loss and habitat reduction, biodiversity's ecosystem services suffer from habitat fragmentation. If certain measures are taken to engineer appropriate artificial ecosystems, biodiversity and endemic species may have the opportunity to thrive and coexist with human developments. In Gloucester, VA and Middlesex, VA, six man-made ponds, located at Beaverdam Park, Rappahannock Community College, Patriot's Way, Madison's Way, and Mrs. Beam's residence were designated as research sites. Implemented parameters, macro and micro life, water quality, and qualitative observations were used to determine each pond's ability to sustain life, and thus, function as a naturally formed pond. The results demonstrate that man-made ponds are able to evolve into fully functioning, sustainable ecosystems under *certain conditions*. ANOVA statistical tests yielded statistical significance in the ponds' dissolved oxygen saturation p-value (<0.05) while the ponds' pH and biodiversity were consistent with each other through statistically insignificant p-values (>0.05). Although biodiversity and pH in naturally formed ponds are similar to man-made ponds, these results must inspire better management of urbanized ecosystems. Conservative landscaping practices such as adhering to bay scaping principles and installing riparian buffers are ways in which suburban citizens can sustain ecological function in their community.

Second Place

The Effect of Plant Type of a Green Roof on Internal Building Temperature

Harriet Shapiro *Washington-Liberty High School*

This experiment was conducted with the goal of determining which plant type of a green roof would best mitigate heat transferred through the roof of a building, subsequently reducing energy and money spent on air conditioning. Three plants were tested (grass, moss, and sedum) along with traditional roofing tiles as the control. It was hypothesized that the sedum roofs would allow the least heat transfer due to the extensive coverage provided by the thick leaves of this plant. Plywood boxes topped with the plants were placed under a heat lamp for an hour to simulate a green roof subjected to heat from the sun. The internal temperatures of the boxes were measured before and after the hour under the heat lamp and the differences between the ending and starting temperatures were determined. The results accepted the hypothesis as the sedum roofs allowed for the least increase in temperature, with a mean difference in temperature of only 1.56 degrees Celsius. Conversely, the control group had the highest mean at 3.59 degrees. The statistical significance of the data was determined using an ANOVA test, which yielded a p-value of 6.0 x 10^-56. This was far less than the critical value of 0.05, allowing the null hypothesis, which stated plant type would have no effect on internal temperature, to be rejected. The results of this study provide vital information on one of many significant advantages of green roofs, a sustainable economic and environmental solution that are beginning to transform modern day cities.

First Place

The Effect of Surface Dynamics on Atmospheric Water Harvesting

Cameron Sharma *Mills E. Godwin High School*

The global water crisis is a well-documented fact. It affects all regions and demographics. Atmospheric water harvesters (AWHs) have not been explored well as an option for freshwater. An estimated 12,900 km3 of water remains suspended in the air, while according to the World Health Organization only 0.075 km3 meets the daily water requirement of one billion people. Aero2Aqua, an AWH presented here is a novel invention. It harvests ground level vapors without using external energy. It combines three diverse bioinspired methods of atmospheric water harvesting into a complementary system. The three methods are hydrophilic and hydrophobic surfaces of the darkling beetle, the water trapping ridges of the cactus spines and the water channeling “liquid diodes” on the skin of Texas horn lizard. A device was designed, built, and tested incorporating these three components. Hydrophilic disks with diameters of 10, 15, 18, 20 and 25 mm were the levels of independent variable (IV). There was no control. The amount of water harvested was the dependent variable. It was hypothesized that the AWH using 25 mm disks would collect the most water. Mean values measured for the IV were 3.323, 5.028, 7.475, 15.753 and 24.889 grams. The related t-values were higher than the table t-value of 2.011. Therefore, the null hypothesis was rejected, and the data was significant. The results supported the hypothesis. Future enhancement could include computer optimized designs that would maximize water collection. The project was done under adult supervision using safety gear.

The Effect of Water Temperature on the Amount of Dissolved Oxygen in Water

Maya Sherlick *Arlington Tech*

The purpose of this study was to test the effect of temperature on the dissolved oxygen levels in the water. Climate change has become a more prominent issue, causing ocean life to be put in danger. This experiment was designed to identify how the rise of temperature could impact ocean life, emulate ocean conditions, and to better understand what might happen because of climate change. The independent variable was different water temperatures (6.1 C; 7.2 C; 18.3 C; and 29.4 C). The control group was 7.2 C because that is the median ocean temperature in Lewes, Delaware, which is the place the experiment is emulating. The dependent variable was how much dissolved oxygen was in the water, measured in ppm. The constants were the concentration of tank salt, external temperature, size of the pitcher, and the amount of water. The null hypothesis was that if the temperature increases, nothing happens to the dissolved oxygen levels. The alternative hypothesis was that if the temperature increases, then the dissolved oxygen levels will decrease because as water temperature increases the factor causing dissolved oxygen levels to go down increases. The research finds that the higher the temperature the lower the dissolved oxygen. The equator and Arctic are the places experiencing the most warming due to climate change. The most prominent example of warming is the melting of the ice caps, this shows a significant increase in temperature. The alternative hypothesis was supported because 29.4 C had the least amount of dissolved oxygen, meaning that it could be problematic for wildlife. This shows that climate change can seriously impact the environment and have lasting effects on our food chain and wildlife

Honorable Mention

The Effect of Additives on Melting Ice

Ananya Sinha *Arlington Tech*

Climate change, caused by the change in the Earth's atmosphere, is an extremely pressing problem in the world today. One effect of climate change is that the polar ice caps are melting. In order to slow the melting of the ice caps, this experiment was designed to determine a method to protect the albedo (reflectivity) of ice. This would be a short-term solution to climate change, as it would postpone the effects of climate change until a long-term solution is presented. Four different additives; glitter, sand, silica beads, and glass beads were added to the surface of ice cubes. It was hypothesized that glitter would protect the albedo of ice the best due to its highly reflective properties. It would reflect light instead of refracting or permeating like the other additives. The ice cubes with different additives were heated up under light for 20 minutes, and the average percent of mass change of the ice cubes was calculated for each group. Silica beads had the lowest average percent change in mass, and glitter was close behind. An ANOVA test showed that the results of the amount of ice melt were statistically significant, meaning that the null hypothesis could be rejected. While the results proved that silica beads were the most effective at slowing the melting of ice, a Tukey test showed that the differences between glitter and silica beads were not statistically significant. Glitter and silica beads are both effective ways to reduce the melting of the ice caps. With climate change becoming a growing concern, these results could be used to slow the melting of ice caps and postpone the effects of climate change.

Lunar Effect on Fish Catch Rate

Jeremey Smith *Chesapeake Bay Governor's School*

An estimated 3 billion people rely on fishing not only as food but also as income. Studies have shown there is a relation with fishing around the lunar phases with majority showing full moon has the greatest catch rate. This study compared lunar effect on fish catch rate while also comparing bait and tide to catch rate. For each lunar phase fishing was conducted on 2 of the possible days per lunar phase. And for each day of fishing 2 hours was spent in low and high tide. Also 3 baits, (shrimp, squid and nightcrawler) were used for each day. This was conducted for 2 full lunar cycles for a total of 32 fishing days. Full moon had 22 fish caught and new moon had 3 fish caught. For bait the larger sum of fish were caught using nightcrawler which was 46 and the least came with the shrimp of 14. For tide majority of the catch coming in high tide of 54 fish and for low tide 38 fish caught with all the results being significant it is possible to reject the null hypothesis. This supports the idea that catch rate is indeed affected by all three independent variables being moon phase, bait, and tide. The results show it is possible to know when the best day of fishing would be possible to determine, and the highest catch rate day should be around full moon using nightcrawler as bait and fishing at times of high tide.

Environmental & Earth Science E (HS ENV-E)

Budgetary Investment in Environmental Preservation and how it relates to Monetary Damage caused by Natural Disasters from 1988-2019

Seonbin Song *Blacksburg High School*

This project sought to discover the specific relation between the average monetary damage caused by natural disasters and the average monetary investment in the environment. The purpose was to figure out how effective state investment into environmental projects was at reducing damage caused by various natural disasters. Investment data was acquired through looking at regional groups of states, each of which provided a report containing annual funding for environmental projects. Monetary damage was gained through a singular collection of all major natural disasters in the United States of America. These two variables were related to one another using a series of linear regression graphs, with which the coefficients of determination and the strength of the variables' relationships was found. It was found that there was a weak-to-moderate positive relationship between the two variables, verifying the null hypothesis. This implied that investment into environmental projects did not lead to an overall reduction in damage caused by natural disasters. Rather, the trend showed that a growing severity of disasters had encouraged governments to invest more in the environment, though this investment had yet to pay off in noticeable margins.

Second Place

The Effect of Distance from I-95 on Prevalence of Epiphytic Lichen

Adam Stievater *Washington-Liberty High School*

The purpose of this experiment was to determine the effects of distance from an interstate highway on the prevalence of epiphytic lichens in Prince William Forest Park. The research hypothesis was that epiphytic lichens would be more prevalent farther from the highway, because automobile pollutants would restrict the growth of the lichens closer to the highway. The null hypothesis was that lichens would be equally prevalent no matter the distance from the highway, because automobile pollutants would have no effect on the lichens. Trees were observed in areas 0.25, 1.0, 4.0, and 10 km from the highway. Each tree in a 30-metre-long section of trail was assigned a qualitative value between 0 and 3, representing the amount of lichen on the tree. The prevalence of each value in that section of trail was calculated and shown on a summative graph. It was found that more trees with large amounts of lichen were observed farther from the highway. A Pearson correlation coefficient was calculated, returning an R-value of -0.937 when looking at trees with no lichen, and 0.873 when looking at trees with significant lichen. These two numbers imply a strong but not perfect correlation. Additionally, a T-test was performed, returning a p-value of 0.005795, approximately a factor of ten less than the confidence limit of 0.05. Therefore, it can be concluded that the prevalence of epiphytic lichens increases as distance from the highway increases, implying that automobile pollutants have harmful effects on lichens.

Honorable Mention

The Effect of Ventilation Method on Level of Indoor Carbon Dioxide

Lanyi Stroud *Yorktown High School*

Carbon dioxide is considered an indoor air pollutant. Up to 1000 ppm of carbon dioxide is generally recognized as safe, while 1000-2000 ppm is the level associated with lowered cognitive function and feelings of drowsiness. Opening the windows is a common way people ventilate their rooms. My project studies the effect of ventilation method on the amount of carbon dioxide indoors. This study is important as it would help us find the most efficient way of maintaining low levels of carbon dioxide indoors. I found that cracking open the windows for three hours was equally effective as opening the windows entirely for one hour, and then closing them for two hours. However, I found that the effects of opening the windows entirely only lasted for about two hours after the windows were shut at the one-hour mark. By then, the level of carbon dioxide had returned to 1000 ppm, the same as when there was no ventilation. Therefore, cracking open the windows would be the better ventilation method in time periods longer than three hours.

First Place

The Effect of Impervious Surfaces on Steam Health: A Study of Machine Learning and Multivariate Statistical Analyses

Lynn Tao *Thomas Jefferson High School*

Impervious surface area is projected to triple within the next three decades as a direct consequence of proliferating urbanization. Impervious surfaces, which are man-made architectural features that prevent absorption of water such as buildings and roads, play a profound role in affecting surface runoff and physio-chemical properties of stream systems. Thus, quantifying and studying impervious surfaces is crucial to understanding the breadth of anthropogenic influence. However, current methods of quantifying impervious surfaces require complex procedures, expensive software, and experienced personnel. As an alternative, we designed a novel machine learning approach that utilizes Google Maps and a K-Nearest-Neighbors (KNN) supervised algorithm to quantify the percentage of impervious surfaces (PoIS) surrounding 21 urban stream sites in Fairfax County, VA. Non-metric Multidimensional Scaling (nMDS) was conducted to analyze the relationship between PoIS and 10 water quality parameters based on the Bray (Sorenson) distance matrix. Permutational Multivariate Analysis of Variance (PERMANOVA) was used to detect the strength of dissimilarities among stream sites. Our research demonstrates that impervious surfaces are negatively correlated with the ecological health of Fairfax County streams. In addition, the developed machine learning algorithm used to quantify PoIS may serve as a useful tool to identify high risk streams, or areas that should be monitored. The algorithm will help both managers and general public better understand our urban stream environment, serving as a foundation for cost-effective water-resource management.

The Effect of Time on Surgical Mask Degradation

Benjamin Tsai *Washington-Liberty High School*

The purpose of this study was to find the effect of time on mask degradation. The independent variable was the amount of time the masks are left in water (no time, one week, two weeks, three weeks). The control group was new masks not put in water. The dependent variable was the mask degradation (grams). The constants were the location, the type of mask, and the weighting procedure. Based on the research, the hypothesis was: If masks are put in water for different amounts of time, then the ones left in water the longest will degrade the most, because plastic degrades in water. 30 surgical masks were submerged in a large tub of water being agitated by a submersible pump, and every week for three weeks, 10 masks were removed and dried. The masks were all weighed individually, then as a group for a more precise average. The data showed masks do not lose significant mass after being left in water for 30 days. These results rejected the hypothesis and supported a null hypothesis, which states that time has no effect on surgical mask degradation. However, imprecise measurements and the presence of outside factors somewhat discredited the findings of the experiment. The study could be improved with a better scale, a way to compensate for the organic matter buildup, and by using more masks. A study should be conducted under the same premise but over a longer period of time, for more substantial degradation of the masks.

The Effect of Carbon Dioxide on the Heat Absorption and Heat Retention of an Artificial Atmosphere.

Evan Tuckley *Mills E. Godwin High School*

Industrial emission of carbon dioxide (CO2), methane, and other greenhouse gases have increased exponentially since the industrial revolution, reaching an all-time high in the 21st century. The effects of such a large amount of waste being released into the atmosphere has been found to cause increased temperature. The purpose of this experiment was to determine the effect carbon dioxide has on temperature, heat absorption, and heat retention. CO2 was chosen because it is the greenhouse gas most emitted by humans. The research hypothesis for this experiment: if CO2 was added to an artificial atmosphere and heat applied over 2 hours, then the change in temperature, the rate of increase in temperature, and the rate of decrease in temperature would be significantly greater than the control. The current concentration of CO2, 400 parts per million(ppm) was set as the control in this experiment. To conduct this experiment all safety precautions were taken and four flasks were filled with varying concentrations of CO2, 400ppm, 600ppm, 800ppm, 1400ppm. The flasks were heated for two hours, from an initial temperature of 22 C, and the temperature recorded in 15-minute intervals. After heating, the time for temperature to return to 22 C was recorded. It was found that CO2 had a significant effect on the rate at which temperature in a system decreases. The increased heat retention caused by CO2 signifies that if humans continue to pollute with CO2 the temperature of the earth could significantly change in the future.

Evaluation of Four Materials for Growing Aquatic Algae to Produce Biofuel

Eleanor Veazey *Chesapeake Bay Governor's School*

In this study, four different material plates (wood, concrete, aluminum, and vinyl) were placed in the Potomac River to see what material would grow algae the fastest to make biofuel. The materials were placed on top of floating oyster bags that were located off the Potomac's shore in sheltered Hex Boxes. The data was recorded over four weeks by using a percent coverage grid. Then the weight of the plates was measured to find the total algae mass, and the algae was analyzed chemically for lipid content. The results show that wood and concrete yielded algae the quickest, but vinyl had the highest percent of energy-rich lipids, which are necessary for biofuel. Since vinyl had the least algae mass, but produced the most lipids, this makes vinyl the optimal material to use when growing algae for lipid use.

Third Place

It’s Not Easy Being Green: Examining Factors for the Growth Rate of *Chlorella vulgaris*

Lydia Wallace *Chesapeake Bay Governor’s School*

Microalgaes, as photosynthesizers, are being considered for usage in the removal of excess atmospheric carbon dioxide. This study tested the effects different types of salt content and varying concentrations of iron have on the growth rate of *Chlorella vulgaris*. Three salt conditions were tested: 2 g/L of NaCl, 2 g/L of a mix of primarily Na_2CO_3 and $NaHCO_3$, and no salt at all. In the second experiment, four iron concentrations were tested: 10-7 mol/L, 10-5 mol/L, 10-3 mol/L, and no iron added (0). Cultures of *Chlorella vulgaris* were received from Algae Research Supply and given equal amounts of water soluble MiracleGro. The growth rate was measured by daily recording absorbance at 425 nm and 675 nm, then subtracting each day’s absorbance from the previous to find a daily change. There was not a significant result for the differences between salt content conditions (p-value of 0.14), so the experiment failed to reject the null hypothesis, suggesting that the type of salt, or its absence, has no impact on the growth rate of *Chlorella vulgaris*. There was a significant result for the differences between iron concentrations (p-value of 0.0023), with further t-tests suggesting similar rates between 0 and 10-3, as well as 10-7 and 10-5. (0 = 10-3 < 10-7 = 10-5). This suggests that moderate amounts of added iron increase growth rate, but an excess amount slows growth. The study suggests that certain conditions, including the iron concentration, can increase growth rate and thus Carbon sequestration.

How Important is the Shallow Water Refuge for Small Prey Species in the Chesapeake Bay Food Web

Laura Walton *Chesapeake Bay Governor's School*

The shallow water SAV habitat is made up of mixtures of seagrasses and macro-algae that are responsible for functions that an ecosystem cannot thrive without. Organisms like fish and crabs use the vegetation mainly for protection from predators and also as an important source of food. However, since 1960 there has been a major decline in submerged aquatic vegetation in shallow habitats in the Chesapeake Bay caused by years of nutrient runoff and sediment pollution. Past studies suggest that shallow water may offer a refuge from predators for juvenile fish and crustaceans like crabs and shrimp in marine ecosystems where SAV beds have declined. Three shallow water locations were tested along the Rappahannock River: Upton Marina in Urbanna, Wake Beach, and a small beach along Jacksons Creek in Deltaville. At each location a 50ft seine, extended from 50ft into the creek and all the way to the shore. Once the seine was hauled in, all of the organisms that were caught were then placed into buckets, counted, measured and identified. Waders were worn to protect feet from shells on the seafloor. The Urbanna Creek site had the greatest abundance and diversity with 1,007 organisms and 7 different species followed by Jacksons Creek in Deltaville with 512 organisms and 6 different species. When shrimp, crabs, and silverside were excluded, the greatest mean number of organisms in Urbanna Creek were Banded Killifish with an average of 12.33, followed by Mummichogs with an average of 6.33 per seine. The data shows that there are prey species in mostly refuge, and there were only a few very tiny juvenile predators (blue crabs & red drum) caught. The loss of submerged aquatic vegetation is continuing, and better efforts need to be made to stop the decline to help preserve the predator/prey ratios and healthy Chesapeake Bay food webs.

The Effect of Firework Display Length and Frequency on Amount of Particulate Matter 2.5 in the Air

Ivy Watson *Washington-Liberty High School*

The purpose of the investigation was to determine a method to coordinate local firework displays in order to decrease levels of particulate matter 2.5 (PM2.5) released. The hypothesis was that having one firework display per night over several nights would release lower levels of PM2.5 than having multiple fireworks displays on one night.

Data from the EPA's Air Quality Service API was downloaded from three locations. The data was organized into three groups: before, during, and after firework events, and the average was calculated for each hour of the day. Hourly data from the night of each firework event showed a large increase in the PM2.5 levels for Washington D.C. in 2019 and 2020. In 2019, Weston, WY didn't have as large of an increase, however it was statistically significant. The highest levels during the night of the firework display were found in DC 2019 and the lowest levels were in Weston 2019.

The results indicate reduction of PM2.5 released by firework displays in a region with frequent displays is to schedule events across several days as opposed to all being released on the same night. Applications of this investigation are relevant as particulate matter has detrimental health effects on people with respiratory conditions, such as Covid-19. Covid-19 increases the risk of lung infections and diseases and can also reduce lung function, placing more people at risk from fireworks and particulate matter.

How the Increasing Microplastic Presence in the Oceans Poses a Threat to Vital Phytoplankton

Bay Wiggins *Chesapeake Bay Governor's School*

Phytoplankton are perhaps one of the most important organisms in the ocean, as they are the primary producers of most oceanic food webs, create about half of the atmosphere's breathable oxygen per year (equivalent to the amount that all land plants produce), and also play a crucial role in the carbon cycle of the ocean. These microscopic critters may be facing a large threat at the hands of the also microscopic microplastics. Microplastics are extremely small pieces of plastic debris (~5-10nm), resulting from the breakdown of plastic pollution all over the oceans.

This study aimed to test microplastics' effects on phytoplankton in a controlled environment. In four separate 2L bottles, a concentration of 1.019sg saltwater was added, and cultures of phytoplankton were grown for 6 days in consistent conditions. Then, ultra-fine glitter that had been broken down was then added to three of the bottles, in high, medium, and low concentrations (High: 3%, Medium: 1%, Low: 0.5%). After one week, samples were then taken from each bottle, and viewed under a 40x microscope to observe and record the number of countable phytoplankton per concentration. There was a significant relationship between the amount of microplastics, and the concentration of phytoplankton, with a P-Value of 4.0×10^{-10}. The results of this study suggest that there may be a notable threat to phytoplankton as concentrations of microplastic pollution in the oceans rise.

The Effect of Various Locations in The Greater Richmond Metro Area on Rainwater Quality

Hanna Wirtu *Mills E. Godwin High School*

The purpose of this experiment was to find the effects of various areas of the Greater Richmond Metro area on the quality of rainfall. The study of the quality of rainfall is important because humans rely on rainwater for the irrigation of crops and for being the main source of drinkable water. Freshwater organisms depend on rainwater for providing and filtering their ecosystems. It was hypothesized that within the Greater Richmond Metro area, the Southside region would have the rainwater resulting in the lowest quality, which is signified by the turbidity levels. Gloves and goggles were worn during the experiment in order to ensure the safety of the experimenter. Rainwater was collected in eight-ounce cups on five different days throughout November and December in the five locations and measured at the end of the fifth day. The turbidity was written into a data chart and the mean, standard deviation, and variance were calculated for the levels of the independent variable. There was no control in the experiment due to none of the levels of the independent variable having water with a turbidity level of 0 NTU. The Southside region resulted in the largest mean of 5.52 while the Lakeside region had the smallest mean of 2.71 NTU. All of the data was statistically significant. This allowed the conclusion to be drawn that the results were due to the independent variable rather than to chance. The results were due to local environmental stimuli such as pollution or air quality. The research could lead to further research about water index quality and the filtration of rainwater.

Honorable Mention

Comparing the Effectiveness of Various Sorbents at Remediating Oil Pollution

Jeffrey Wooters *Central Virginia Governor's School*

The purpose of this experiment was to evaluate the effectiveness of different varieties of sorbent on oil reclamation. 427.5 mL of water and 22.5 mL of Valvoline motor oil were used to approximate a five percent oil concentration in water. Four varieties of sorbent were tested: a control group of no sorbent, five centimeters by five-centimeter pieces of cotton fiber, *Oscillatoria* and *Nostoc* algae, and *Pseudomonas fluorescens* bacteria. Over the course of each trial, groups were left to sit for one week before and/or during the remediation process. After exposure to the pieces of cotton fiber or 10 mL of micro biotic culture, a separatory funnel was used to remove all water from each trial. Then, a pi-pump was used to measure the amount of oil remaining in each trial group. The data supported my research hypothesis, which stated that the cotton fibers would be the most effective at removing oil from the simulated aquatic environment. After absorption, cotton showed an average of 2.93 mL of oil remaining, control 14.25 mL, algae 17.65 mL, and bacteria 18.35 mL. A one-way ANOVA was used to determine significance with an alpha value of .05; it returned a p-value of 8.07x10-14, which indicated significance. A post-hoc Tukey test determined that the significance existed between each permutation of group with the exception of algae and bacteria. The experiment yielded unexpected results; however, it revealed possibilities for further testing of microorganisms to be used in bioremediation.

The Effect of Fuel Octane on Carbon Monoxide Emissions

Marshall Wright *Mills E. Godwin High School*

This experiment was conducted in order to determine if carbon monoxide (CO) emissions from a car were changed based on the octane of gas. The environmental effects of this could increase the wellbeing of all creatures on the planet by reducing air pollutants. The hypothesis said if fuel with and 91-octane rating was used, the car would emit the least carbon dioxide. The control for this experiment was the 87-octane group because 87-octane is considered standard most places. This experiment took place on three separate days, one for each group of trials. The results indicated that the 91-octane group had significantly more CO concentrated in it than both the 89 and 87-octane group. The 89-octane group was also significantly more concentrated with carbon monoxide than the 87 group. It was concluded that the results were caused by the octane raising agents put in the gasoline.

The Effect of COVID-19 Quarantine Measures on AQI of 100 US Cities

Rose Yang *Mills E. Godwin High School*

Although services like transportation are convenient for a growing world, they release pollutants that reduce the quality of the air humans need to breathe. This can aggravate respiratory illnesses, so airborne pollution should be decreased to protect overall public health. In March 2020, the SARS-CoV-2 (COVID-19) pandemic caused many American states to enact restrictions to reduce its spread. These measures restricted travel, gatherings, and caused many employees to work remotely. It was hypothesized that the decrease in nonessential travel would improve air quality and, thus, a decrease in AQI values. To investigate the impact of COVID-19 restrictions on the AQI (Air Quality Index) of the two most populous counties in each state, 2015-2020 AQI data was collected from the EPA website. A six-week period was observed in each county after the strictest COVID-19 order was enacted. Due to data availability constraints, latest start date was April 7. An average of this observation period was calculated and compared to the same period average from preceding years 2015-2019 (ex. 2015 v. 2020, 2016 v. 2020). It was found that all of the data was statistically significant, and the null hypothesis was rejected. The hypothesis was supported despite probably confounding due to a trend of O3 increase seen in other similar studies.

The Effect of Different Heating Methods on Vitamin C Concentrations in *Capsicum annuum*

Aaron Yuan *Mills E. Godwin High School*

The purpose of the experiment was to find the effects of different heating methods on the retainment of vitamin C. A dietary material that is essential for the development and survival of humans are vitamin C. It occurs naturally in many fruits and vegetables, including oranges and peppers. Capsicum annuum, more commonly known as the bell pepper, contains a variety of necessary nutrients. A collection of nutrients, including lutein and vitamin C, are present in green bell peppers. Green bell peppers were found to contain double that of the well-known orange. It was hypothesized that if different heating methods were tested, then a flat iron pan will cause the least amount of vitamin C loss. 25 bell peppers heated using a microwave set on medium heat for thirty seconds, 25 bell peppers heated with an iron pan set to medium heat for thirty seconds, 25 bell peppers placed into boiling water for thirty seconds, and 25 bell peppers were obtained, and all were juiced. Indophenol was placed into test tubes at a 1% concentration and the dependent variable, juice in the pipettes dropped into the indicator solution and mixed until the solution became clear, was measured. The less drops taken to convert the solution indicates a greater concentration of vitamin C. Multiple t-tests were performed, comparing each level of the independent variable to the control (no heating). This revealed that the data for each level of the independent variable to be significant. The results supported the research hypothesis as pan heating resulted in the lowest amount of vitamin C loss. Because pan heating utilizes convection heating, only the outside of the bell pepper was heated within the thirty seconds allotted. This research could lead to further studies by testing the effect of heating methods on additional vegetables.

Math: Theoretical & Modeling (HS MTM)

Honorable Mention

Using Transit Light Curves for Ground-Truthing the Orbital Radius and Planet Radius of Exoplanets Examined by the K2 Campaign 10 Mission

Mahin Atturu *Mills E. Godwin High School*

The purpose of this experiment was to determine whether or not calculated values of planetary radius and orbital radius are similar to the official values of planetary radius and orbital radius. In addition, the experiment strived to use astronomical formulas to ground-truth the data collected by the K2 Campaign 10 Mission. Ground-truthing is the process of verifying the results of a remote sensing mission using ground measurements. These formulas will verify the orbital radius and planetary radius collected from the K2 Campaign 10. In order to test the effectiveness of ground truthing, calculations for the planetary radius and the orbital radius were collected from the transit light curves and compared with the official data in a K2 Database. Prior to calculation, a permission form was signed by a parent that indicated that they had read and understood the risks and possible dangers involved in the research and they consented to their child participating in this research. It was hypothesized that the data calculated using the transit curve will be statistically the same as the recorded data within a 99% confidence interval and a two-tailed t-test. The results revealed that both the calculated and the recorded values for planetary and orbital radii were statistically the same in both the confidence interval and the t-test, thus supporting the research hypothesis. It was believed that the results were due to the uniformity of the curves, making interpretation of the transit light curves difficult. For continued study, interpretation of exoplanets using different methods, such as the radial velocity method, and further ground truthing will be conducted.

The Effect of Model Type on the Accuracy of Predicted Values

Pranav Bandla *Mills E. Godwin High School*

The purpose of this experiment was to determine which model would be the most effective in predicting disease progression given two months of data. If which model is more accurate is known, governments can develop and use the models to respond to disease more effectively. The SIR and SEIR are commonly used compartmental models for diseases. The SIR model incorporates another factor. It was hypothesized the values predicted by the SEIR model would be more accurate than the values predicted by the SIR model. The experiment was conducted by first calculating an SEIR model and an SIR model based on data from the first 2 months of 3 different Ebola outbreaks in 2014. The actual values of data were compared against the predicted values of data by the SIR and SEIR value by use of percent error. The SEIR model had a lower mean percent error than the SIR model, which supports the hypothesis. A t-test performed on the data revealed it was not significant. The null hypothesis of no difference in the accuracy of the data predicted by the SIR model and the data predicted by the SEIR model failed to be rejected. It is believed there is no difference in the accuracy of predictions of the SIR model vs the SEIR model. This may be because there are outside factors such as people's responses and non-disease related death and births. Research can be done into more adaptable models that are able to accommodate birth and death rates and effects of the responses of people.

Honorable Mention

Using Energy Conservation to Estimate Bullet Penetration into Differing Materials

Christopher Behre *Chesapeake Bay Governor's School*

During a mass shooting, victims must choose one of three options: run, hide, or fight. When a victim hides, they may choose to hide behind a desk, table, or chair. This study was conducted to determine the safety of those victims behind wooden or plastic tables. The project was carried out through energy conservation equations and unit conversions, resulting in the average plastic table being safe for victims, but not the wooden ones. Although the results did not agree with my hypothesis that the wood tables would be stronger than the plastic tables, they did support the general conclusion that it is possible for a victim to be safe behind a table during a mass shooting.

Second Place

Seizure Seeker: A Novel Approach to Epileptic Seizure Detection Using Machine Learning

Tony Bright, Hamza Lateef & Gabriel Ralston *Charles J. Colgan High School*

Background: Epilepsy is a neurologic disease characterized by seizures which occur due to sudden and synchronized bursts of excessive electrical energy in the brain. An electroencephalogram, or EEG, can detect seizures in real time but requires trained medical expertise for extended periods of time. The main objective of this research was to devise a more efficient method (Seizure Seeker) for analyzing EEG data using machine learning algorithms that allows for complex data processing and can automatically distinguish between normal EEG signal and epileptic seizures. **Methods and Study Design:** We used an open access EEG dataset containing pre-identified records of 500 patients. Seizure activity was designated as a simple binary 1 or 0, where 1 indicated a seizure and 0 indicated no seizure. We then partitioned our database into two randomly assigned groups, a training set of 80% of the data and a testing set containing the remaining 20%. For the study, we compared 3 different classification algorithms: Logistic Regression, Support Vector Machines (SVM), and Long Short-Term Memory (LSTM). All models were fitted using existing software from Python libraries and the orange data mining application. **Results:** Logistic regression had poor accuracy, but SVM achieved impressive results with an overall accuracy of 94%. LSTM is a more complex algorithm based on recurrent neural networks and generated near perfect classification results with an accuracy of 99%. **Conclusions:** The memory property of the LSTM model makes it an ideal choice for the time series EEG data. The LSTM results proved the efficacy of the machine learning model to automatically detect seizure activity in EEG data. Models such as Seizure Seeker can be developed to reach more timely diagnoses of seizures and can be used where access to specialized medical expertise is especially limited.

Investigation in Microbiota Dysbiosis of E-cigarette Users and Smokers

Nina Dao *Ocean Lakes High School Mathematics and Science Academy*

Dental caries, known as cavities or tooth decay, have been perplexing humans with their high rate of occurrence, especially with children and adolescents. With much research evolving in microbiomes and bioinformatics, this research intertwines the two fields to produce a product that can help support current science literature's stance on e-cigarette usage and smoking. Based on preliminary data, observations, and ideas learned from previous data science journals, evidence collectively suggests a correlation between changes in the microbiome in e-cigarette users and smokers. This project proposes a bioinformatics approach to discover potential biomarkers for dental caries in smokers and e-cigarette users. These biomarkers can detect dental caries more accurately and efficiently to these specific individuals who are highly prone to this disease. Using metagenomics, this project also studies how the microbiome or bacterial diversity impacts human health. Data were obtained from the Alkek Center for Metagenomics and Microbiome Research Database with a sample size of 99 of three body sites of buccal swab, saliva, and feces. The contributions of this project are characterizing bacterial communities for dental caries in smokers and e-cigarette users, and this project allows for the future identification of roles of specific taxa in human health, and disease.

Predicting Ideal Group Sizes for COVID-19 Pooled Testing Using Mathematics

Rose Haron *Washington-Liberty High School*

This experiment was aimed to distinguish the relationship between COVID-19 prevalence, number of people in a COVID-19 testing group, and reduction in testing through the use of a pooled testing strategy. Pooled testing is a method which combines multiple individual samples together and tests the combined individual samples as one. If that sample returns positive, one or more members of the pool are COVID-19 positive, and the entire group must be retested individually to confirm which members are positive. If the pooled sample is negative, then all individuals in such group are negative. This strategy is particularly relevant to the unprecedented global pandemic the world currently faces. Pooled testing could potentially be an efficient method for curbing the spread of COVID-19 through increasing testing capacity. For this experiment, it was assumed that a group size of 20 would result in maximum reductions in testing across the most prevalence's of COVID-19 since at this point group size would be large enough to decrease the number of tests needed to test a population, without having to retest the majority of pooled groups. COVID-19 prevalence and group size were plugged into a mathematical equation in order to obtain the theoretical percentage of groups which would return positive, leading to the number of tests required to sample an entire population of 5,000 individuals. The results did not support the hypothesis. A group size of 4 achieved the maximum reduction for 30 of the 40 COVID-19 prevalence tested. The p-value regarding the effect of COVID-19 prevalence on reduction in tests required was 2.64e-245. The p-value regarding the effect of group size on test reduction was 2.48e-132. These p-values indicate that there was a statistical significance between prevalence, group size, and test reduction, meaning the null hypothesis was rejected.

Momentum-Based Interaction Networks for Modeling Rigid Body Dynamics

Junho Lee *Thomas Jefferson High School for Science and Technology*

Realistic rigid body simulation is a foundational tool for solving complex engineering and robotics problems. But analytical simulations often do not match the real-world dynamics of a system, and data-driven methods have typically only been tested for simple collisions between circles and walls. This study proposes a scheme that takes advantage of deep learning and the laws of conservation of momentum to model complex rigid body interactions. The momentum-based interaction network outperforms the baseline model in producing feasible simulations for certain scenarios. These results suggest that this methodology may be used as, or integrated into, a practical model for learning useful dynamics.

The Effect of Various Software on Protein Structure Prediction

Abhinav Mara *Mills E. Godwin High School*

The purpose of this experiment was to research which protein structure prediction software was the best. The three software that were compared in this experiment was PHYRE2, SWISS-Model, and Raptor X. These three were chosen because they used the most accurate computational method for protein structure prediction: homology modeling. Twenty-five different protein sequences were inputted into each of the software. The resulting protein structure was superimposed onto a structure determined through biophysical methods acquired from a validated database and the root mean square deviation (measured in Angstroms) was recorded. There was no control in this experiment as no software was considered to be the "norm." It was hypothesized that the PHYRE2 software would have the greatest accuracy, implied by the lowest RMSD. The results revealed that the SWISS-Model's mean RMSD (0.818) was slightly lower than PHYRE2's mean RMSD (1.373) and Raptor X's RMSD (1.039). A t-test was done on the data, and it revealed that none of the data was significant. The research hypothesis was also not supported. It is believed that the varying results were due to internal variations in the algorithm to predict the protein structure. The SWISS-Model used energy minimization, while PHYRE2 used a little bit of threading to be more accurate, and Raptor X used a specialized multiple-threading template procedure. All safety guidelines and COVID protocols were followed throughout the duration of this entire experiment.

Algorithmic Simulations of Hydrocortisone-Induced Degeneration

Philip Naveen *Mills E. Godwin High School*

The Elk River, Gulf Wars, and Atlantic Oxybenzone instances proved chemical contamination is a serious threat. HC is a common corticosteroid used to treat skin lesions that hasn't undergone testing. This research will utilize real plant cultivation, mathematical modeling, machine learning, and custom Python3 programming to determine the effect of HC on plant life. During data collection, safety precautions such as handwashing, aprons, and eyeglasses were used. Metadata significant at a 0.01 level under 48 degrees of freedom was gathered by cultivating real *Raphanus sativus* plants treated with various levels of HC contaminated water; the t-test was verified using Java8 computer code. The simulation comprised of three independent algorithms. Because the metadata was very sparse, the first algorithm was dedicated to using modified bootstrapping to iteratively generate synthetic data points with less entropy. The second algorithm was a deep learning substructure incorporating concepts of linear regression and neural networks; the backpropagation used the MSE loss function and ADAM optimizer, which has aspects of previously engineered AdaGrad and RMSProp models. The third algorithm measured the effect of HC on a terrain based on aquatic content. The simulations used an HC contaminator based of the Gulf Wars event and five semi-aquatic terrains in North America, which were the contaminator and terrestrial parameters respectively. The plant cultivation and software simulations supported the research hypothesis stating that the uncontaminated plants would be healthiest was accepted. Future research could use convolutional neural networks to achieve a higher R-squared value and real-time procedural terrain generation to improve the simulations.

First Place

De Novo Prediction of RNA-Protein Interactions for Discovery of Tissue-Specific Binding Sites

Lillian Sun *Thomas Jefferson High School for Science and Technology*

In eukaryotes, RNA-binding proteins (RBPs) interact with RNA to control post-transcriptional processes, including alternative splicing, polyadenylation, stabilization, localization, and translational regulation. RBPs and RNAs are differentially expressed between tissues, influencing the transcriptome-wide RNA-protein interactions that occur within each tissue. Current experimental techniques to identify RBP binding sites in vivo, such as UV cross-linking immunoprecipitation and sequencing (CLIP-seq), are expensive, time-intensive, and difficult to perform reproducibly. Here, I introduce a de novo method to predict tissue specific RBP binding profiles from an RNA sequence in silico. This approach simulates RNA-protein interactions using a probabilistic model that leverages binding affinities predicted from in vitro RNA Bind-n-Seq data and protein compositions measured by mass spectrometry. I apply this method to investigate the binding of 86 RBPs across 30 human tissues, outperforming existing computational methods. I show that the model recapitulates well-studied examples of tissue-specific binding, such as the brain-specific binding of protein NOVA1. In addition, using this approach, I identify NOVA1 as a potential critical protein in the progression of benign adult familial myoclonic epilepsy (BAFME), as NOVA1 binds the UUUCA repeat expansions present in the intronic region of SAMD12. Predictions from this model may aid researchers in understanding functions of RBPs and uncovering their roles in understudied diseases.

Third Place

Assessing the Efficacy of Various NOX Enzyme Inhibitors as Potential Treatments for Ischemic Stroke in Silico

Samhita Vinay & Keertana Yalamanchili
Thomas Jefferson High School for Science and Technology

This study investigated the effectiveness of different NOX inhibitors as treatments for ischemic stroke in silico. Ischemic stroke occurs when blood flow to the brain is interrupted, causing brain damage. There is evidence that ROS (reactive oxygen species) are produced by the enzyme family NADPH oxidase (NOX) following ischemic stroke, which leads to further brain injury. The hypothesis was that VAS2870 would be the most effective inhibitor in silico due to the fact that it was commonly used in in vivo and in vitro studies, and due to its specificity to NOX2. The ADMET profiles of each inhibitor was taken, in which four classifications, namely applicability domain, human intestinal absorption, blood brain barrier, and human oral bioavailability, were observed. Then, Auto Dock Vina was used to model the docking of the inhibitors: VAS2870, GSK2795039, Apocynin, and AEBSF to NOX2, an isoform of the NOX family. The binding affinities of each of the inhibitors to NOX2 were recorded, and the value was used to calculate the Ki value of each inhibitor. It was found that VAS2870 and Apocynin were the most potent NOX2 inhibitors ($p < 0.001$) and that all four inhibitors had favorable ADMET profiles. This study helps corroborate previous in vivo and in vitro studies in an in-silico format and can be used towards evidence for developing drugs to treat ischemic stroke.

Honorable Mention

Investigating Trends in the Multiple Ligand Activation of PPAR Gamma

Jacqueline Wang *Blacksburg High School*

Peroxisome proliferator-activated receptors (PPARs) are ligand-activated transcription factors involved in the regulation of energy homeostasis. PPAR gamma (PPARγ) activates genes in muscle, fat, and liver. They regulate glucose metabolism and other functions in those parts. Currently, PPARγ agonists are used as Type 2 diabetes treatments such as Thiazolidinediones (TZD) treatments. While rather effective, many side effects have appeared. Fluid retention, lower bone density, and increased intravascular volume from these treatments has made researchers look for another treatment, PPARγ partial agonists. These new PPARγ ligands with enhanced therapeutic efficacy and reduced adverse effects include the selective PPARγ modulators (SPPARγMs). For this study, PPARγ was examined to elucidate what residues are necessary for multi-ligand binding to PPARγ. The binding pocket interactions were analyzed using the software PyMOL. The models were taken from the RCSB PDB database. Models of PPARγ with 2 or 3 unique ligands were looked at so drugs can be developed to mimic the multi ligand binding feature and activation. All polar residues that are 5 angstroms or less away from the ligand were found. The process was repeated with other models, and similar residues were accounted for. The residues that were found in each model were deemed as “critical” in the binding of multiple ligands to PPARγ. The residues were all of the possible amino acids. From the data collected, there was not one residue that was present in every model. However, tyrosine, serine, histidine, and arginine were present in over a third of the models. Finding these critical residues will help discover more possible treatments for Type 2 diabetes to decrease the number of side effects.

Medicine & Health A (HS MDH-A)

The Effect of Hand Sanitizer Composition and Brand on Antimicrobial Efficacy

Emma Almassy *Chesapeake Bay Governor's School*

Hand sanitizer is a frequently used form of antiseptic to maintain hand hygiene. This study analyzed how different components of alcohol-based hand sanitizers affect antimicrobial efficacy when handling infectious bacteria. Ten treatments were made, consisting of a Control, 62% ethanol Generic sanitizer, 62% ethanol Name brand sanitizer, 62% ethanol and water, 40%, 60%, 80% ethanol with glycerol, 70% ethanol with aloe, 70% ethanol with glycerol, and 70% ethanol with water. *E. coli* was mixed with nutrient agar and treatments, which were then incubated and observed over the course of multiple days. Once growth was visible, the *E. coli* colonies on each of the plates were counted. Based on the results, the brand of hand sanitizer and carrier molecules have little to no effect on antimicrobial efficacy. Alcohol percentage is the key factor in antimicrobial efficacy, with hand sanitizer becoming more effective as the concentration of alcohol is increased. This could be useful for consumers, allowing them to spend less money on name brand sanitizers while still ensuring its efficacy

First Place

Identification of Fluoxetine as a Direct NLRP3 Inhibitor to Treat Atrophic Macular Degeneration: Molecular Modeling, Mechanism, Morphometry, and Meta-analysis (Year 2)

Meenakshi Ambati *Albemarle High School*

The atrophic form of age-related macular degeneration (dry AMD) affects nearly 200 million people worldwide. There is no FDA-approved therapy for this disease, which is the leading cause of irreversible blindness among people over 50 years of age. Vision loss in dry AMD results from degeneration of the retinal pigmented epithelium (RPE). RPE cell death is driven by accumulation of *Alu* RNAs, which are noncoding transcripts of a human retrotransposon, amyloid $Beta$ deposition, and iron overload. *Alu* RNA, amyloid *Beta*, and iron induce RPE degeneration by activating the NLRP3-ASC inflammasome. In new data, I report that fluoxetine, an FDA-approved drug for treating clinical depression, binds NLRP3 in silico, in vitro, and in cells. In new data, I also report that Fluoxetine inhibits NLRP3 ATPase activity. In an extension of last year's work which focused solely on *Alu* RNA, I provide new data that fluoxetine blocks RPE degeneration induced by oligomerized amyloid *Beta* and iron in mice. In a substantive expansion of last year's work in which I studied a single health insurance database comprising 25 million people, I present new data by analyzing three health insurance databases comprising more than 130 million Americans, which identify a reduced hazard of developing dry AMD among patients with depression who were treated with fluoxetine. In addition, new analysis from a random-effect meta-analysis model employing propensity score matching and confounder adjustment demonstrates a pooled risk reduction of 17% for fluoxetine users. A prediction interval analysis based on these three databases estimates a >95% probability of a future clinical trial identifying a benefit of fluoxetine in reducing the risk of dry AMD. Collectively, these interdisciplinary studies provide strong support for testing fluoxetine as a potential drug repurposing candidate for dry AMD, which causes blindness in millions of people in the United States and across the world.

The Effect of Tissue Thickness on Temperature Change Induced by Cellular Radiation

Lina Aniss *Washington-Liberty High School*

This experiment tested the effect of different brain tissue thicknesses on temperature change induced by cellular radiation. This experiment was conducted to show how vulnerable brain tissue is to cellular radiation. For this experiment, I purchased five cattle brains which were all cut into halves. For each trial, I placed a cell phone 10 cm away from the brain tissue, which was also in a call with another phone to simulate a phone call. Three precision thermometers were then placed in different thickness to measure the temperature change. The temperature was recorded every minute for 15 minutes. The results showed that the highest change was found in the grey matter (2mm, 12mm) of the brain, which increased on average .64 degrees Celsius. The lowest change was found in the white matter (22mm), which increased on average .4 degrees Celsius. An ANOVA test and three T-Tests were done in order to determine if the data was statistically significant, which according to the tests they were. Standard deviation was calculated as well, which showed that the data was also reliable. These tests led to a rejection of the null hypothesis because they showed that the independent variables did have an effect on the dependent variable. This experiment's results were also compared to online resources in order to assess how dangerous the temperature increase was for humans. The results demonstrated that the temperature was enough the following health impairments in humans; eye cataracts, cell proliferation, permeable blood-brain, tissue damage, and irregular sleeping habits.

The Effect of Different Suturing Techniques on Skin Closure

Shreyas Arcot *Mills E. Godwin High School*

Sutures have become a critical part of medicine and are found in hospitals, doctor offices, ambulances, anything relating to the medical world. Their use is to successfully close open wounds to prevent excessive bleeding. However, different types of suturing techniques exist including a running stitch, a mattress stitch, or an interrupted stitch. Some are proficient at reducing scar tissue and others are proficient at making sure the stitched-up organ will function properly. The purpose of this experiment was to determine which technique most efficiently prevents blood leakage. The hypothesis for this experiment is, if a simple interrupted percutaneous technique is used, there will be the least blood loss. The control for this experiment was no stitching to represent an open wound with no treatment. In this experiment, a scalpel was used to create a two-inch incision in a chicken breast. A simple, interrupted, percutaneous suture was performed on some, a horizontal mattress suture was performed on others, and the rest were left without a suture. A single water droplet was placed on the surface of the incision and whether or not the drop made it through the chicken breast was recorded. All possible safety precautions were taken throughout the entirety of this experiment. The results showed that the interrupted stitch was the most effective in preventing blood loss. Afterwards, a chi-square was calculated and proved the data to be significant. As the simple interrupted stitches are the first ones taught and the most commonly used, the results of theexperiment are understandable.

Third Place

Discovery of Novel Extracellular Vesicle Plasma and Tumor miRNAs As Biomarkers for Lung Cancer via Next Generation Sequencing, Bioinformatics, and In-Vitro Analyses

Perisa Ashar
Maggie L. Walker Governor's School for Government and International Studies

Lung cancer is the leading cause of cancer death worldwide. Diagnostic methods including CT-scans are expensive and time-consuming. miRNAs participate in gene-silencing and can be dysregulated in cancer. Extracellular vesicles (EVs) circulate our bloodstream and participate in cell-cell communication within tumor microenvironments during metastasis. This project identified both plasma and tumor miRNAs as biomarkers for lung cancer. Small RNA libraries of patients' plasma were quantified by PCR, underwent next-generation sequencing (NGS), and pre-processed. Novel miRNAs with their default parameters on sRNA-Analyzer and their abundance changes were identified. A heat map (biomarker panel) was constructed to display the expression of miRNAs with p-values <0.05 and fold-changes >1.5, for Stages I-III of lung squamous cell carcinoma (LUSC), lung adenocarcinoma (LUAD), and small cell lung carcinoma (SCLC) from the NGS. miR-374a and miR-374b were selected for qRT-PCR validation of NGS. Due to safety risks with potential damage, a lab coat, gloves, and goggles were worn. qRT-PCR confirmed that miR-374a-5p and miR-374b-5p were downregulated in LUAD patient plasma samples. TCGA bioinformatics analyses showed that miR-374a and miR-374b were downregulated in LUAD and LUSC patient samples. Survival-fit analyses showed that low levels of miR-374a-5p and miR-374b-5p result in LUAD and LUSC patients having a lower probability surviving over time. Deep-learning neural networks were trained develop automated diagnosis of lung cancer based on histopathological images from available online datasets, with an accuracy rate greater than 95%. Discovery of these novel plasma and tumor miRNAs via potential simple blood extraction tests can be used in conjunction with automated deep-learning diagnosis for effective and rapid detection of lung cancer.

The Effects of Tap Water $CaCO_3$ on Kidney Health

Emily Atkins *Chesapeake Bay Governor's School*

A supply of drinking water is an important aspect of human health. Drinking water supplies must be safe and clean in order to protect those who drink it. Contaminated drinking water can cause severe illnesses, including cancers, neurological disorders, and reproductive issues. While hard water, which is water with abnormally high amounts of calcium or magnesium ions, is not deemed unsafe, it is known to cause health issues for many people. Hard water is known to cause kidney dysfunction when consumed over long periods of time. Kidney dysfunction is not usually life threatening, however it can lead to more serious, life-threatening illnesses such as diabetes, cardiovascular disease, and cerebrovascular disease. This study observed how tap water hardness affected the kidney health of homeowners in Tappahannock, Virginia. Tap water was collected from 21 different homes, then its hardness was tested using a Chemetrics titration kit. Residents completed a survey that asked about the severity of any kidney ailments they have been diagnosed with. In homes with healthy calcium carbonate levels, 22.22% of residents had kidney ailments of some kind, while 62.50% of residents of homes with very hard water had kidney ailments. On a scale of 1-5, the average severity of kidney illnesses in homes with healthy calcium carbonate levels was 1.82, while the average rating for homes with hard water was 2.5. the collected data was run through a standard t-test in order to check for significance. While data was not statistically significant ($p=0.058$), it was trending towards significance and would likely be significant if more data was collected.

Honorable Mention

The Effect of Comorbidities on COVID – 19 Mortality Rate

Jacob Bayer *Washington-Liberty High School*

This experiment was conducted with the goal of adding to the available information about the effects of certain comorbidities on COVID – 19 mortality rates in five separate age groups. The goal was to create an accurate summarized data table that is accessible to medical professionals and patients alike so they can understand the relative likelihood of death caused by the combination of 6 comorbidities and COVID-19 infection within five age groups. By collecting raw data from the Center of Disease Control (CDC) and converting it into summative data using a mortality rate conversion equation, the information was able to be analyzed. Initially the hypothesis was if a patient has a respiratory comorbidity, then they will have a higher mortality rate with COVID – 19. This hypothesis ended up being supported after the null hypothesis, comorbidities have no effect on COVID – 19 mortality rates, was rejected by the ANOVA test (as expected). This result was supported by several studies conducted which yielded similar results. One specific result that was notable was the extremely high mortality rate of influenza/pneumonia with COVID – 19 compared to the other five comorbidities.

Second Place

The Relationship Between Exposure to Fine Particulate Matter During Pregnancy and Preterm Births.

Malek Ben Hammouda *Washington-Liberty High School*

The purpose of this study was to test the correlation between exposure to fine particulate matter, commonly known as PM2.5, during pregnancy and the number of preterm births. The levels of fine particulate matter were measured using an Air Quality Index. The relationship between Air Quality Index scores and preterm births were examined using data from the Environmental Protection Agency and the Kids Count Data Center. The annual Air Quality Index scores and number of preterm births was recorded for seven of the states with the highest levels of fine particulate matter between 1999-2017, in intervals of every other year. The states used were Alaska, California, Pennsylvania, Oregon, Texas, Utah, and Washington. The hypothesis was: If Air Quality Index scores are associated with preterm births, then Air Quality Index scores will have a direct positive correlation with preterm births. A Pearson's R Correlation Coefficient was used to test the type of correlation between the annual Air Quality Index scores across the seven states and the number of preterm births in those corresponding states. The results showed a strong, direct correlation between the variables, leading to the acceptance of the hypothesis and the rejection of the null hypothesis. The standard deviation and the linear trendline showed somewhat high variability in the data, slightly decreasing the accuracy of the data.

The Effect of Mask Type on Ability to Block Droplets from Passing Through

Jonah Bierman *Washington-Liberty High School*

Covid-19 is a highly infectious strain within the coronavirus family which is transmitted through respiratory droplets when an infected person coughs, sneezes, or speaks in a close vicinity to others. The risk of contracting the disease while in contact with an infected person can be significantly minimized through the wearing of face masks. With the wide variety of masks that are commonly used, the purpose of this experiment was to determine which type of mask is most effective in blocking respiratory droplets from passing through the mask. The research hypothesis stated that if different types of masks are tested to determine which type allows droplets to pass the furthest distance beyond the mask, then the droplets sprayed through the KN95 mask will travel the least distance. The hypothesis was supported by the data, with the droplets sprayed through the KN95 mask averaging a distance of 0.0 cm, the surgical mask at 13.5 cm, the tight-weave cotton mask at 13.9 cm, the bandana at 26.0 cm, and the polyester neck gaiter at 116.4 cm, as compared to the control at 175.6 cm. Both an ANOVA and T-Test were conducted for further analysis. The ANOVA test returned a p-value of 7.96409E-48, which indicated that the results were statistically significant. The T-Test conducted between the surgical mask group and the cotton mask group however, returned a p-value of over 0.05, indicating that there was no significant difference between those particular groups. The experimental setup consisted of a standard spray bottle filled with water and food coloring, which was then sprayed repeatedly through each type of mask to replicate a human sneeze. Blank pieces of printer paper and a tape measure were placed in front of the mask as a method of measuring the distance in which the droplets traveled. The farthest droplet from the mask in each trial was recorded.

Honorable Mention

The Effect of Homeopathic Antifungals on Yeast CO2 Production

Sarah Bolles & Lucy Anderson *Washington-Liberty High School*

This experiment was performed to determine which homeopathic antifungal (coconut oil, oregano oil, or apple cider vinegar) would help inhibit yeast CO2 production the most. This experiment was conducted because of an interest in which affordable and natural antifungal is the most effective treatment for common topical fungal infections, such as jock itch and athlete's foot. The hypothesis was that if yeast was treated with a homeopathic antifungal, then the CO2 produced would indicate inhibited fungal growth due to the antifungal components of the homeopathic ingredients such as thymol, caprylic acid, and acetic acid. The null hypothesis was that if yeast was treated with homeopathic antifungals, then it would produce no more or less CO2 than the untreated yeast. This study was done using small jars with balloons secured to the opening of the jars. The yeast mixtures inside the jars were given 25 minutes to produce CO2, which would then inflate the balloons. The circumferences of the balloons were measured and used to compare the levels at which each type of antifungal inhibited yeast CO2 production. The data gathered allowed the null hypothesis to be rejected, since the antifungals tested had a statistically significant effect on the yeast. The hypothesis was supported with the data. All of the antifungals had a significant effect on the yeast, though oregano oil had the strongest effect. This experiment demonstrated that oregano oil is an effective and natural antifungal that inhibits yeast CO2 production at a statistically significant rate. Partnered with prescription antifungals, oregano oil can be an accessible and safe ingredient to treat minor fungal infections.

Analyzing Custom DNA Oligo Synthesis Using a Polymerase Chain Reaction to Target TGFR-Œ≤1

Madison Brown & Dhruvi Patel *Roanoke Valley Governor's School*

Once fibroblasts are settled in a tumor microenvironment, they go through cellular differentiation to form into cancer-associated-fibroblasts (CAFs). CAFs promote the tumor microenvironment and cancer metastasis through the production of transforming growth factor-beta-1 (TGFR-β1). Inhibition of this growth factor will provide an application for CAF-targeted cancer therapy. CRISPR-Cas9 is a powerful tool to edit DNA. The utilization of CRISPR-Cas9 can serve as a novel approach to CAF-targeted cancer therapy through genetic editing that results in TGFR-β1 inhibition. The gene TGFR-β1 was chosen to target due to its promotion of CAFs, and in turn, support of cancer metastasis and tumor microenvironment; inhibition of TGFR-β1 would mitigate this support. The purpose of this experiment was to successfully design custom DNA oligos to serve as a tool to knock-in GFP and target TGFR-β1. It was hypothesized that the PCR amplification of the DNA oligos would have been confirmed through the electrophoresis showing band lengths of 1.3-1.5kb. Oligos/homologous arms were designed to target TGFR-β1using ChopChop, an online web tool used for genome editing. Both the left and right oligos were diluted to a 10 µM concentration. 25 µL 2X Phusion™ Flash High Fidelity PCR Master Mix, 1 µL left homology arm, 1 µL right homology arm, 1 µL C-Puro GFP/C-Blast GFP (20 ng/µL), and 22 µL water were added into a PCR test tube. This process was repeated for twenty samples (ten for each donor DNA). The samples were placed into a thermal cycler. To confirm the PCR reaction, each sample underwent electrophoresis in a 1-2% agarose gel. There was no presence of bands from the expected 1.3-1.5kb range. This, combined with the presence of primer dimers, signifies that PCR did not successfully amplify the DNA samples.

The Effect of the Type of Cardiovascular Exercise on the Number of Calories Burned

Natalie Cecil *Washington-Liberty High School*

The purpose of this experiment was to determine the effect of the type of cardiovascular exercise on the number of calories burned. The hypothesis was that if several types of cardiovascular exercises were performed, then jumping jacks would burn the most calories because they have the highest intensity and use the most muscle groups. The hypothesis was tested by having a subject run across an area of no incline, bike across the same area, walk across the same area, and do jumping jacks. Each trial lasted 5 minutes, and the number of calories burned was calculated using heart rate. Jumping jacks had the highest mean number of calories burned, with an average of 61.2 calories burned. Running had the next highest average of 56.6 calories burned. Cycling had the next highest average of 53.7 calories burned, and walking had the lowest average of 30.3 calories burned. The p-value of the ANOVA test performed on the data was 2.09 x 10^-32, which showed a significant difference between the independent variable levels, meaning the null hypothesis could be rejected. The conclusion was that between jumping jacks, running, cycling, and walking, jumping jacks burn the highest number of calories. This information could be beneficial to people trying to lose weight by burning more calories. If they are trying to maximize the number of calories they can burn in a given time frame, jumping jacks are the best exercise.

The Effect of Hairbrush Design on Amount of Hair Collected

Allison Chen *Clover Hill High School*

This experiment was conducted to figure out the effect of using different types of hairbrushes on the amount of hair collected. The research hypothesis was that the Wet brush Original Detangler collected less hair than Conair: Conair Pro Hairbrush with Nylon Bristles, Revlon Soft Touch Nylon Pin Cushion Hairbrush, Tangle Teezer, the Original Detangling Hairbrush, and Xtava Natural Double Bristle Hairbrush. This experiment was conducted by using a pulley system to brush the hair eighteen times with each brush per trial. Following that, the hair strands collected are counted and recorded in a data table. The null hypothesis was rejected because the different types of hairbrushes did affect the number of hair strands collected. The research hypothesis was not supported because the Tangle Teezer collected the least hair out of all the brushes on average. On average, the Revlon Soft Touch Nylon Pin Cushion Hairbrush collected the most hair strands, followed by the Xtava Natural Double Bristle Hairbrush, the Conair Pro Hairbrush, the Wet Brush Detangler, and the Tangle Teezer the Original Detangling Hairbrush.

The Effect of Elapsed Time on the Thickness Level of Commercial Kefir as Measured by the IDDSI Flow Test and Framework

Charlotte Cunningham *Washington-Liberty High School*

The purpose of this experiment was to determine the effect of elapsed time on the thickness level of commercial kefir as measured by the International Dysphagia Diet Standardization Initiative (IDDSI) Flow Test and Framework. Kefir is a lactose-free fermented beverage made with beneficial bacteria. Despite its known health benefits and use with persons with dysphagia, there has been no prior study found on how the IDDSI Level of kefir changes over time. The hypothesis was that if the amount of time a glass of kefir is set out increases, the IDDSI Level will decrease as the drink warms and thus flows faster through the syringe. Three brands of commercial kefir, Lifeway, Green Valley, and Maple Hill, and three levels of milkfat, Nonfat (0%), Low fat (1%), and Whole Milk (3.25% and 3.5%), were tested in 5-minute intervals over an elapsed time period of 30-minutes. These intervals were important to notice changes in the IDDSI Level over time. Results showed that the hypothesis was partially accepted. As elapsed time increased, the temperature of the kefir increased, making it flow faster through the syringe. However, the overall IDDSI Level did not change within the 30-minute elapsed period. This experiment benefits persons with dysphagia or other swallowing disorders who need to consume liquid thickened to a specific level to avoid choking or aspiration. Based on this research, these persons could safely pour a glass of commercial kefir and consume it over a period of time knowing that the IDDSI Level would not change. All necessary safety precautions were taken. An extension of this project could involve a continuation of additional pours until the entire kefir bottle is empty and testing additional kefir brands and milk fat levels. Future work could survey and consult speech pathologists and hospitals on applying this research to their practice.

Left vs. Right Handedness: The Effect of Handedness on Aspect Chosen to Order Objects

Morgan Dalton *Southwest Virginia Governor's School*

It is widely known that the human brain's right and left hemispheres are in constant communication. The human brain also operates under functional asymmetry and hemispheric dominance; the left hemisphere has shown dominance in language and linguistics, while the right has shown strength in visuospatial recognition. Combining functional asymmetry and hemispheric dominance leads to the central question of this project: Is there a connection between handedness and how certain tasks are carried out? More specifically, is there a difference in how right and left-handed people order objects? To test this, randomly selected participants were sent a survey, which first asked them to state their handedness and gender and then to view 4 graphics. Each graphic contained 6 boxes either sorted in color, size, numerical order, or alphabetical order. By providing two aspects of visual ordering and two ways of value-based ordering, participants were given an equal representation of aspects prospected to be dominated by the right and left hemispheres, respectively. In the right-handed group of 26 participants, 22 chose size, 2 chose color, 1 chose alphabetical order, and 1 chose numerical order. In the left-handed group of 4 participants, 2 participants chose size, 0 chose color, 1 chose alphabetical order, and 1 chose numerical order. Results were analyzed using a Chi Square Test of Homogeneity that provided a p-value of 0.1398, which was insignificant at the 0.05 level, suggesting that the distribution of characteristics chosen between the right- and left-handed groups was the same. In future studies, larger representation of left-handed participants is very important, as well as testing other daily tasks, such as grouping, to discover how hemispheric communication and dominance may change from task to task, as well as with maturity of the human brain.

Honorable Mention

The Effect of Public Health Policy on COVID-19 Mortality

Maryam Elgindy *Washington-Liberty High School*

The purpose of this experiment was to understand if the preventative public health policies being implemented by states in the US were actually assisting in slowing the transmission of COVID-19. The question that was answered was what the effect of these public health polices was on COVID-19 mortality in the US. It was hypothesized that the policies would have an effect, because studies on public health and COVID-19 transmission have shown that mask-wearing and physical distancing play a role in slowing the spread of COVID-19. The independent variable was constructed by combining quantifies values of the policy measures implemented in each state of a three-month period. The first secondary independent variable, number of adults at risk of serious illness if infected with COVID-19, was defined as adults who had at least one NCD, or noncommunicable disease. The second secondary independent variable, the percentage of the state population who lived in urban areas, was analyzed as well because COVID-19 spreads faster in areas with high population density. The dependent variable was constructed as an average of the CDC reported excess deaths in each state during the same period, which was used instead of reported COVID-19 deaths to avoid error. A multiple linear regression was run, and the model was statistically significant, with a negative trend, meaning that as policy score increased, COVID-19 deaths decreased. This supports the hypothesis, and the null hypothesis was rejected.

Medicine & Health B (HS MDH-B)

The Effect of Antipsychotic Drugs on Patients Diagnosed with Schizophrenia

Skylar Farrar *Central Virginia Governor's School*

The purpose of this study was to determine how antipsychotic drugs affected heart function in schizophrenic patients. The hypothesis was that if clozapine, sertindole, and ziprasidone were tested, clozapine would most consistently affect the heart. This study was completed by reading online journals of studies that related to this topic; then gathering and combining data sets to utilize for testing. For the data, four groups of different receptor blockades were used, each one representing different effects of the medication. Each receptor blockade related to a different group of possible negative side effects of the three medications. A one-way ANOVA test deemed the results statistically insignificant with an alpha value of .05 and a p-value of .56. The results suggested that all three medications had negative effects on the patients' health, particularly their heart health. My hypothesis was not supported. In conclusion, none of the medications had a stronger effect than the other.

The Effect of the Occurrence of CD226 Gene Variants on the Death Rate of COVID-19

Kara Felker *Washington-Liberty High School*

The purpose of this study was to determine any role the CD226 gene plays in the severity of COVID-19. There were two independent variables: the CD226 polymorphisms rs73661 and rs727088. The IV levels were: two countries with ~66% mutated allele; two countries with ~50% mutated allele; and, two countries with ~33% mutated allele. The dependent variable was the death rate of COVID-19. The constants were the database used for each dataset (gene mutations and COVID-19 death rate) and the date used for the death rate of COVID-19. The hypothesis was: if the death rate of the countries with ~66% mutated allele is compared with the death rate of the countries with ~33% mutated allele, then the countries with ~66% mutated allele will have a higher death rate. This experiment was completed by compiling population samples of gene mutations for countries with several percentages of the mutated alleles and comparing the COVID-19 death rates of these countries. The data show that the countries with ~66% mutated allele of the rs73661 polymorphism had a higher death rate than the countries with ~33% mutated allele, however the countries with ~50% mutated allele had the highest death rate. For the rs727088 polymorphism, the countries with ~66% mutated allele had a lower death rate than the countries with ~33% mutated allele. These results reject the hypothesis. The null hypothesis was accepted. From the results, no conclusions can be drawn about the role of CD226 in the severity of COVID-19.

The Effect of Cellular Device Type on the Amount of Electromagnetic Radiation

Caroline Fern & Caleigh Sleeth *Washington-Liberty High School*

The purpose of this study was to identify the cellular device that emitted the most electromagnetic radiation when it received a phone call; thus, informing consumers of possible cancerous side effects stemming from such radiation. The devices tested included the Apple iPhone X, Apple iPhone 6, Samsung Galaxy S8, and the Jitterbug which acted as the control/generic phone due to its basic composition. For the experimental design, the cellular device was placed two centimeters away from an EMF meter and a call was made to the phone for a ten second span. The maximum milligauss amount reached in the ten second time period was recorded. This process was repeated a total of ten times on each cellular device. The hypothesis for this experiment is if the electromagnetic radiation from different phones is measured, then the Samsung Galaxy S8 will emit the highest levels of electromagnetic radiation. The results did not support the hypothesis. The Apple iPhone 6 emitted the highest average of 31.3 milligauss, followed by the Samsung Galaxy S8 which emitted an average of 21.9 milligauss. The lowest average was presented by the Apple iPhone X at 14.21 milligauss. To determine if the results collected were statistically significant an ANOVA test was conducted. In order for the results to be statistically significant the probability of obtaining a result or p-value must be less then 0.05. The calculated p-value for the experiment was 4.55 x 10-5 making the results statistically significant. As stated, the data collected demonstrated a contrast to the hypothesis. The reasons why are varied. For example, the iPhone 6 may have emitted the most due to its older composition compared to the more current device builds. Ultimately, this experiment can educate buyers when looking to purchase a new cellular device by providing data related to the amount of electromagnetic radiation emitted by various devices.

The Effect of Different Drinks on Electrolyte Content

Reagan Goodwyn *Mills E. Godwin High School*

The purpose of this experiment was to discover the effects of different drinks on electrolyte content. The results could be used by athletes or the everyday person at their local gym to replenish electrolytes lost through sweat. This could also help medical personnel provide the best drink for dehydrated patients. The nine levels of the independent variable were measured prior to being placed in 266mL plastic cups. The electrolyte content was found by measuring the conductivity with a conductivity meter. The control that was used in the experiment was bottled water. It was hypothesized that chocolate milk would have the greatest electrolyte content compared to bottled water, Gatorade, Powerade, Body Armor, Pedialyte, white milk, coconut water, and alkaline water. The results revealed that Pedialyte contained, on average, 3.4 µS/cm more than coconut water and more than the rest of the levels of the independent variable. A t-test was done on the data and it revealed that the data was significant for 35 out of the 36 comparisons but not significant for Pedialyte vs. the control. The results did not support the research hypothesis, likely because each drink consists of a different percentage of electrolytes. This research could lead to further studies that investigate different electrolyte elements and how different Pedialyte flavors may affect electrolyte content.

First Place

Using a Computational Model to Determine the Binding Ability of Selected Estrogen Derivatives to α- AND β- Type Estrogen Receptors to Prevent Amyloid-β Aggregations

Keren Czyra Gonzaga, Iqra Ahmad & Thu Luong
Governor's School@Innovation Park

Using a Computational Model to Determine the Binding Ability of Selected Estrogen Derivatives to α- AND β- Type Estrogen Receptors to Prevent Amyloid-β Aggregations Alzheimer's Disease (AD) is a progressive neurodegenerative disease affecting nearly six million individuals in the United States alone. Despite several advances in AD research since its discovery over a century ago, there remain no significant treatments or cures, and therapies are limited to alleviating symptoms. Estrogens — a class of multifaceted steroids best known for their role in female sexual development — are robust inhibitors of AD-causative Amyloid-β (Aβ) protein plaques. However, there is a lack of knowledge surrounding the molecular mechanisms enabling this promising yet inconclusive correlation. The present study aims to address this gap by utilizing a computational molecular modeling interface to visualize, model, and quantitatively assess and analyze the binding abilities between various natural and synthetic estrogens to the naturally occurring Estrogen Receptors (ERs) α and β. Using the molecular modeling software Schrodinger, selected estrogens and the ERs were prepared to undergo binding simulations carried out via the Ligand Docking task, which ultimately revealed the natural estrogen estetrol and the synthetic estrogen Cyclodiol — a derivative of estradiol — to have the best binding affinities. T-Tests were carried out between all pairings of test groups and revealed insignificance between estetrol and Cyclodiol at the 95% confidence interval, ultimately supporting the study hypothesis and answering the research question. Despite limitations stemming from in silico testing, the present study's findings, as well as further examination of the most efficiently-binding estrogens and their properties, can be used to develop a "super-estrogen" preventative therapy for AD pathogenesis.

The Effect of Suture Material on Dissolution Rate

Yasmine Groener *Mills E. Godwin High School*

Each day, doctors perform thousands of procedures that use sutures. The type of suture used depends on various factors, and when choosing a certain suture, one thing considered is how compatible the suture's absorbability is with how long the wound takes to heal. A study was done to test how long suture types would take to absorb to see which suture would be the best to use in procedures, requiring a short healing time. Finding this would allow for application of the information to real life procedures. The independent variable of this experiment was the suture material. A control was not used for this experiment because there is not a standard suture material used in the medical field. A hypothesis was formed that if silk, catgut, polypropylene, polyester, and nylon sutures were put in a solution to dissolve, then catgut would take the shortest amount of time to dissolve. There were 25 trials performed with each of the types of suture material, and the threads were then observed and recorded as absorbed (A), partially absorbed (P), or not absorbed (N). Throughout the experiment, the correct safety precautions were taken. As a result of the medium of silk being N, catgut being A, polypropylene being N, polyester being N, and nylon being N, it was determined that suture type did have an effect on dissolution rate. A chi-square test was performed with a degree of freedom of 2 and the level of significance was 0.05. This test showed the data was significant and the null hypothesis was rejected. Catgut was found to dissolve the quickest, which is due to it being made of natural fibers which can be absorbed. This data meant that the research hypothesis was supported.

Third Place

The Genetic Correlation Between Multiple Sclerosis and Various Autoimmune and Neurodegenerative Diseases

Holly Hinchy & Ella Bryant *Roanoke Valley Governor's School*

Those who struggle with autoimmune or neurodegenerative disorders may never experience the luxury of normalcy. The battle to understand and cure these types of diseases is ongoing, and although scientists can treat some symptoms, a full lifespan is not always guaranteed. This study aimed to better understand the genetic aspect of autoimmune and neurodegenerative diseases in the hopes of growing closer to potential cures. This study compared differentially expressed genes of multiple sclerosis (MS) to those of various autoimmune and neurodegenerative diseases, including psoriasis, rheumatoid arthritis (RA), Crohn's disease (CD), Alzheimer's disease (AD), Parkinson's disease (PD), and amyotrophic lateral sclerosis (ALS). MS is theoretically an excellent disease to use as a base because it falls under both autoimmune and neurodegenerative diseases. NCBI datasets for each disease were selected; afterward, each dataset was analyzed to determine the top differentially expressed genes in the affected tissues. The results were exported into CSV files. A Python program was created to compile all gene commonalities between diseases, recording the gene symbol, gene id, and expression type. Neurodegenerative diseases resulted in the most differentially expressed commonalities, such as HTR2A, SCN3B, and TRIM36, while autoimmune diseases possessed moderate commonalities, such as AQP9, C7, KYNU, and MPZL2. Despite the lack of notable commonalities between multiple sclerosis and other diseases, autoimmune and neurodegenerative diseases displayed commonalities, such as CDH13, RCAN2, AIM2, RAP3A, NETO2, DMD, CR1, MAOA, NR4A2, ADAM23, CD24, and CCN2 (CTGF). Overall, the results support the hypothesis that there are genetic linkages between neurodegenerative and autoimmune diseases.

Second Place

The Effect of Increasing Indoor Ventilation on Artificially Generated Aerosol Particle Counts

Ashwin Johri *Collegiate School*

The COVID-19 global pandemic has caused millions of infections and deaths despite mitigation efforts that involve physical distancing, mask-wearing, and avoiding large social gatherings. The number of cases, hospitalizations, and deaths soared following indoor holiday gatherings because of easy transmission of the virus through respiratory aerosols in poorly ventilated areas in homes. The purpose of this study was to compare ways to improve indoor ventilation and assess its effect on artificially generated aerosol counts. It was hypothesized that inbuilt kitchen vents would be more effective in reducing indoor aerosol counts than opening windows alone. A fixed amount of aerosol was generated with 3 milliliters of saline for 20 minutes using a nebulizer under constant temperature (21° C) and a narrow range of humidity (35-40%). A laser air quality monitor (particle counter detecting up to 0.5 microns) was used to record small particle counts every 30 minutes from baseline to 120 minutes in four scenarios that included: vent on-windows closed (Group 1), vent off-windows closed (Group 2), vent on-windows open (Group 3) and vent off-windows open (Group 4) for 10 trials each. The results of the study demonstrate that aerosol counts were lowest with the vent on and windows open. This study suggests that liberal use of home exhaust systems like the kitchen vents could achieve significantly more air exchange than open windows alone and may present an effective solution to improving indoor ventilation, especially during the colder months when people tend to congregate indoors in closed spaces. There were no safety concerns involved when conducting this experiment.

Honorable Mention

The Correlation Between a Country's Development, Unclean Fuel Use, and Prevalence of Respiratory Disease

Pranav Jothi *Central Virginia Governor's School*

The purpose of this study was to determine whether the development of a country correlated to the mortality rates from respiratory diseases while taking into account the use of unclean fuel sources. The hypothesis stated that if a country was less developed, then it would have higher mortality rates from respiratory disease due to unclean fuel use. Twelve countries were selected for each development category (underdeveloped, developing, developed), and percentages of the population using unclean fuel sources and the mortality rates from respiratory diseases were collected for each country. A regression analysis test was conducted on a list of all of the countries' unclean fuel use percentage to their mortality rates. There was a correlation coefficient of .84 and a p-value of 9.22 10-11, which was lower than the alpha of .05 and showed statistical significance. Then, a single factor ANOVA was run on a set of data that organized each country's mortality rates based on development. A p-value of 2.08 10-9 was found, which was lower than the alpha of .05 and showed statistical significance. Finally, a Tukey test determined that each group was significantly different as the difference between each of the means all exceeded the minimum difference (Dmin) of 19.04. Overall, the results suggested that as the development level of a country increased, the mortality rates decreased. The results supported the hypothesis as the lowest developed countries had the highest mortality rates as well as the highest percentages of unclean fuel use.

The Effect of Acidic Substances on Dental Erosion

Harleen Kaur *Mills E. Godwin High School*

A multitude of people consume acidic substances on a daily basis without understanding the negative effects they pose. This project evaluates the result of acidic substances on dental erosion. The initial idea was to compare as well as measure the true effects of the acidic substances on dental erosion by using eggshells to simulate teeth. It was hypothesized that if eggshells are submerged in high-sugar content acidic beverages, then this group will lose the most mass from start to end. All proper safety precautions were taken. To conduct the experiment, 100 eggshells were weighed (in grams) and brushed with toothpaste before being placed into four separate containers with 25 eggshells in each. The four independent variable levels (water, energy drink, orange juice, soda) were measured out and poured into their respective containers. The eggshells were removed 30 minutes later and were brushed 12 hours later. This process was repeated for 30 days. On the final day of the experiment the eggshells were weighed; and the mass of eggshells were subtracted from the recorded mass, measured in the beginning of the experiment. The results indicated that the orange juice had a greater impact on dental erosion than the energy drink, soda, and water. The orange juice had the greatest impact on the eggshells because it contained citric acid, which gave it the ability to soften dental enamel and demineralize it. Due to these results, the research hypothesis was supported by the data as the orange juice, being the acidic substance that had the most sugar content and induced the most mass loss. Overall, the data for the effect of acidic substances on dental erosion was statistically significant, implying that the results of this experiment were likely due to the independent variable, thus rejecting the null hypothesis.

The Effect of Different Lenses on Blue-Light Filtration

John Mario Kiely *Mills E. Godwin High School*

This experiment intended to determine if blue-light filtering lenses transmitted a significantly lesser percentage of blue-light compared with regular lenses. The increased use of screens emitting blue-light in an ever more virtual world have called into question the effectiveness of blue-light glasses, which filter excessive blue-light from the eyes. Blue light from a computer screen was transmitted through three types of lenses (sunglasses, blue-light, and regular), and the percentage rates of transmission were recorded via a spectrometer. It was hypothesized that the blue-light glasses would transmit less blue-light than the control lenses, and the results revealed that they filtered 78.5% more light than them. Furthermore, the t-test performed on the data indicated that every level was significantly different from each other. They supported the research hypothesis and were most likely due to the independent variable and not chance or error. They could be explained by the fact that blue-light filtering lenses sincerely reduce the transmission of most blue-light.

Blue-light is a component of natural sunlight and is important in keeping humans awake and rejuvenated during the day, and its absence at night lets the body produce the sleep-inducing hormone melatonin. Nevertheless, what needs to be examined further is not whether the glasses actually filter the blue-light, but rather if blue-light causes eye strain and disrupts the circadian rhythm and sleep cycle or if simple daily habits and more precautions with superfluous screen time hours are more effective.

The Effect of Soluble Factors on turning Stem Cells into Kidney Cells

Sricharan Lankalapalli *Mills E. Godwin High School*

The purpose of the experiment was to study the effect of soluble factors on turning stem cells into kidney cells. The field of medicine is evolving and extending the human life span. Advancements in medicine have given multiple solutions to treat organ failures, yet many must wait over a decade to get a transplant due to the lack of donors. The most common transplants in the world are kidney transplants. Success in Bioengineering has created new possibilities in the field of transplantation using stem cells. In this experiment, we researched the effects of soluble factors on stem cells, explicitly with the creation of kidney cells. By looking at the amount of signaling shown by the soluble factor within a kidney, an estimation of the best microenvironment for the stem cells can be created. In specific, the soluble factors that are evaluated within this experiment are Retinoic acid receptor alpha, transforming growth factor-alpha, transforming growth factor-beta, Activin A, and Platelet-derived growth factor, which will each be tested over six kidneys. The research hypothesis that was formulated is that if the cell is exposed to Retinoic acid, then it will produce the most signals that indicate kidney cells. There is no control in this experiment due to there being no original value for comparison. Only one of the independent variables, Activin A, was significant. Results did not support the hypothesis but mostly supported the null hypothesis. This experiment could not prove if data were not by chance.

Honorable Mention

Differential Expression of Genes Associated with Innate Immune Cell Function in Individuals with and without Alpha-gal Syndrome

Katerina Leedy *Blacksburg High School*

Alpha-gal Syndrome (AGS) is a unique, IgE-mediated allergy to the galactose-α-1,3-galactose (alpha-gal) glycan found primarily on glycoproteins and glycolipids in red meat and some medications. A strong association between bites from the Lone Star Tick (*Amblyomma americanum*) and development of AGS has been shown in the United States. Little is known about the immune mechanisms that cause AGS. Recent research identified differences in gene expression relating to antigen presentation, antigen-experienced T-cells, and type 2 immune responses between subjects with AGS, subjects sensitized to alpha-gal, and control subjects. However, investigation of gene expression relating to innate immune response has not been performed. I analyzed secondary data from this recent research to determine the transcriptional differences relating to cytotoxicity and Natural Killer (NK) cells, two parts of the innate immune response. Out of the 28 genes included in the dataset relating to NK cell function, 4 showed statistically significant differences in gene expression between the AGS and control groups when compared through 1-way ANOVA. Compared to control subjects, AGS subjects demonstrated upregulation expression of genes associated with the production of interferon-gamma (IL18, IFNG) which plays a role in stimulation of both innate and adaptive immune responses. AGS subjects also demonstrated a lower expression of genes coding for receptor proteins known to play a role in stimulation of NK cell cytotoxicity and amplification of T cell activation (KLRK1, CD2). No statistically significant differential gene expression associated with cytotoxicity pathways were found between the AGS and control groups. Subjects with AGS did not show distinct differences in gene expression primarily characteristic of the innate immune response.

The Effect of Proximity and Particles Exhaled Based on Breath Rate on the Number of COVID-19 Virus Particles Accumulated

Anne Licato *Washington-Liberty High School*

In early March of 2020, the COVID-19 pandemic overtook the world. Since then, the CDC and other public health organizations have stressed wearing masks and remaining 6 feet apart from others to help prevent the spread of the virus. They have also encouraged citizens to not go to places such as grocery stores and pharmacies unless it is absolutely necessary. Preventing the spread of COVID-19 is key to fewer people getting infected and potentially dying from the deadly virus.

The purpose of this experiment was to determine how many COVID-19 virus particles were accumulated by ten people standing in a line at different proximities to an infected person and by the position of the infected person in the line. The hypothesis for this experiment was if a person with a higher breathing rate was infected with COVID-19 and they stood in a line with a proximity of 1.5 feet to the people around them, then the people around them would accumulate more COVID-19 virus particles, because the infected person had a higher breathing rate, and they were standing closer to the people around them. The breathing rates for all simulated persons was randomized and the number of particles exhaled and inhaled per person was calculated. The number of virus particles accumulated based on the infected person was then calculated. The results found that when infected, position 4 caused the most spread of virus particles. It was also found that the greatest accumulation of virus particles for distances and positions, occurred when position 9 was infected and stood 6 feet apart. All data was statistically significant, however the breathing rate of the infected person had little to no effect on virus particles accumulated. Therefore, the null hypothesis, if a person with a higher breath rate is infected with COVID-19 and they stand in a line with a proximity of 1.5 feet to the people around them, then the people around them will not accumulate more COVID-19 virus particles is partially accepted.

Neuro Sense: A Quantitative, Cost-Effective, and Portable Device for Early Detection and Nonpharmacologic Treatment of Diabetic Neuropathy

Alan Mach *Ocean Lakes High School Mathematics and Science Academy*

Among diabetic patients, diabetic neuropathy stands as one of the most common complications. Diabetic neuropathy is a severe, yet relatively unobtrusive disease that damages the nerves, leading to the potential for more severe consequences, such as paralysis or the need for amputation. However, few options exist for early detection and tracking of diabetic neuropathy, as nerve damage is not easily quantifiable. In this study, the efficacy of a self-made detection and tracking system was evaluated. To effectively detect diabetic neuropathy in its early stages, a quantitative process must be developed. To accomplish this goal, a sensor for blood flow was programmed to track parameters that correlate with the presence of neuropathy to a very high degree. A total of 12 volunteers (5 males, 7 females; age 45 16 years) participated in the study with varying levels of diabetic neuropathy. Each volunteer was tested by the device once per day for five days. Raw data from these trials were simultaneously run through a program that computed a diagnosis of diabetic neuropathy for the patient. Patients determined to have any severity of diabetic neuropathy were referred to a specialist for further action. Overall, blood volume change over time was the parameter most successful in trials, accurately diagnosing diabetic neuropathy for 57/60 trials and all patients. However, the relative accuracy of other parameters suggests that a quantified diagnosis of diabetic neuropathy should likely include multiple parameters. The creation of the device depicts the possibility of the development of a commercial device for tracking diabetic neuropathy among all diabetic patients, as the model showcases future affordability and utility that can be implemented in a future medical device. With refinements and commercialized production, this device could provide a convenient, comfortable, and cost-effective tracking method for those in the diabetic community.

Honorable Mention

The Effect of Chemically Active Skincare Products on the Zones of Inhibition of Propionibacterium acnes

Lantz Martin *Central Virginia Governor's School*

The purpose of this research experiment was to determine the efficiency of chemically active skincare products on the zones of inhibition of Propionibacterium acnes. Using 10% Azelaic Acid Booster and 2% BHA (salicylic acid) Liquid Exfoliant, discs were created to measure the zone of inhibition on P. acnes. A total of 27 trials were run in this experiment. Once the zones were created, they were measured in millimeters and analyzed. From the analysis, it was discovered that the Azelaic acid had the greatest average zone of inhibition at 19.636mm, Salicylic acid had an average zone of 13.8235, and the control had an average of .0. Two different tests were used on the experiment's results. First, an ANOVA test was run with an alpha value of .05. This resulted in a p-value of 2.00x10-54, which established the significance. To determine where the significance lay, a Post Hoc Tukey was run. This suggested that each individual group was significant from every other group. This analysis supported the research hypothesis that Azelaic Acid would create significantly larger zones of inhibition than Salicylic Acid and the control. In conclusion, Azelaic acid had the greatest effect on P. acnes inhibition, with salicylic acid coming in as a close second.

Medicine & Health C (HS MDH-C)

Examining Potential for Prognostic Predictions by ALS Biomarkers using Neural Networks

Vaibhavreddy Maru *Mills E. Godwin High School*

The purpose of this experiment is to examine various ALS biomarkers for potential as prognostic indicators using Neural Networks. This has implications because many ALS patients die within 3-5 years, and it could be extremely beneficial if biomarkers can be used to stratify patients by how much resources need to be allocated based on the disease progression. The PRO-ACT database, the largest ALS database, was used to gather data for biomarkers creatinine, bilirubin, and neutrophils. Using TensorFlow, a Neural Network model was created and trained to predict the ALSFRS-R scores for each subject. All models were created in a well-lit, safe environment under the supervision of an adult. It was hypothesized that the mean absolute errors for all three biomarkers would not differ significantly, and this was supported due to the results. The average mean absolute errors for each of the biomarkers were close, and t-tests yielded that the results were not significant, thus supporting the hypothesis. These findings are significant since they suggest that bilirubin and neutrophil count have potential as prognostic biomarkers. Obtaining these clinical results is relatively cheap, non-invasive, and fast compared to other biomarkers obtained through cerebrospinal fluid, MRI scans, or PET scans. These results could be due to bilirubin and creatinine being part of oxidative stress, an established cause for ALS. Neutrophils inhibit neuronal repair, thus likely causing the progression of the disease. Other researchers have made models for ALS disease progression; however, this experiment is unique in that it compares various easily attainable biomarkers. Psychological moods could be investigated as a biomarker for ALS for further research since few studies have focused on mental health biomarkers for ALS and bilirubin has been lined to psychological stress.

Third Place

The Effect of Third-Hand Smoke (min) on the heart rate of *Daphnia magna* (bpm)

Maggie Matzen *Clover Hill High School*

The purpose of this experiment was to determine the effect of third-hand smoke on the heart rate of *Daphnia magna*. Knowing the dangers of third-hand smoke can allow smokers to better protect those around them from exposure. The smoke of one cigarette was sucked into a chamber. After the smoke sat in the chamber for 2 minutes the Daphnia were exposed for the desired time. The heart rate was measured with a microscope manually. The five levels of the independent variable were control, 2 minutes, 5 minutes, 10 minutes, and 15 minutes. The heart rate was recorded in a table, and different heart rates were collected until each level had 10 trials. The control group (no exposure) had a mean heart rate of 172.4 beats per minute. The group exposed for 2 minutes had an average heart rate of 242.0 bpm. The group exposed for 5 minutes had an average heart rate of 297.2 bpm. The group exposed for 10 minutes had an average heart rate of 315.6 bpm. The group exposed for 15 minutes had an average heart rate of 330.5 bpm. After the data collection, an ANOVA test was conducted to test if the data was statistically significant. The results of the ANOVA test stated that there was a statistically significant difference between the levels of the independent variable because the F value was greater than the F Critical value. The experimental hypothesis was that third-hand smoke would increase the heart rate of *Daphnia magna*. This was supported.

The Effect of Obesity on Drosophila Reproduction

Jessica Medlin *Chesapeake Bay Governor's School*

Obesity rates have been steadily increasing since the 1970s. These increasing obesity rates are especially high in the United States, and prevalent in all genders and all ethnic groups. Obesity is becoming one of the largest contributors to ill health, replacing even infectious diseases. Moreover, in the United States, obesity is one of the leading causes of death. It seems that this new, over nourished American population could be potentially dangerous for more reasons than just a reduced quality of life. It is known that obesity affects mental health and physical health, but it could possibly be affecting reproductive ability also. Reproductive rates have been steadily decreasing over the years, reaching an all-time low in 2018. However, it is undetermined if the increasing obesity rates and decreasing reproductive rates are related.

Drosophila, or fruit flies, were chosen to conduct an experiment that tested if obesity affects fertility rates. The fruit flies were separated into three groups- underfed, regularly fed, and overfed fly pairs. All of the flies received the same type of food at the same time and were given the same environment to inhabit during the experiment. Data was taken on ten mating pairs from each feeding group based on the number of eggs found that were produced by each pair alone. After running several tests, the data was statistically highly significant. It found that overfed flies had the lowest reproductive rates out of all three groups. With this information in mind, it would appear that being overfed or obese does affect a Drosophila's ability to reproduce; and possibly could be the reason for the decreasing reproductive rates in humankind also. To see if obesity does affect human reproductive rates, future experiments on humans would have to be conducted. These types of studies could potentially help the ever-growing issue that is obesity

Honorable Mention

Comprehensive Computational Genomic Analysis of 1,134 Samples to Understand Genomic Alterations and Their Influence on Outcome in Colorectal Cancer: A Retrospective Study

Anju Natarajan *Collegiate School*

Colorectal Cancer (CRC) is a growing concern in the world and is steadily rising in incidence. Investigating the genomic and clinical characteristics of data is imperative to discovering actionable and clinically relevant findings to expand knowledge about CRC. Analyses resulting from this retrospective study include both univariate and multivariate models regarding overall survival (OS) for certain clinical and genomic features within the cohort. In addition, novel analyses regarding TP53 (p53) codon sites and metastatic site enrichment were conducted, and machine learning (ML) models were used to predict whether a patient would have a p53 mutation based on a specific clinical profile with the data available. All 1,134 samples experimented upon were downloaded from the 2018 Metastatic Colorectal Cancer cohort on cBioPortal for cancer genomics (Yaeger et al, 2018). Kaplan-Meier curves and Cox Proportional Hazards models were created to analyze clinical and genomic features and their association with OS. Significant features include age at diagnosis, metastasectomy status, primary tumor location, gene alterations in specific genes such as APC, KRAS, and more. K-Nearest Neighbors and general logistic regression models were used to predict the presence of a p53 mutation, each with an accuracy of 74.74% and 76.76% respectively. These models indicating potential predictors for p53 mutations in CRC are key to the process of cancer diagnosis and treatment; they can help identify biomarkers and clinical attributes after DNA sequencing and can be used to assess the aggressiveness of a patient's cancer, therefore enabling targeted clinical care. With more refined and evenly distributed data, the existing accuracy scores can be improved upon, and further research and models of p53 and its codon sites using cleaner data is warranted.

The Effects of Information Source on Acceptance of COVID-19 Vaccine

Kimayah Nelson *Portsmouth STEM@I.C. Norcom High School*

The purpose of this project is to distinguish between students, teachers, and faculty members whether they would take the Coronavirus vaccine. The hypothesis stated people who watch the local news would be more likely to be excited to get vaccinated than the people who get their sources from friends, associates, or an online source. Of the 109 people that took the survey (76 were students, 33 were adults), 62% of the students said they would not take the vaccine, and only 24% of the adults said they would not. These results lead me to believe there may be a correlation to education level as well, which was not a question asked in the survey. The information that was revealed in this survey proves the hypothesis, but with the knowledge that there is more to investigate and with ideally, a lot more adult participants.

The Effect of Different Liquids on Dissolving Time of Iron Supplements

Manushi Nepal *Mills E. Godwin High School*

The purpose of this experiment was to see the effect different liquids had on the dissolving of iron supplements. Iron supplements are the usual treatment for anemia, and while they are generally taken with water, taking them with different liquids has the chance to enhance iron absorption for anemic people through faster dissolving rates. It was hypothesized that orange juice would cause the supplements to dissolve faster than the other 2 liquids. Three groups of 25 iron tablets were either exposed to orange juice, tomato juice, or tap water. They were placed in these liquids and the time taken for them to fully dissolve was recorded. The control in the experiment was the group of tablets exposed to tap water. On average, the tablets in water took the least time to dissolve, while tomato juice took the most. A t-test was performed on this data, and it showed that the data was significant for all three tests. The results for this experiment did not support the hypothesis. From analysis, it is believed that the experiment produced these results because water is a universal solvent, and many solutes can dissolve in it. This research could inspire future studies focusing on creating an experiment to mimic the human body to observe iron absorption instead of dissolution.

Using Raman Spectroscopy to Identify Bladder Cancer Biomarkers

Lacey Ngo *Roanoke Valley Governor's School*

The purpose of this experiment was to see the effect different liquids had on the dissolving of iron supplements. Iron supplements are the usual treatment for anemia, and while they are generally taken with water, taking them with different liquids has the chance to enhance iron absorption for anemic people through faster dissolving rates. It was hypothesized that orange juice would cause the supplements to dissolve faster than the other 2 liquids. Three groups of 25 iron tablets were either exposed to orange juice, tomato juice, or tap water. They were placed in these liquids and the time taken for them to fully dissolve was recorded. The control in the experiment was the group of tablets exposed to tap water. On average, the tablets in water took the least time to dissolve, while tomato juice took the most. A t-test was performed on this data, and it showed that the data was significant for all three tests. The results for this experiment did not support the hypothesis. From analysis, it is believed that the experiment produced these results because water is a universal solvent, and many solutes can dissolve in it. This research could inspire future studies focusing on creating an experiment to mimic the human body to observe iron absorption instead of dissolution.

Investigating Alternatives to Conventional Chronic Kidney Disease Treatment Through Analysis of Differential Gene Expression

London Paige *Roanoke Valley Governor's School*

Chronic Kidney Disease (CKD) affects about 37 million adults each year. CKD treatment costs about $22,000 annually per person, which does not include an additional $80,000 for treatment if the condition progresses into End-Stage Renal Disease. Treatment varies due to APOL1 variants and histopathological states. This experiment explored a treatment option for high-risk CKD patients. Datasets on in the NCBI GEO database were analyzed using GEO2R. One dataset contained gene information for individuals with different variants (G0G0 and G1G1 were compared) and another focused on African American biopsy patients with different pathologies (Minimal Change Disease and Focal Segmental Glomerulosclerosis were compared). Another dataset that was analyzed determined gene expression of CKD patients with and without a paricalcitol treatment. A paricalcitol treatment was chosen for analysis because it is a Vitamin D analog that decreases proteinuria. About 50% of people of African descent have one or both risk alleles, hence why African Americans experience CKD more often than other racial groups. Therefore, this experiment explored a possible treatment option that has linkage to Vitamin D deficiency and CKD. After the lists of the top 500 differentially expressed genes were analyzed, it was determined that each list contained FERD3L. This gene is of particular interest because the FERD3L protein inhibits transcription of genes with an E-box sequence in the promoter, meaning in can impact a range of downstream effects. FERD3L was under-expressed in the CKD patients, but it is upregulated in the paricalcitol study, indicating that it may be an effective treatment.

The Effect of Virgin Coconut Oil on Regeneration Rate of *Dugesia tigrina*

Ponnarasi Rajakumaran *Mills E. Godwin High School*

The purpose of this experiment was to research whether coconut oil influences the regeneration of planaria. Recently, the demands for traditional medications, such as Ayurveda and Chinese Traditional Medications, in the market has become increasingly higher. Coconut oil has been studied as a possible wound healing treatment in the ulcer wound of diabetic mice and had a positive impact on the regeneration rate of the mice's skin tissue. Coconut oil may have the same impact on planarian regeneration. Planarian were treated with coconut oil either before or after dissection. The planarian were given seven days to grow and their height was measured on day one and on day seven. The control that was used in the experiment was the planarian that received to coconut oil treatment after dissection. It was hypothesized that applying coconut oil after dissection will result in a much faster regeneration rate than receiving no coconut oil application and those who receive coconut oil prior to dissection. The results revealed that planarian treated with coconut oil after dissection grew 0.5mm, on average, more than the planarian which received coconut oil prior to dissection and the control. A t-test was done on the data, and it was concluded that the data for coconut oil after dissection vs. control was significant but not significant for coconut oil prior to dissection vs. control or coconut oil prior to dissection vs. coconut oil after dissection. The results did not support the research hypothesis. It is believed that the results are because coconut oil interactions can cause inactivation of bacteria, viruses, and fungi, and stimulate antioxidant production, helping the skin heal faster. This research could lead to further studies that investigate how coconut oil could be incorporated as burn wound healing treatment and how coconut oil battles against specific bacteria such as *Staphylococcus aureus* that are commonly found to infect wounds in the skin.

The Effect of Plant-Based Metabolites on the Binding Affinity between the ACE2 Receptor and the Prefusion Spike Glycoprotein

Divya Ramakrishnan, Soneha Datta & Hermela Tadesse
Governor's School@Innovation Park

Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) is responsible for the current COVID-19 pandemic. At the start of this research study, there were no released drugs or vaccines for the treatment and prevention of SARS-CoV-2. Furthermore, little research was done on the preventative effects of herbs. Therefore, this study's goal is to determine whether plant-based metabolites inhibit or neutralize the virus, lowering the risks it poses on the general population. By using herbs, the public has an affordable, accessible, and inclusive preventative treatment option. The hypothesis is if the binding affinity between the ACE2 receptor and metabolites and the prefusion spike glycoprotein and metabolites are calculated, then docking value will be higher on average between the glycoprotein and the metabolites, because this protein has a larger active site. The computational software Schrodinger was used to prepare all molecules, dock each metabolite to each protein, and calculate the strength of the bind using docking scores. A T-Test was utilized to analyze the docking scores produced. There is a significant difference between the population mean of 16 out of 23 metabolites binding with the ACE2 receptor and the prefusion spike glycoprotein ($p < 0.05$). This signifies the prefusion spike glycoprotein binds to metabolites stronger that the ACE2 receptor does. Therefore, our hypothesis was supported. In the future, testing the binding affinity between the metabolite and glycoprotein compound to the ACE2 receptor, testing more metabolites, and binding metabolites to different receptors will broaden this study's potential in successfully mitigating SARS-CoV-2's effects.

Honorable Mention

Effects of Supplemental Oxygen on the Regeneration of Planaria

Leanne Ranger *Central Virginia Governor's School*

The purpose of this study was to determine if supplemental oxygen had a significant effect on the regeneration of Planaria. There were two groups: oxygenated Planaria and ambient Planaria. The ambient and supplemental oxygen were transported into the flasks via aerators and tubing. The supplemental oxygen was chemically produced with 150 mL of 12% Hydrogen Peroxide and ⅔ oz. of yeast. A dissolved oxygen probe was used to measure the amount of dissolved oxygen that was in each of the flasks before and after the experiment each day. A two sample T-Test was performed on the averages (13.04 mg/L and 8.43 mg/L) of dissolved oxygen for the oxygenated and ambient groups. The data was significant with a p-value of 5.6x10-8 and an alpha value of .05. Another two-sample T-Test was performed on the before and after lengths of the Planaria. The data for this test was also significant with a p-value of .00207 and an alpha value of .05. Since both tests were significant, the research hypothesis was supported in that the group with supplemental oxygen did regenerate longer during the two weeks of supplementation. Planaria have similar organ structures and cells to Homo sapiens. Planaria and Homo sapiens have triploblastic cells, meaning they both have an endoderm, mesoderm, and ectoderm layer. Since they are similar, the Planaria results were able to be compared to Homo sapiens. The results of this experiment could help improve people’s lives by helping them with endurance and lung complications.

Honorable Mention

The Effect of Breast Cancer Medications on Various Body Tissues of Patients

Elina Rastegar *Mills E. Godwin High School*

As a worldwide public health dilemma, breast cancer has raised concerns among scientists due to its global rapid increase. Reputable healthcare organizations have recently announced breast cancer to be a modern, deadly epidemic among women. This experiment was designed to study the effects of breast cancer treatments on organs, including the lung, heart, brain, colon, liver, and kidney. The objective of the study was to contribute to society's health by providing information on the effects of chemotherapy drugs on vital human tissues in the hope of reducing mis prescriptions that could harm patients.

The following safety procedures were practiced to reduce visionary risks accompanying the experiment: sitting approximately two feet away from the computer screen, using a matte screen filter and soft lighting, taking frequent breaks, and wearing monofocal glasses.

Using two online databases, the effect of 15 breast cancer drugs on human tissues was examined by comparing the targeted and similar proteins' amino acid sequence and the abundance of the similar proteins in the studied organs. A ranking system was developed to compare the effects of the drugs on each tissue. Based on the data, the brain was the most affected tissue by the studied drugs, rejecting the research hypothesis, which predicted the heart and the lung to be the most affected tissues. The chi-square test performed revealed the data for the lung, heart, and brain to be statistically significant. However, the colon, liver, and kidney data were proven not to be statistically significant.

It was concluded that breast cancer drugs have varying effects on different human organs that could interfere with patients' health. Further investigations could be done with other chemotherapy drugs and different body tissues to expand upon the research.

Second Place

RayGAN: Employing Generative Adversarial Networks for 3D Human Anatomy Reconstructions from Planar 2D X-Rays

Pranav Ravella & Swesik Ramineni
Thomas Jefferson High School for Science and Technology

Precision and accuracy are essential in orthopedic surgery, as the potential damage to surrounding tissue and the nervous system is a grave hazard. Solutions to combat this problem, such as methods aimed at enhancing pre-operative planning and robotic applications used during operation, require a considerable amount of time, cost expenditure, and harmful radiation content. For example, the industry standard for detailed pre-operative planning is a Computed Tomography (CT) scan that provides three-dimensional data (3D), but this has a high patient cost, requires incident exposure to radiation and takes an immensely long time to generate results (around thirty minutes). As a result, such imaging and technology that relies on CT scans cannot be used for every patient. This problem compounds further in orthopedic trauma surgery, where surgeons only have a matter of seconds for pre-operative planning. With RayGAN I aim to create an end-to-end system that utilizes Generative Adversarial Networks (GAN) to construct a 3D rendered reconstruction of orthopedic operation sites from only preliminary X-Ray images. By utilizing a combination of a GAN, ElectronJS, Redis, and Firebase, RayGAN provides surgeons access to such a reconstruction in fifteen seconds, where the output can be synthesized in a 3D print or a Virtual Reality (VR) environment for better pre-operative planning. Through RayGAN I can enable orthopedic surgeons to achieve greater precision and accuracy during surgery, alleviate radiation exposure, significantly decrease cost and time taken for results, and enable every patient to receive the same degree of success during surgery.

First Place

The Effect of Children's Helmet Cost Variance (USD) on Mass Deviation (g) from Simulated Skull Impact

Charles Redding *Clover Hill High School*

Traumatic Brain Injury (TBI) is common among adults and athletes but may be extremely dangerous when inflicted upon children. The effects of TBI can include short-term pain or concussions but can also cause major cell and structural damage that may induce long-term complications on a developing brain. For these reasons, finding effective and consumer-friendly head protection for children remains critical. The Effect of Children's Helmet Cost Variance (USD) on Mass Deviation (g) from Simulated Skull Impact examined the correlation of helmet purchase prices to the mean mass change in a simulated skull. Four helmets of varied price points ($24.99, $29.99, $35.99, and $49.99) were studied by dropping a 4.53 kg bowling ball on different positions of the helmet. Each helmet was hit at the Top, Right, Left, Front, and Back position ten times. The research hypothesis stated that the most expensive helmet ($49.99) would provide the most protection (smallest change in mass) to a simulated skull. The results paralleled the research hypothesis, with the $49.99 helmet providing a 1, 1.1, 1, 1.1, 1.1 change respectively (g). Statistical testing did not reject the null hypothesis. However, the visible damage to both the helmets and melons clearly determined which helmet provided ample protection. This experiment effectively determined the most protective and cost effective helmets.

Honorable Mention

The Effect of Different Types/Brands of Water on Avocado Root Length

Ryann Remias *Clover Hill High School*

The purpose of this experiment was to determine the effect of different types/brands of water on avocado root length. By determining which type/brand of water best supports avocado growth, this information can be applied to the general public in the sense that this experiment will determine which type/brand out of the waters tested best sustains life. The hypothesis was that the most expensive brand of bottled water, Fiji water, would best promote avocado seed root growth. The avocado seeds were placed into cups and lined up in 5 rows, with 12 seeds each for 12 trials per type/brand of water. Each row was assigned a different type of water, and 237 mL of the assigned kind of water was poured into the cups at the beginning of the experiment. Water was replaced as necessary. The seeds were exposed to sunlight and the growth of their roots was measured over 7 weeks, recorded once every week. Avocado seeds that were treated with all types/brands of water except for Voss water exhibited growth over the 7 weeks (after 3 weeks). The seeds treated with Fiji water grew the most over the period, and the seeds treated with Voss water grew the least. An ANOVA test was conducted to determine if the data was statistically significant. The null hypothesis was not rejected and therefore the data was determined non-statistically significant.

The Effect of Different Types of Tinted Sunscreens on How Much llght Goes Through a Solar Panel Measured in Kilowatts

Sofia Reyes *Washington-Liberty High School*

This experiment is the effect of different types of tinted sunscreens on how much light goes through a solar panel measured in kilowatts. The initial purpose of this experiment was to provide data on which topical tinted sunscreen would block the most sun from the solar panel, which simulates human skin. The more sunlight blocked would hypothetically mean the less sun damage taken. In order to conduct this experiment, a 20-watt solar panel was placed in direct sunlight, and three different types of tinted sunscreen would be applied on the solar panel in an even layer. A digital multimeter would measure the kilowatts the solar panel was receiving to find out if any light was going through at all.
The Amavara Tinted Mineral Sunscreen blocked the most sunlight, the average amount of light in watts being 17.47 compared to the 18.55-watt control. There was a significant difference in the results with the p-value being less than 0.05, meaning the data was accurate and the null hypothesis could be rejected. Overall, the data was accurate, and the null hypothesis could be rejected. Tinted sunscreen works to block visible light, which can protect skin from dangers like sunburn or skin cancer, all of which spawn from over exposure to visible light.

Medicine & Health D (HS MDH-D)

The Right Mask for the Task: The effect of different face masks on the expelled droplets or particles

Zahra Rizvi *York High School*

According to the Centers for Disease Control and Prevention (CDC), masks are a simple yet powerful barrier to help prevent respiratory droplets from reaching others. The N95 mask is the most effective defense against the spread of COVID-19 virus. However, the N95 masks are critical supplies that must continue to be reserved for health care workers and other medical first responders. Therefore, alternative fabrics are being discussed to overcome this shortage of effective masks. Some researchers have suggested masks made of silk to be quite effective when it comes to blocking the expelled particles or droplets. The objective of this paper is to investigate which type of face covering is most effective in preventing expelled droplets or particles from transmitting. More specifically, this paper aims to find out if masks made of silk are the best among all the available non-N95 masks. The hypothesis is that a face mask made of silk will have lower transmission of expelled droplets or particles than other types of non-N95 face masks/coverings. A novel and inexpensive experiment was designed and executed to test this hypothesis. To the best of my knowledge, this is for the first time such a method has been used to identify, record, and measure the number of expelled droplets/particles for testing such type of face mask-oriented hypothesis. On different types of face masks or coverings, a hair dryer was used to spray saliva mixed with a material that can glow in the dark. The expelled droplets or particles that come out from the other side of masks were then allowed to stick and settle down to a clean glass face surface. The volume of expelled droplets/particles were recorded using a camera technique under a UV light. To prevent eye damage when dealing with UV light, UV safety glasses were worn. In this experiment, the less the expelled droplets or particles for a face mask or covering, the superior the face mask/covering was considered. This experiment has given new and valuable insights in understanding the extent to which a specific mask type can prevent droplets or particles from transmitting. It was observed that some face masks were more effective than others in blocking droplets. Clearly, the N95 was the most superior mask. The surgical mask performed better than the mask made of silk. Therefore, the hypothesis was proven wrong. This experiment highlighted that silk face coverings possess properties that make them capable of blocking the spreading of expelled droplets or particles. The research is quite relevant, given the official global death toll has now exceeded 2.6 million people as of early March 2021, and as many places around the United States begin to reopen, the CDC strongly recommends wearing a face covering in public, whether going to the grocery store or the park.

First Place

Comparing the Antimicrobial Efficacy of Hand Sanitizers on *Staphylococcus epidermidis* and *Escherichia coli*

Avery Roark *Central Virginia Governor's School*

The purpose of this study was to determine which percentage of ethyl alcohol in hand sanitizers had an effect on the antimicrobial efficacy of Escherichia coli K-12 and Staphylococcus epidermidis. The hypothesis was if the amount of ethyl alcohol in hand sanitizer is increased, then the hand sanitizer with the highest percentage will inhibit the most Escherichia coli K-12 and Staphylococcus epidermidis. First, filter paper discs were soaked in hand sanitizers containing 62%, 65%, and 70% ethyl alcohol, with a control of distilled water. These discs were then placed onto an even lawn of each bacterium and left for 24 hours. This process was repeated for 17 trials. Pictures were taken of each petri dish, then put into a computer software program to measure each hand sanitizers zone of inhibition. A one-way ANOVA determined significance in the Staphylococcus epidermidis ($p < .001$, $\alpha=.05$), but not the Escherichia coli K-12 ($p > .05$). A Tukey test was then performed on the average means for each group to determine between which groups significance was held for Staphylococcus epidermidis. This test resulted in a Dmin value of 3.60, which showed that the 70% was statistically significant from the 62% and 65% hand sanitizers. The hypothesis was partially supported by the data obtained from S. epidermidis, but not E. coli K-12, which stated that the highest percentage of alcohol will inhibit the most bacteria. The results suggest that alcohol percentage does have an effect on Staphylococcus epidermidis, but not Escherichia coli K-12.

Honorable Mention

Knowledge of Tissue Donation Survey Project

Lauren Rylander *Washington-Liberty High School*

This study examined the past experiences high school students had in relation to their knowledge of tissue donation, initially intended to study what can affect a person's intent-to donate and coming to focus on accumulation of knowledge. It was the hope that more scientific data could be compiled on the factors behind the decision to donate tissue, and on the motivations of those donors. Through an online survey, students at Washington-Liberty High School were asked about their firsthand and secondhand experience, as well as their education or volunteer experience in areas relating to the medical field. They were then given a quiz on the basics of tissue donation, including questions on blood and organ donation, in order to ascertain their knowledge and understanding of the topic. It should be noted that blood is classified as connective tissue, and thus, can be included under the term "tissue". The original hypothesis postulated that those with educational or volunteer experience would know the most about tissue donation. After analysis of the involved data, low overall scores and very little variance in mean test scores across the levels of the independent variable resulted in a high p-value that rejected the null hypothesis. No statistical significance between experience types was found. Further study is recommended, and the study should emphasize the importance of studying tissue donation from the perspective of the donor.

The Effect of the Storage Temperature on the Tomatoes' Nutritious Value

Veronica Samaan *Mills E. Godwin High School*

This experiment was conducted to determine how the nutritional value of tomatoes correlates to the temperature it was stored at. Food storage was found to be used by most people on the daily, mainly in the form of refrigerators and freezers, which led the independent variable to be storage temperature. It was hypothesized that if the tomatoes were kept at zero degrees Fahrenheit, then they would've had a higher nutritional value. Cherry tomatoes were divided into three groups of 25 and each tomato was placed in a zip lock bag with its group symbol and trial number marked on the bag. The first 25 were left to sit in room temperature (70°F), which acted as the control group. The second group of 25 was refrigerated at 40°F, and the last group was frozen at 0°F. Each group sat in its storage temperature for 24 hours and were removed onto a tray. Each tomato was then cut in half and its juice was squeezed onto the prism assembly of the refractometer. The nutritious value that was measured in Brix was then recorded onto a data table.

After words, a t-test was conducted on the data, it was found that the data was significant when the results from the control group and the 40°F were compared. The rest of the data was not significant, therefore the null hypothesis that stated "If the tomatoes were kept at zero degrees Fahrenheit, then they would've had a higher nutritional value" was not rejected and the research hypothesis was rejected. A source of error in this experiment could be that not all tomatoes had the same nutritious value before storage. Future research could be done where the change in nutritious value was tested, as well as the quality of the tomatoes after storage.

The Effect of Vitamin Supplements on the pH of Stomach Acid

Saniya Sangle *Mills E. Godwin High School*

Use of multivitamin supplements is widespread across the world for multiple reasons. Also 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 but only 24% have vitamin deficiencies. The effect of commonly consumed vitamin supplements B6, C, D and E was studied by simulating their impact on pH of the stomach acid using white vinegar which has pH in same range 1.5-3.5 as pH of stomach acid. Maintaining pH level of stomach acid is very critical for digestion and prevention from viral, bacterial infections. Different vitamin supplements impact the pH levels of stomach acid differently. It was hypothesized that if a vitamin C tablet is dissolved into 30mL of white distilled vinegar, then the pH of the mixture will be between 1.5 to 3.5 which is same as stomach acids. Which also implies that when vitamin C consumed in recommended daily value it may help increase or maintain acidity of stomach acid. Other vitamin mixtures formulated with 30mL of white vinegar will show higher pH levels than vitamin C. A daily suggested quantity of vitamin 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 vitamin supplement type. The result data of the experiment have been discussed in terms of mean, variance, standard deviation, and t-test. Post experiment observations and data captured, supported hypothesis. This study revealed that the daily recommended value of vitamin C will decrease the pH of stomach acid (increase in acidic nature) than vitamin B6, D and E.

Second Place

The Effect of Using Multiple Languages on Parkinson's Disease Detection with Machine Learning

Yash Saxena *Maggie L Walker Governor's School*

Parkinson's Disease is a neurological disease that is caused by a loss or lack of neurons in the part of the brain that controls body movement. This disease usually leads to impairment of body movement and many other symptoms, such as difficulty with muscle movement, difficulty or changes in speech, and various other muscular problems. Around 60,000 American are diagnosed with Parkinson's disease every year. Approximately 90% of Parkinson's patients exhibit vocal changes, which is a clear sign of muscular degeneration and can be tested. Using voice samples from healthy people and people affected by a disease, scientists could use machine learning to predict whether a person would get a certain disease or not. Using publicly available language datasets, the hypothesis was 'If the Italian, Turkish and combined datasets are tested, then the combined set will be able to detect Parkinson's disease with the highest accuracy'.

The experimenter sorted and cleaned the datasets and coded a machine learning program to run the experiment using Sci-Kit Learn's Gradient Boosted Tree model. The experimenter then did 100 trials for each dataset. For each trial, the experimenter collected the confusion matrix statistics, accuracy, precision, recall, and f1 score. Over the 100 trials, the experimenter calculated the mean, median and standard deviation as well. The Italian dataset had the highest mean accuracy with an accuracy of 89.25%. The combined dataset had a mean accuracy of 74.49% and the Turkish dataset had a mean accuracy of 69.31%. The hypothesis was not supported by the data because the Italian dataset was more accurately able to detect Parkinson's Disease than the combined dataset over the 100 trials. In the future, the experiment could be performed with different languages, different machine learning models, or more data.

Honorable Mention

The Effect of Early Monocyte Reconstitution on CD4+ and CD8+ T Cell Populations after Allogeneic Stem Cell Transplantation

Aashka Shah *Maggie L. Walker Governor's School*

After stem cell transplantation (SCT), a patient is at risk of developing an infection or a reoccurrence of the former malignancy as a result of a delayed reconstitution of the immune system. The purpose of this project was to understand the effect of monocytes on day +30 and day +60 on the number of CD4+ and CD8+ T cells on day +60 and day +100 as this information provides valuable data for predicting clinical outcomes. The independent variable was the number of monocytes per microliter (μL), and the dependent variable was the number of CD4+ and CD8+ T cells per μL. The hypothesis was the magnitude of early monocyte reconstitution would be positively correlated with the magnitude of later T cell populations due to the dependent nature of the adaptive immune system on the innate immune system. The programming language R was used to calculate the correlations and the p-value and to create scatterplots of data from 64 deidentified patients who underwent allogeneic stem cell transplantation at the Virginia Commonwealth University Medical Center. The only necessary safety precaution was deidentifying the patients and not including any personal information on them in order to protect their privacy. The hypothesis was supported as a positive correlation was found between all the data pairs studied with one strong, three moderate, and two weak correlations. All the correlations were statistically significant. The correlations increased in magnitude over time supporting the monocytes having a temporally increasing effect on T cells. While the studied correlations were not perfect, this data supports that the reconstitution of the innate system can be used to predict the recovery of the adaptive system.

The Effect of the Type of Toothpaste on Enamel Damage

Yousif Shakroo *Mills E. Godwin High School*

The purpose of this experiment was to determine which type of toothpaste defended the enamel best. There are many types of toothpaste, and all promise perfect oral health. It can be confusing for consumers as to which type protects their enamels best. Before the experiment was done, goggles were worn for safety reasons. First, the eggs were rated using a 1-6 scale, with 1 being no enamel damage and 6 being extensive enamel damage. A total of 150 brown eggs were brushed using 6 different types of toothpaste (25 eggs per type of toothpaste), with no toothpaste being the control because there was no toothpaste to affect the results, allowing it to be used for comparison. The eggs were placed into cups filled with vinegar. The eggs were placed in the vinegar and rated every 12 minutes for a total of 60 minutes. It was hypothesized that pro-enamel toothpaste for sensitive teeth would defend the enamel best because of its high levels of fluoride and its weaker abrasives. The results showed that all toothpaste types defended the enamel much better than no toothpaste, but pro-enamel toothpaste for sensitive teeth defended the enamel best overall (with whitening toothpaste being a close second). This is because of pro-enamel toothpaste for sensitive teeth's low median (1) when compared to the control's median (6). It is believed that pro-enamel toothpaste defended the enamel best because of its high levels of fluoride and less powerful abrasives, which helped make sure that the enamel is not damaged. The null hypothesis was rejected as most chi-squares were significant.

Analyzing Different Socio-economic Factors and its Effects on Pandemic Response

Ameya Sinha *Yorktown High School*

In December of 2019, COVID19 or SARS-COV-2 was reported to the WHO. This new strain of coronavirus strongly affects the elderly population as well as those who contain pre-existing conditions such as diabetes; yet millions of deaths occurred worldwide. The virus devastated countries that were poorly prepared for the pandemic and who could not fulfil responsibilities placed forward by the National Center for Biotechnology Information (NCBI). The primary objective of this research was to analyze the different socio-economic factors that have determined the severity of the pandemic in various nations around the world.

Demographic and economic data was gathered for every country listed in the CIA World Factbook. Data regarding mask mandates and strictness of mandates was gathered from the Bloomberg Opinion. Data regarding COVID19 deaths, cases, deaths/million, and cases/million were gathered from the Worldometer COVID19 database. Both sets of data were analyzed using data gathered regarding COVID19 as the dependent variable.

A multivariable regression analysis was done and found that only COVID19 caseloads affected COVID19 deaths ($p<0.001$) whilst other factors had no effect. It is also notable that voluntary approach to masking leads to a lower-case death rate (29.64/million cases). As mask mandates became stricter, the case rate rose which is contrary to normal belief.

The findings from this study demonstrated that COVID19 cases had a profound effect on COVID19 deaths, and all other factors had little to no effect on the deaths. It was noted that when mask usage is voluntary, the lowest case and death rates occur. This indicates that education about the gravity of the pandemic leading to voluntary mask use and other preventive measures is an important preventive measure. The results of this study can be applied to future and past pandemics to study governmental actions pre and during a pandemic.

Testing Food Formulas for Glucose Concentrations Before and After Invertase

Tanvee Sunkari *Mills E. Godwin High School*

Glucose is one of the most biologically important molecules since it is the primary fuel for our bodily functions. However, life threatening medical conditions can occur if there are insufficient glucose in the bloodstream. Therefore, it is important to study how the body converts sucrose to glucose through invertase and how it affects glucose concentrations that are absorbed. A hypothesis was formulated that if invertase is added to honey, then it will result in the highest glucose concentration. Invertase was added to four food samples containing various glucose concentrations: baby banana food, honey, milk, and fruit juice. These levels of IV were compared to 0% glucose which was the negative control. The glucose concentrations for each sample were taken after 25 minutes, the calculated linear time point (conversion of sucrose to glucose at a constant rate) for the invertase enzyme. Glucose test strips were used to measure glucose concentrations before and after invertase was added to the food sample. Additionally, the original sucrose concentration of the samples was calculated and compared to the glucose concentrations after invertase was added. The honey sample was observed to have the highest concentration of glucose after invertase was added, therefore accepting the research hypothesis. A t-test was determined the data was statistically significant for all comparisons except the banana baby food (before invertase) versus the fruit juice (before invertase) and the fruit juice (before invertase) versus the fruit juice (after invertase). Therefore, the data was most likely a result of the independent variable rather than human error. Glucose concentrations after digestion greatly varies from the original glucose concentration of the sample, which could be useful information for diabetes patients. Finally, further studies can be done on how pH level affects the activity of invertase. Parents understood the risks and consented to their child's participation.

Third Place

Correlation of the National Institute of Health Stroke Scale (NIHSS) with Emergent Large Vessel Occlusion (ELVO) in Stroke Alert Patients - A Single-Center Experience

Annabel Tang *Maggie L. Walker Governor's School*

The purpose of this study was to evaluate the feasibility of using the NIHSS to predict Emergent Large Vessel Occlusion (ELVO) in Virginia Commonwealth University Medical Center stroke patients. The National Institute of Health Stroke Scale (NIHSS) is the most commonly used clinical score to assess the severity of neurological deficits in acute stroke patients, but there remains controversy on the association of the NIHSS to predict vessel occlusion on computed tomography angiography (CTA) and CT perfusion (CTP). Significant association of NIHSS scores and vessel occlusion, and subsequent use of the NIHSS to predict vessel occlusion in select patients, would eliminate the drawbacks of CT testing for patients relying solely on the NIHSS, including the high cost and detrimental effects on kidney function and allergic reactions to contrast. Patients diagnosed with anterior circulation ELVO presented to the VCU stroke center were compared with patients presented with negative ELVO on CTA. Statistical analyses were performed using SPSS 26 software and the NIHSS of the ELVO and non-ELVO groups were compared by t-test. Receiver Operating Characteristic (ROC) analysis was used to determine the best NIHSS cutoff to distinguish these two groups. The relationship between NIHSS and the size of ischemia was assessed using Pearson correlation. The results found that although NIHSS is positively correlated with the presence of ELVO on CTA, no threshold can be identified to detect LVO patients with acceptable sensitivity and specificity. Vascular imaging remains essential for all patients of suspected acute stroke regardless of symptom severity.

Race vs. the amount of Confirmed Covid-19 Cases in the US

Abby Welker *Washington-Liberty High School*

The purpose of this experiment is to see the effect of race on the amount of confirmed Covid-19 cases in America. Racial injustice and discrimination are a real present problem in the United States, and the Covid-19 pandemic just illuminates the problem. There are many factors in the reason for the increased amount of confirmed Covid-19 cases such as the number of people who still had to go to work due to their jobs being classified as “essential”, the number of people of color in poverty or are homeless and the racial discrimination in the medical community. After the statistical analysis was conducted, the results of the ANOVA test yielded a p-value of 1.7018E-18 which allowed for the null hypothesis, race will not affect the percentage of confirmed Covid-19 cases, to be rejected and determined that the data was significantly different. After data collected, the hypothesis, if there are millions of confirmed Covid-19 in the United States then non-white racial groups are more likely to have more confirmed Covid-19 cases than the white population, can be supported by the data collected in the experiment.

The Effect of Fermentation Time on Sugar Content of Kombucha

Tuong Vo *Mills E. Godwin High School*

The purpose of this experiment was to figure out which fermentation time would result in the lowest sugar content of kombucha, without the drink spoiling. Kombucha is a drink made from fermented tea, originating from China in 220 BC. Some health benefits of kombucha include the reduction of cholesterol levels and blood pressure. Because it is so easy to brew, many people decide to make kombucha by themselves so that they can save themselves money and control the sweetness of the beverage. It was hypothesized that if the black tea is fermented for six days, then the kombucha will have the least sugar content. In the experiment, SCOBY was grown and used to produce kombucha from black tea. Safety protocols were used. Each of the jars were categorized into levels of days and left to ferment. The data showed that the more days kombucha fermented, the lower the average sugar content (in brix percentage) was. Multiple t-tests were done to find the significance of the results of each level of independent variable compared to the control, which was no fermentation. Based on the results, it was concluded that the longer kombucha is left to ferment, the lower the sugar content will be. Compared to an experiment done with fermenting wine, results of this experiment were similar. This is because over time, the fermentation process eats up the sugar and converts it into carbon, making the drink contain a lower sugar content, but higher acidity.

The Effect of Building Age on the Amount of Lead in Water

Lewis Wearmouth & Brady Krohl *Washington-Liberty High School*

The purpose of this study was to find if building age had an effect on lead levels in drinking water. This study was conducted to determine if there were dangerous amounts of lead in Arlington's drinking water. The independent variable was the building age. The experimental group included Lubber Run Community Center, Ballston Mall, and Thomas Jefferson Community Center. The control group was distilled water. The dependent variable was the amount of lead in the drinking water. The constants included the Health Metric drinking water testing kit, the county, the type of water cups, and the amount of water per sample (300mL). The hypothesis stated that if water samples were taken from buildings of different ages, then the older buildings will have more lead in their drinking water. 20 samples of drinking water were taken from each of the experimental groups (300 mL each group). The samples were tested for lead using a health metric lead testing kit. The results showed that Ballston Mall had the least amount of lead in its drinking water. This partially accepted the hypothesis. This study suggested that generally, newer buildings will have less lead in their drinking water. Overall, the lead levels in Arlington were safe.

Honorable Mention

The Effect of a Musical Composition on Stress Levels in the Listener

Owen Tucker
Ocean Lakes High School Mathematics and Science Academy

Music is a universal language, and it serves as a powerful tool to communicate complex thoughts and emotions. Many studies have documented the benefits music can have to the listener. The goal of this research was to compose a brief piece of music intended to reduce stress and anxiety in the listener using a combination of music theory and neuroscience. The measurable physical attributes used to determine the composition's effect on the stress levels of the listener were heart rate, blood pressure, and temperature. Each was measured before and after listening to the composition, testing the hypothesis that the composition would cause a decrease in all three indicators, showing a decrease in anxiety. The results supported the hypothesis with regards to heart rate and blood pressure. There was an average heart rate decrease of 2.7 bpm, and two-thirds of participants experienced a decrease in heart rate. The blood pressure results also showed a decrease of both systolic and diastolic blood pressure on average, and in a majority of respondents. The temperature results did not clearly support or contradict the hypothesis. This research demonstrates the powerful potential for music in medicine, and its direct effects on stress levels in the listener. The composition is now available as a free resource online for anyone who needs to relax or reduce anxiety.

Microbiology & Cell Biology A (HS MCB-A)

The Effect of Antiseptics on Bacterial Growth

Anika Agarwal Mills E. Godwin High School

In resource-poor countries outbreaks of diseases are common because most people are not able to afford disinfectants. The purpose of this project was to determine which cheap antiseptic (rubbing alcohol, ammonia, and a homemade disinfectant) inhibits the growth of bacterial colonies, in this case *Lactobacillus,* the most. *Lactobacillus* colonies were swabbed into one hundred petri dishes. Rubbing alcohol was dropped into twenty-five petri dishes. The same procedure was done with ammonia and a homemade disinfectant, made of vinegar and distilled water. The control was no antiseptic on the remaining twenty-five petri dishes. After twenty-four hours, the number of bacterial colonies were recorded. Throughout the experiment, hair was tied back, gloves were worn, and the materials were disposed of safely. A parent signed a form indicating that the risks of the experiment and that they consented to their child participating in the research project.

The results indicated that the homemade disinfectant had the greatest impact on the growth of the colonies with a mean of 2.76, and ammonia had the least impact with a mean of 4.76. This may be due to vinegar containing the active agent, acetic acid. A t-test performed on the data indicated a significant difference between the means of the groups ($t= 9.2024 > 2.0106$; $t= 14.5549 > 2.0106$; $t= 17.2735 > 2.0106$ at $\alpha=0.05$ and $df=48$). The data did not support the research hypothesis that if many different antiseptics are tested on *Lactobacillus*, then rubbing alcohol will inhibit the growth of *Lactobacillus* colonies the most.

An Analysis of Cleaning Method Efficacy on Shared Surfaces in a Gym

Lane Anderson *Chesapeake Bay Governor's School*

Lack of surface hygiene in athletic environments causes multiple skin irritations and diseases. The layers of human residue on athletic surfaces build up after each use. The microbiota can reside on the outer layers of gym equipment and multiply. This experiment tested the cleaning methods individuals use every day to allow for cleaner, better managed gym usage. This experiment was executed by testing an uncleaned surface 3 times as the control. Then the surface was used to allow for more germs to accumulate before the next sample was taken. Then the surface was cleaned 3 separate times with Lysol brand spray for the spray treatment, and 3 times with a Clorox brand wipe for the wipe treatment. The different layers of bacteria that build up in athletic facilities can be significantly decreased with a cleansing after each use. Bacteria can store into the layers of a bench press seat if not cleaned right away and are harder to remove if the bench is not immediately cleaned. Spreading information about bacteria and making others aware will bring attention to it and should prevent high numbers of infections.

Third Place

Effects of 5G Compatible Broadband Waves on Average Change in Color of *Sacchoromyces cerivisae*

Ryan Beck *Central Virginia Governor's School*

The purpose of this study is to discover if there is a correlation between 5G broadband signals and growth processes of Saccharomyces cerevisiae. Using aseptic technique, small colonies of Saccharomyces cerevisiae were grown on small YPD agar plates whilst under a small concentrated broadband beam of 4.8 Ghz (well within 5G range). In hourly periods, 8 samples were being tested at a time and were photographed accordingly. Following this period the photographs were processed into an average RGB value at the center of the colony, which was then compared to other samples for comparison of the percent change in color. The findings suggested that the differences in color changes between the samples were not statistically significant. Looking at the Single Factor ANOVA test, which was used to compare data points, a p-value of .144 was found, and when compared to the given alpha-value of .05, it is seen that the data is not statistically significant. With this, the research hypothesis that if Saccharomyces cerevisiae is exposed to a steady 5G capable wave, that there would be an effect on Saccharomyces cerevisiae growth efficiency by measuring it's percent change in color is suggested as false as it is seen that 5G broadband signal waves do not affect Saccharomyces cerevisiae enough in terms of reproductive capability or the change in color of the colony to be statistically significant.

Analyzing the PETase Enzyme Activity in *Bacillus cereus* and Its Effect on Plastic Degradation

Kallena Branham *Central Virginia Governor's School*

The purpose of this study was to see if the bacteria *Bacillus cereus* that contained PETase, an enzyme known to degrade PET (polyethylene terephthalate) plastic, affected the mass(g) of two-inch by one-inch plastic pieces. PET plastic is better known as the plastic found in disposable water bottles. The enzyme PETase reacts with the plastic and breaks it down into its basic carbon elements. There were seven mason jars per independent variable: nutrient broth (with and without bacteria) and water (without bacteria) at temperatures of (37°C and room temperature(22°C)). The control was water at 37°C. two-inch by one-inch pieces of PET plastic were cut and exposed to separate independent variables. The plastic was incubated, dried, and weighed again for six more trials. The percent difference of each plastic piece from its initial weight was calculated and averaged out. A single-factor ANOVA was used to determine if there was significance using an alpha of .05. This resulted in a p-value of .353 and showed that the data was not statistically significant. Therefore, the research hypothesis “If PET plastic was exposed to different liquids (Inoculated broth, Un-inoculated broth, and water) in different temperatures (22°C and 37°C), then inoculated broth in 37°C temperature will degrade the plastic the most,” was not supported. While these results were not significant, more research into *Bacillus cereus* and PETase’s plastic degrading abilities offer possibilities for there to be significance in future projects. Hopefully with time, future research can help reduce plastic waste for the world.

The Effect of Different Hand Drying Techniques on Quantity of Microbes

Sumiyya Butt *Mills E. Godwin High School*

The purpose of the experiment was to find which hand drying method will result in the least amount of germs. The reason why the experiment was conducted was to raise awareness about hand drying and that hand drying is an important aspect of hand hygiene. Knowledge about hand hygiene is necessary especially when a virus can spread through contact and is considered contagious. Most studies are done about the handwashing concept, but hand drying is an integral part as well. The hypothesis being studied was if paper towels are used to dry hands, then it could result in the least amount of germs. Germ-simulator was used to study the effects of hand and then the hands were observed by ultraviolet light. The control of the experiment was not drying at all. Chi-square test was performed to calculate the result of the data and it was found that the expected vs. paper towel, expected vs. control, expected vs. air dryer, and expected vs. towel were all found significant. This research can be studied further by experimenting with different drying methods or finding how much time should one spent on drying their hands.

Second Place

The Effect of Temperature on Concentration of Sugar After 10 Days in the *Musa acuminata*

Ella Cohen *Washington-Liberty High School*

The purpose of this experiment was to see if temperature has an effect on the concentration of sugar after 10 days in *Musa acuminata* Cavendish Subgroup. Enzymes act as a catalyst for chemical reactions that turn starch into sugar, once activated by Ethylene. Therefore, this measure would provide an accurate depiction of the ripening. It was hypothesized that the temperature of 20 degrees Celsius would produce the *Musa acuminata* Cavendish Subgroup with the highest concentration of sugar in Brix because high temperatures do not affect Amylase, one key enzyme in the transfer of starch into sugar as the banana ripens. The bananas were stored at 8 degrees Celsius, 14 degrees Celsius, and 20 degrees Celsius and 12 trials were conducted at each temperature. The mean concentration of sugar was measured by a refractometer instrument. The mean concentration of sugar at 8 degrees Celsius was 6.4 degrees Brix, at 14 degrees Celsius 18.9 degrees Brix, and at 20 degrees Celsius 18.8 degrees Brix. The p-value was calculated to be 1.9751E-11, lower than the critical value of 0.05 and the null hypothesis was rejected as an ANOVA test was conducted. The results did not fully support the research hypothesis as the bananas stored at 14 degrees Celsius had the highest mean sugar concentration. However, another T-Test was conducted which concluded that the difference between 20 degrees Celsius and 14 degrees Celsius was not statistically significant due to overlap. It was concluded that the results of the measurements taken at 14 degrees Celsius were caused by small gains of heat due to observational methods in the procedure such as the method.

First Place

The Comparison Between Different Straw Materials to Determine Which Material Grows the Most Bacterial Colonies

Brooke Coleman *Central Virginia Governor's School*

The purpose of this project was to determine which straw material grows the most bacteria when drinking 0.5 cup of water a day for six days. The hypothesis was that if plastic, silicone, and stainless steel were tested, then stainless steel would grow the most colonies. Eight raw material straws were drank out of for six days and rinsed every two days with warm water, then five mL of Phosphate Buffer Solution were added to a Whirl-Pak with the straw. After letting the straws soak individually for one minute, one mL of the solution was plated onto a large petri dish and placed in the incubator at 37 degrees Celsius for two days. Data was calculated by counting each colony present on the dish, and this process was repeated for each straw and for the controls that were not drank out of. The single factor ANOVA, which had a p-value of $5.13x10^{-21}$ and an alpha value of .05, found a significant difference. A post-hoc Tukey test was then used to determine the location of significance with a Qt value of 3.58 and Dmin of 29.39. There was a significant difference between each group, but stainless steel grew the most colonies out of the three materials tested. This data supported the research hypothesis that stainless steel would grow the most colonies out of plastic, silicone, and stainless steel. In conclusion, the results suggested that stainless steel straws grow the most colonies, followed by silicone, then plastic.

Second Place

Diversity of Arctic Ice Bacteria in Relation to Position and Distance from the Shore

Katelyn Collett *Southwest Virginia Governor's School*

Microorganisms that live in sea ice are essential to the Arctic ecosystem. The presence of Arctic ice is rapidly declining, so time is running out to study the unique environment. There have been studies done to identify bacteria in ice, but few studies that investigated a correlation between the diversity of bacteria and environmental factors. The observance of these organisms over a period of time could allow for the prediction of other species levels in the Arctic. The identification of these microorganisms is also a gateway to theorizing the characteristics of microscopic life on other planets. Eight ice cores were taken from the Chukchi Sea off the coast of Utqiagvik, Alaska, and divided up into forty-two samples. The samples were melted down, centrifuged, and then plated onto nutrient agar. Then, a sample from each unique colony was taken and run through Polymerase Chain Reaction (PCR). The PCR product was then sequenced and used to identify the species of bacteria. From the linear regressions performed, no significant relationship was found between any of the seven bacteria identified and the position in the ice or distance from the shore. The p-values for the relationship between bacteria A, E, and F and the distance from the seawater were 0.12, 0.3, and 0.055 respectively, while the p-values for shore distance were 0.76, 0.46, and 0.94. Future studies should examine other variables such as salinity or temperature on a larger scale to look for a relationship with bacterial diversity.

Honorable Mention

The Analysis of the Viral Transmission between the HIV-1 Envelope Glycoprotein and the Lymphocyte Receptor Integrin α4β 7

Harrish Ganesh
Thomas Jefferson School for Science and Technology

The Human Immunodeficiency Virus (HIV) infects approximately 40 million people globally, and one million people die every year from Acquired Immune Deficiency Syndrome (AIDS)-related illnesses. The HIV-1 virus is proliferating, infecting people, and killing those who host the virus. Unfortunately, there is little research on the structural interactions between HIV-1 proteins and human cell receptors. This study examined the interactions between the HIV-1 envelope glycoprotein gp120 and the human lymphocyte receptor integrin α4β7, the putative first long-range receptor for the envelope glycoprotein of the virus in mucosal tissues. The specific site of binding between the glycoprotein and the receptor has not been determined. However, discovering the binding site can open the field towards the research of molecules that could potentially block this interaction and prevent the initial binding of the HIV-1 virus. We hypothesized that the V1 and V2 loops of the envelope glycoprotein of HIV-1 are involved in the binding between the HIV-1 virus and the human lymphocyte receptor α4β7. Using structural analysis software, we analyzed the electrostatics and structural interactions between the glycoprotein and receptor. We report structural insights into the interactions between α4β7 and envelope glycoprotein gp120. Our data support the claim that the V1 loop is involved in the binding between α4β7 and the HIV-1 envelope glycoprotein through molecular dockings.

The Effect of Supplements on the Regeneration of Planaria

Matthew Gavin *Mills E. Godwin High School*

The purpose of this experiment was to find the effects of different supplements on the regeneration of planaria. Planaria, as well as humans, use a type of regeneration called stem cell regeneration, which helps repair injured, diseased, or dysfunction tissue using stem cells. Since we both share this regeneration, planaria make perfect test subjects for drugs and chemicals prior to human testing. Planaria were placed in water mixed with Polyphenols, Vitamin C, or Vitamin D3. The Planaria grew for 3 weeks, and their length was measured. The control that was used in the experiment was distilled water. It was hypothesized that planaria with polyphenol supplements in the water, would regenerate longer than planaria with Vitamin C, and Vitamin D3 supplements, as well as distilled water. The results revealed that planaria placed in Polyphenols length increased, on average, 0.4 mm more than planaria placed in distilled water. However, decreased, on average, 0.2 mm less than planaria placed in Vitamin C, and Vitamin D3. A t-test was done on the data and it revealed that everything was significant except Vitamin C vs Vitamin D3. The overall results did not support the research hypothesis. The probability of the results being due to chance is less than 0.05 and implies that the results of the experiment are most likely due to the independent variable. This research could lead to further studies that investigate different types of drugs or chemicals on the regeneration of planaria.

Analyzing the Cell Viability and Cell Signaling Activity of an Alginate-based Synthetic Extracellular Matrix Scaffold

Caroline Grant, Vineel Kavuru & Catherine Chen
Roanoke Valley Governor's School

This experiment analyzed the cell viability and cell signaling of cells grown in various bioinks, including commercial CELLINK A-RGD alginate enhanced with a cell-adhesion peptide, alginate hydrogels of varying concentration, and a decellularized extracellular matrix (dECM) bioink derived from porcine dermis, to determine the optimal biomaterial for bioprinted cell-encapsulating scaffolds. It was hypothesized that the CELLINK A-RGD and alginate bioinks would have cell viability and signaling comparable to the dECM bioink. It was also hypothesized that the CELLINK A-RGD would demonstrate higher cell signaling and viability in comparison to the alginate hydrogels, and alginate hydrogels at higher concentrations would demonstrate lower cell viability and signaling.

Alginate hydrogels (2%, 3.5%, 5%) were prepared. A dECM bioink was prepared by treating porcine dermis with a 1% Triton X-100 solution, rinsing with dH_20, subjecting to DNase treatment, lyophilizing, neutralizing, and incubating over a period of two weeks. The dECM bioink failed to gelatinize and could not be tested for cell viability and signaling. Using a cell-mixer, 6mL of each bioink was combined with 0.5 mL of breast cancer cell suspension and bioprinted to construct three-dimensional scaffolds designed using SolidWorks. Cell-laden scaffolds were crosslinked with $CaCl_2$ solution, placed in well-plates, covered in culture media, and placed in a 37 °C incubator overnight. To analyze cell viability, an MTT assay was performed. To analyze cell signaling, an ADP assay was performed.

The 5% alginate bioink had the highest average absorbance for the MTT assay, which was significantly higher than the mean absorbances of both the CELLINK A-RGD and 2% alginate bioinks (ANOVA, $p = 0.0016$). The 3.5% alginate bioink also displayed a significantly higher average absorbance than the 2% alginate bioink (ANOVA, $p = 0.0016$). Therefore, 5% and 3.5% alginate hydrogels yielded bioinks with higher cell viability than the CELLINK A-RGD and 2% alginate bioinks. Because there was no significant difference in the average ADP concentration between bioinks (Welch's ANOVA, $p = 0.0882$), enhancing alginate with the RGD peptide did not significantly improve signaling ability. In conclusion, the 5% alginate hydrogel could be considered a valuable bioink for bioprinting cell-laden scaffolds, as it can be quickly made, successfully printed, and supports metabolically viable cells. The dECM bioink was unprintable and thus further research should be conducted to explore procedures for creating dECM bioinks that are less time-intensive and reliably produce functioning gels.

Analysis of Bacteria Presence After High Pressure Hand Dryer Use

Katelynn Headley *Chesapeake Bay Governor's School*

Hand hygiene is important in many aspects of life, both publicly and privately. It is highly beneficial to have good hand hygiene for you to stay healthy, reducing the transmission of viruses as well as other infections and harmful germs, as well as help keep others healthy. The main three methods of hand drying today to maintain this good hygiene are paper towels, hand towels, and high-pressure hand dryers. These high-pressure hand dryers were first introduced to replace paper towels, thus reducing the overall paper towel costs for establishments. The problem with these high-pressure hand dryers is that there have been many debates of their efficiency in contributing to good hand hygiene. This study compared the bacteria presence after drying hands with paper towels, hand towels, and a hair dryer, to mimic the properties of the high-pressure hand dryer. It was hypothesized that the paper towels would have the least amount of bacteria presence while the high-pressure hand dryer would have the greatest amount. Every 30 minutes the test subjects' hands were swabbed and swiped in agar plates after drying with first paper towels, hand towels, and finally the hair dryer. The agar plates were then incubated at 37.5 degrees Celsius for 48 and 72-hour incubation periods. The results showed the hand towels have the lowest average bacteria count than both the hair dryer and paper towels after the 48-hour period while the paper towels showed the lowest average bacterial count after 72 hours. The hair dryer showed the highest average bacterial count after both incubation periods. After an ANOVA: Single Factor test was run, the resultant p-values included 0.04 for 48 hours and 0.20 for 72 hours. This study shows that paper towels and hand towels, compared to the hand dryer, are the most hygienic method of hand drying as well as shows the importance of effective hand drying to prevent the spread of bacterial/viral contaminants.

The Effects of Natural Antifungal Remedies on Baker's Yeast

Diya Johar *Mills E. Godwin High School*

The purpose of this experiment was to determine the effect of natural remedies such as essential oils on the reproduction of baker's yeast. In recent years, human fungal infections have gone up significantly, specifically yeast infections. The chemically induced medication often used to treat these infections can cause harmful side effects. In this experiment, there were four groups of baker's yeasts that were added in sugar water. In group one Lavender Oil was added, in group two Tea Tree Oil was added, in group three Grapefruit seed Oil was added. Group four was the control group, and no natural remedy was added. A research hypothesis was formulated that if Lavender Oil was used on the baker's yeast, then it would cause the least growth resulting in the diameter of the balloon being the smallest. The results were measured by seeing how much carbon dioxide was released by the yeast. It was captured in a balloon which was placed over the growth chamber then the diameter was measured in centimeters. Proper safety precautions were taken for the duration of the experiment. The results showed that the group that contained Tea Tree Oil had the greatest effect on stunting the growth of the Baker's yeast. The results did not support the research hypothesis. A t-test was preformed and revealed that the data was not statistically significant. The results are most likely due to the lack of appropriate equipment and although not significant, show that natural remedies do substantially decrease the growth of baker's yeast. This research could provide information in studying the effect of natural essential oils on fungal infections.

The Effect of Container Material on *Lactobacillus* Count in Yogurt

Anika Kashyap *Mills E. Godwin High School*

The purpose of this study was to determine whether container material affects the *Lactobacillus* count in yogurt. *Lactobacillus* is a probiotic, a type of bacteria that serves as a versatile health supplement and assists with a variety of health issues. If it is ingested more often, the overall population will be healthier. *Lactobacillus* based yogurt was stored in styrofoam, stainless steel, glass, and plastic containers for a period of three days. Dilutions from the yogurt were then stored in petri dishes, causing bacteria to grow, and the bacterial colonies were counted. This was done 25 times for each level of the independent variable. Safety was thoroughly considered, and safety measures were met. There was no control because the yogurt could not be stored in the air or in a container made of no material. It was hypothesized that if the yogurt was stored in the glass container, then it would have the highest *Lactobacillus* count because studies have indicated that glass causes a very high *Lactobacillus* count in yogurt. The results revealed that the yogurt in the glass containers had the highest *Lactobacillus* count, at an average of 32,028,000 colony forming units. The yogurt in Styrofoam containers had 28,676,000 CFUs, stainless steel had 20,284,000 CFUs, and plastic had 23,716,000 CFUs. Multiple t-tests were conducted and revealed that all of the data was significant at the level of significance of 0.01. The research hypothesis was supported by the results. The results can be explained by glass having low oxygen permeability (creating a better environment for bacterial growth), Styrofoam having more surface area for the *Lactobacillus* to grow, plastic having a higher level of oxygen permeability, and stainless steel making it difficult for bacteria to grow. This research could lead to further studies on different container types or types of probiotics.

First Place

Testing the Effectiveness of Different Supplements on the Breaking Down of Lactose in Whole Milk

Diana Kirilov *Mills E. Godwin High School*

The purpose of this experiment was to study the effectiveness of different supplements in the breaking down of lactose in whole milk. Lactose intolerance occurs when the body does not produce a sufficient amount of lactase enzymes, causing symptoms such as abdominal pain and diarrhea upon the consumption of dairy. This condition negatively impacts an individual's quality of life, as dairy products have become difficult to avoid, and dairy contains essential nutrients that are part of a balanced diet. This research was intended to offer a solution that does not entail completely avoiding dairy. It was hypothesized that if the supplements were added to samples of whole milk, then the probiotic supplement would break down the most lactose. This was measured by determining the difference in the samples' glucose concentrations after adding the supplements. Prior to experimentation, a permission form was signed by a parent that indicated that they had read and understood the risks and possible dangers involved in the research and they consented to their child participating in this research. The levels of the independent variable were Lactaid supplements, generic lactase supplements, *L. acidophilus* probiotic supplements, and no supplement as the control. The difference in glucose concentration was measured in mg/dL using glucose test strips. It was found that only the Lactaid and generic lactase supplements produced an increase in glucose concentration, and a t-test confirmed their significance when compared to the control but not against each other. The probiotic supplement was not significant when compared to the control, and the research hypothesis was rejected. These unexpected results were likely due to the dosage of the probiotic supplement not being longitudinal and the stomach environment not being accurately replicated.

The Effect of Hand-washing vs Hand Sanitizer on Hand Bacteria

Nitya Kumar *Douglas S. Freeman High School*

Bacteria and viruses are ubiquitous. More than 80% of infectious diseases are spread by contact, especially contact by hands. Resident and transient bacteria are two types of bacteria that can be found on human hands, usually resident bacteria do not cause illnesses. More people fall sick when the germs, which are on the surfaces of peoples' hands, pass from person to person. Handwashing with soap and usage of hand sanitizer removes the germs and the bacteria from the hands, which makes the chance of passing on harmful bacteria and germs less likely. The world is going through a global pandemic. Now, more than ever it is necessary to have good hand hygiene. Washing hands and use of sanitizer will continue to be beneficial during the pandemic, as well as in the future. The hypothesis of the experiment is, "If the hands are sanitized with either hand washing or hand sanitizer, then it would reduce the quantity of hand bacteria, with hand sanitizer reducing more bacterial quantity than hand washing." The procedure consisted of swabbing the dorsum, palm, and crevices of the left hand for all levels of IV. After the hand was swabbed, the swab was taken and gently rolled over the agar plate in criss cross manner. The agar plate was placed in the incubator at a temperature of 33.5 degrees Celsius. The experiment was conducted at the same time at three o'clock in the afternoon. The mean of all of the independent variables (all rounded) were 6.67 (control), 5 (handwashing), and 0.33 (sanitizer). The experiment findings showed that hand sanitizer decreased hand bacteria. Both hand washing and application of hand sanitizer prove to be very important and effective ways to kill the germs, with hand sanitizer being more effective than hand washing. To prevent the spread of germs, people should wash their hands or apply hand sanitizer every time they touch something that could be contaminated in order to stay safe and healthy.

Microbiology & Cell Biology (HS MCB-B)

Honorable Mention

The Effect of Medicinal Plant Concentrates on *Saccharomyces cerevisiae*

Hannah Loos *Mills E. Godwin High School*

Medical plant concentrates' effects on yeast survival were tested. It was hypothesized that if licorice concentrate was added to the yeast, then the most yeast would be killed. The experiment was conducted by extracting concentrate from medicinal plants; there was a positive control of no concentrates and negative control of vinegar. Once the concentrates were obtained, a CO_2 probe was attached to the tubing. The concentrates were added to separate graduated cylinders which contained yeast and after 210 seconds, sugar and water were added to the solution. Immediately afterward, the tube that was attached to the lip of the graduated cylinder and the results were recorded, graphed, and analyzed. The experiment was conducted while wearing safety equipment: gloves, goggles, and an apron. The research hypothesis was supported by the data because the least CO_2 was emitted from the yeast and licorice mixture than any of the other concentrates. Licorice had the lowest mean of 1325 ppm which was similar to the negative control of 1215 ppm. Ginger had the highest mean of the independent variables, 1651 ppm, suggesting that ginger was the least effective and licorice the most effective. T-tests were performed on the data and implied that the data was statistically significant. This was deducted to be a result of the licorice medicinal plant containing high quantities of triterpenoid, flavonoid, and licochalcone molecules. Future studies could be conducted testing these medical plant concentrates' effects on other types of fungus strands that commonly cause fungal infections.

The Effect of Water pH on Bioluminescence of Dinoflagellates

Akul Miriyala *Mills E. Godwin High School*

The purpose of this experiment was to find the effects of pH on the bioluminescence of *Pyrocystis fusiformis* dinoflagellates. As society becomes industrialized, carbon emissions rise. These emissions are absorbed by the ocean, causing acidification and lowering the pH of the ocean. A lower pH can harm dinoflagellate bioluminescence, which is an integral process in the sea that serves a variety of purposes, from being a light source for navigation to scaring predators. Three equal dinoflagellate groups were put into environments with 6.5 pH deer park spring water, 7.5 pH tap water, and 8.5 pH alkaline water. The dinoflagellates were put in 12-hour night and day cycles for 7 days and the bioluminescent rank (0-10) was measured. There was no control for this experiment as the ocean's pH is different based on geographic areas. It was hypothesized that a pH of 8.5 would yield the highest bioluminescence rank. The results revealed that pH of 7.5 had the highest median bioluminescence rank of 7, 3 more than 8.5 pH and 4 more than 6.5 pH. A chi-square test was calculated, and it revealed that this data was significant overall and that the results did not support the research hypothesis. It is believed that the results are because the dinoflagellates were retrieved from the coast of California where the pH is more acidic than other places, which makes a pH of 7.5 more optimal for the dinoflagellates. This research could lead to further studies that investigate more pH levels and other bioluminescent species.

Third Place

The Effect of Transition Metals on Gram-negative and Gram-positive Bacterial Growth

Reagan Morford *Central Virginia Governor's School*

The purpose of this study was to determine which transition metal was most effective at inhibiting Gram-negative and Gram-positive bacteria from replicating. The study was conducted by inoculating three different metals- copper, nickel, and zinc- with .1 L of either P. fluorescens or S. epidermidis. After sitting for 24 hours, the metals were washed in a phosphate-buffered saline solution. 50 µl of the new solution was then plated onto micro petri dishes using spread plate techniques. There were eight trials for each of the six groups. A one-way ANOVA test determined significance with a p-value of .005 for the S. epidermidis trials, and a second ANOVA found a p-value .03 for the P. fluorescens trials, with both compared to an alpha of .05. A post-hoc Tukey test was performed, which showed that both copper and zinc were more antimicrobial than nickel against S. epidermidis. A second test showed that zinc was more antimicrobial than copper and nickel against P. fluorescens. Therefore, the research hypothesis, “If copper, zinc, and nickel are tested on Pseudomonas fluorescens, a Gram-negative bacterium, and Staphylococcus epidermidis, a Gram-positive bacteria, then copper will be the most effective at limiting the bacterial growth of both types of bacteria” was not fully supported. In conclusion, out of zinc, copper, and nickel, both copper and zinc are antimicrobial against Gram-positive bacteria; whereas zinc is the most antimicrobial metal against Gram-negative bacteria.

Your Shoes are More than Smelly

Grace Oren *Chesapeake Bay Governor's School*

Many people own a pair of tennis shoes which are for athletics or for other comfort. As these shoes are worn more and more for hours at a time, day after day, bacteria start to build in due to the likely sweaty tight conformant of the shoe. Other shoes like crocs, however, have holes in them and consequently, breathe better but open the shoe to other bacteria that can come in through these holes. No one wants bacteria in their shoes, but many people don't think about it. Since the threat of COVID-19 has become relevant people are taking more precaution regarding cleanliness using Lysol and other cleaning materials. This study compared the amount of bacterial difference between the tennis shoes and crocs after being worn for a day and tested the effect Lysol had on the amount of bacterial difference from tennis shoes and crocs. The crocs and shoes with no Lysol had significantly higher levels of bacteria. The P-value comparing bacterial levels between Crocs and Tennis Shoes was 1.03E-05 while the P-value of the data comparing Lysol and no Lysol was 1.9E-06. The data and P-values suggest that crocs have more bacteria than tennis shoes and shoes with no Lysol have more bacteria in them than shoes with Lysol. This study can help the understanding of bacterial growth in shoes so that the amount of growth can decrease.

The Effect of *Trametes versicolor* Infused Bandages on *Staphylococcus epidermidis*

Jennie Pham, Cynthia Lin & Emma Greer
Roanoke Valley Governor's School

Cuts and abrasions occur commonly in everyday life. Without treatment, wounds can become infected and cause further complications. To combat this, new, natural alternatives, like *Trametes versicolor*, Turkey Tail, are of rising interest. This fungus is known to have many therapeutic properties, from combating cancer to aiding other sicknesses, and its structural component, chitosan, could play a large role in its medicinal properties. It was hypothesized that if chitosan was extracted from the Turkey Tail mushroom and made into a wound dressing, then the product will successfully inhibit the growth of Staphylococcus epidermidis. Chitosan was extracted from Turkey Tail through various processes, including grinding, NaOH and acetic acid baths, and ethanol washes. The rest were dried and combined, alongside other experimental groups, with sodium alginate to create 5% bio-inks. After printing, wound dressings were tested against S. epidermidis. After 24 hours, no observable zones of inhibition were apparent in all trials. After 48 hours, other bacterial and fungus growth was seen on top of samples and a second test was administered for under each bandage. The second trial indicated yellow, white bacterial growth and obvious contamination, which may have resulted from not autoclaving bandages. Under a gram-stain, S. epidermidis, unidentified pink shaped rods, and large strands were seen under a microscope. Results indicate that both the Turkey Tail and chitosan were unable to inhibit the growth of bacterium and other pathogens. Further studies may include a briefer time period between testing or removing extraction to simply test Turkey Tail alone.

Introduction

Honorable Mention

The Effect of Lyophilization on Rates of *Saccharomyces cerevisiae* Proliferation

Mihir Pokhriyal *Mills E. Godwin High School*

The purpose of conducting the experiment was to determine the effects of a home lyophilization method on the proliferation rate of *Saccharomyces cerevisiae*, a yeast strain that is known to cause food spoilage. Lyophilization is a dehydration process which has had studies in the past to reduce bacteria, so it was hypothesized that 24 hours allotted to lyophilization would yield the smallest amount of *Saccharomyces cerevisiae* proliferation.

The experiment was conducted using dry ice to lyophilize yeast within Petri dishes as safety cautions were noted and practiced, including wearing protective gear and having adult supervision. After 0, 12, and 24 hours lyophilized, the yeast was activated and its growth over 10 minutes was measured using an activation process. Trends were analyzed after being recorded on a line graph. The control for the experiment was 0 hours lyophilized as there was no lyophilization at the time interval.

Observations indicated that increased lyophilized times yielded greater yeast proliferation. The control had, on average, 5.2 mL, 12 hours had 15.6 mL, and 24 hours had 19.6 mL of yeast growth. After conducting t-tests for inferential statistics, it was concluded that these results were statistically significant at a 0.001 level, rejecting the null hypothesis.

These results were most likely due to the suitable environment the Petri dishes provided. The lyophilization was not enough to reduce the yeast from growing at the rate it did. Due to its rapid growth within the Petri dish, the growth of the yeast was increased when activated. As the experiment showed, this lyophilization technique was not able to reverse the effects of the rapid yeast growth and it’s most likely not as effective to prevent food spoilage caused by yeast.

The Effect of Time Spent in Contact Lens Solution on Number of Bacterial Colonies Plated from the Lenses

Swetha Poluri *Clover Hill High School*

The question that was addressed in this experiment was if the amount of time that contact lenses spend in contact lens cleaning solution affect the number of residual bacteria? The hypothesis of this experiment was if the contact lenses were put into the cleaning solution for a longer period of time, then the lenses would have less bacteria on them. Contact lenses in the following intervals: before being put in eyes, contacts used and taken out after 7 hours, one minute in cleaning solution, one hour in cleaning solution, and eight hours in cleaning solution, were taken out, swabbed, and placed into 10 ml of buffer solution. These vials were placed into an incubator for 48 hours, and then the number of bacterial colonies on each lens was counted. This process was repeated 10 times for each of the time intervals. The results indicated that contact lenses that spent more time in contact lens solution, had less bacterial colonies. The null hypothesis was rejected, and the data supported the research hypothesis.

Honorable Mention

The Effect of Water-Soluble Vitamins on *Saccharomyces cerevisiae* Survival Rate

Avirat Raj *Mills E. Godwin High School*

The purpose of the experiment was to understand how certain water-soluble vitamins impacted the growth rate and survival rate of *Saccharomyces cerevisiae* cultures. This experiment was conducted to better learn the effects that water-soluble vitamins have on the integrity and sustainability of eukaryotic cells. Water-soluble vitamins, such as the B complex, would help in boosting the immune system by lowering its need for more energy and increasing its ability to fight off the infection. The research hypothesis was stated that if the *S. cerevisiae* cultures are exposed with vitamin B12, then the rate of cell growth will be highest. Additionally, a control was set in the experiment to test the effects of no vitamins on the survival and growth rate of the *S. cerevisiae* cultures acting as a baseline. A permission form was signed by a parent that indicated that they had read and understood the risks and possible dangers involved in the research and they consented to their child participating in this research. The method to test this included four YED agar plates with *S. cerevisiae* cultures. Each were exposed to a thin layer of either vitamin B6, B7, or B12. One was not exposed to any vitamins and acted as the control. The agar plates were placed in an incubator for maximum growth while minimizing unnecessary variables. The cells' living to dead ratio were counted and recorded. The average growth rate of each were also calculated and compared. All recorded data for vitamin B12 indicated that this has the lowest standard deviation among the other levels of the independent variable with a value of 2.80. After completing the t-test, vitamin B7 had a higher t-value when compared to the critical value, which indicates that the results were significant. Vitamin B12 also had the highest t-value indicating the results were significant. Vitamin B12 helps in DNA synthesis and cellular energy production, which may have been the cause of high living/dead cell ratios during the data collection of the experiment.

The Effect of Children's Toothpastes on *S. cerevisiae* Growth

Shreya Rajkumar *Mills E. Godwin High School*

Early childhood caries is a significant oral health problem, with the prevalence of tooth decay up to 85% in underserved communities. Pathogenic yeast is often found in the oral cavity and toothpaste is the most prevalent form of oral hygiene. Thus, this experiment was conceived with the purpose of determining which children's toothpaste was the most effective antifungal. The research hypothesis was as follows: If samples of *S. cerevisiae* are exposed to Toothpastes A, B, and C, then the samples exposed to Toothpaste A will show the least growth because it contains a larger amount of its active ingredient. Toothpaste A was also unique in having sodium monofluorophosphate as its active ingredient. Toothpastes B and C contained sodium fluoride instead, and the fluoride ion concentration varied.

The experiment's procedure involved administering four milliliters of a diluted mixture of toothpaste and water, which was 50% water by weight, to *S. cerevisiae*. The control group received no substance. The growth of *S. cerevisiae* was assessed by using water displacement to measure the milliliters of carbon dioxide gas emitted. To protect the hands, latex gloves were worn. Remaining yeast was killed and disposed of separately in a leak-proof bag.

Only Toothpastes A and C had a significant impact on the growth, and only Toothpaste A reduced the growth of the yeast. These results could have been due to human error and the difference in inactive ingredients in the toothpaste. Further studies are required to truly make conclusions on the antifungal effectiveness of children's toothpaste. Successors of this experiment should consider using *C. albicans*, a pathogenic yeast found in the oral cavity.

The Dependence of Milk Type on the Shelf Life beyond the "Best by Date"

Netra Shah *Mills E. Godwin High School*

The purpose of this experiment was to determine the shelf life of different types of milk after the printed date had passed and which type of milk stays the longest. Many people throw away milk after the printed date has passed even though the milk may not be spoiled. Printed dates on cartons are misleading and are a significant cause of milk wastage, which has environmental and economic consequences. In this experiment, different types of milk were rated by smell, curdling and pH to estimate the shelf life of the milks after the printed date had passed. All approved safety protocols were followed during the duration of the experiment. There was no control since there is no standard in milk types. It was hypothesized that milk stays good beyond the printed date and skim milk will spoil the slowest. The results showed the average shelf life after the printed date of skim milk and 1% milk was 8 days while 7 days was the average for whole milk and 2% milk. Hence, all milk can stay good past the printed date and the type of milk does not have a significant effect on the shelf life. Six t-tests were calculated and revealed that the data was not statistically significant. Two factors that most likely caused the results are the raw milk quality and temperature of the refrigerator where the milk was stored during production and distribution. This experiment demonstrates that the shelf life of milk is significantly longer, about a week, than the printed dates which has major economic and environmental implications.

The Effect of Different Materials on Purity of Water

Sudarshan Sriniaiyer *Mills E. Godwin High School*

The purpose of this experiment was to see which materials were best at purifying water. A control was added to determine the pH of the contaminated water without any purification. In many areas around the world, fresh water is very scarce. Many communities have contaminated water which is hazardous to health. If an effective method of purification is discovered, then more communities can receive cleaner water. Tap water was contaminated using 50 grams of fertilizer. Activated charcoal, no material and cotton balls were used to purify the contaminated tap water. A research hypothesis was formulated that if the contaminated water was treated with activated charcoal, then it would be the purest. The control in this experiment was when no material was used to treat the water. The reason for having this control was to see how contaminated the water was without any treatment. This was used as a baseline to compare to the results of the other purification methods.

The results of the experiment revealed that the water was purest after being treated with activated charcoal. A t-test was performed on the data and it was found that the data was statistically significant. The results supported the research hypothesis. It is believed that the results are due to the fact that activated charcoal has the ability to cleanse water chemically as well. Some of the chemicals that are commonly found in fertilizer such as potassium, ammonia, and sulfur could have been filtered out by the activated charcoal. This research could lead to further research investigating which other methods of purification are effective and inexpensive to treat contaminated water.

Second Place

The Effect of Turbidity on the Reproduction of *Culex pipien* Mosquitos

Leem Taha *Mills E. Godwin High School*

The vector borne disease malaria, known to transmit through mosquitos, plagues the African continent as one of its leading causes of death. Although medicinal treatments are common in the western world, preventive health care is uncommon and rarely effective in third world African countries. To combat this issue, people look for other approaches to reduce malaria transmission such as home remedies and environmental changes. The purpose of this experiment is to investigate turbidity as a possible method affecting the reproduction of mosquitos. A permission form was signed by a parent that indicated that they had read and understood the risks and possible dangers involved in the research and they consented to their child participating in this research. In this study, *Culex pipien* mosquitos reproduced in three environments with liquids of different turbidites including 5 NTU, 50 NTU, and 500 NTU. The control group was the 5 NTU mixture, and a hypothesis was made that if the environment holds waters of 500 NTU or greater, then the reproduction of mosquitos will decrease. The mosquitos were placed in separate environments and given mixtures of water, dirt, sand, and sugar at different ratios. The amount of living mosquitos was recorded after a thirty-day time period. The comparisons of the 50 NTU mixture (11.4 mosquitos) and the 500 NTU mixture (2.08 mosquitos) to the control 5 NTU mixture (15.4 mosquitos) imply that turbidity does have an effect on the reproduction of mosquitos. Due to these results, the research hypothesis was supported by the data. To improve upon this experiment, more precise methods of data collection and a more accurate representation of malaria transmission through other species of mosquitos could have been established. Similarly, other mosquito species should be investigated in future studies.

The Effect of *Streptococcus thermophilus* on Average Bread Crumb Grain

Raymond Wen *Mills E. Godwin High School*

The purpose of the experiment was to determine the effect yogurt had on the number of perforations found in bread. In past years, the most common way to incorporate air into a loaf of bread was through the activation of yeast. The process that yeast goes through to produce the amount of air needed to support the robust crust of bread is fermentation. Fermentation is used to culture many products from wine to cheese, but yogurt is considered a specialty in fermentation. Since the properties that yogurt has includes the preservation of bacteria like *Streptococcus thermophilus*. This can be used as an alternative to the standard yeast risen bread for a more complex loaf.

The type of bacteria used was *Streptococcus thermophilus*, a common yogurt bacterium. Four groups of starter mixture were given 0 grams of yogurt, 20 grams of yogurt, 40 grams of yogurt, and 60 grams of yogurt. The hypothesis stated that the greater the amount of yogurt in a mixture, the more holes were to be found in the final product. The group with that had the most amount of yogurt was the most effective with an average of 35 holes. A t-test was performed for every comparison and proved that the data was not significant, and the outcome was most likely due to chance. The data also supported the research hypothesis. This proves that yogurt had an impact on the amount of air integrated in bread with fermentation. This experiment can be improved by having more constant temperatures throughout the project and more consistent measurements with the baking and starter preparations.

Finding the Least Harmful Aircraft Runway De-icing Chemicals on Nitrifying Bacteria in Water Masses

Noor Zakriya *Southwest Virginia Governor's School*

The purpose of this experiment was to determine the which aircraft runway de-icing chemicals did the least amount of damage to nitrifying bacteria population growth and survival in nearby water sources. This was achieved by growing cultures of Nitrosomonas, Nitrospira, and Nitrobacter in optimal conditions, while monitoring the inhibition of growth that occurred by adding the de-icing chemicals. The results were collected by observing the bacterial culture from each trial under a microscope on a hemocytometer and counting the number of visible bacteria under 250x magnification. Due to the fact that each hemocytometer chamber contains 10-4 mL of suspension area, it was possible to calculate how many bacteria per mL there were for each variable. These results were compared to the control sample as well as each other to determine which chemical had the worst effects on the growth of the nitrifying bacteria population. Throughout the trials, propylene glycol allowed for the least amount of bacteria growth, and caused an average of 48.50% inhibition of growth and allowed for the cultivation of 1.424 x 106 bacteria per milliliter. Potassium formate was the second most-harmful, causing on average 34.32% inhibition and the cultivation of 1.816 x 106 bacteria per milliliter. It was discovered that the least harmful aircraft runway de-icing chemical was potassium acetate, causing only 23.25% inhibition of growth and the cultivation of 2.122 x 106 bacteria per milliliter.

First Place

The Effect of Coronavirus Species on the Binding Strength to a Neutralizing Antibody

Monona Zhou *Mills E. Godwin High School*

SARS-CoV, SARS-CoV-2, and MERS-CoV are three human coronaviruses (HCoVs). They each cause highly pathogenic and infectious diseases that have damaged society in past two decades. The spike (S) protein resides on the outermost layer of these three HCoV particles with its receptor binding domain (RBD) being crucial for viral infection. As a result, there is a high demand for effective antibodies against the RBDs of these HCoVs for treating viral infections. In this experiment, the binding strength of the HCoVs to a neutralizing antibody, COVA2-04, is measured by the amount of potential binding energy present between the RBD and COVA2-04. The purpose of this experiment is to determine whether different HCoV species affect the binding strength of the viral RBDs to COVA2-04. The experimental hypothesis stated if the SARS-CoV-2 RBD is used, then the binding strength of the virus RBD to COVA2-04 will be the strongest.

The crystal structure of SARS-CoV-2 RBD attached to COVA2-04 was downloaded and the other two viral RBD structures were modeled before the missing residues were added to the complex structure. These structures were then run through Molecular Dynamic (MD) simulations to measure the potential binding energy between the viral RBDs and COVA2-04. There is no control since there is no standard virus species. SARS-CoV-2 had the lowest average amount of potential binding energy to COVA2-04, thus, bound the strongest to COVA2-04. In contrast, MERS-CoV had the highest amount of potential binding energy and bound the weakest to COVA2-04. Three t-tests, SARS-CoV vs. SARS-CoV-2, SARS-CoV vs. MERS-CoV, and MERS-CoV vs. SARS-CoV-2, revealed that the data was statistically significant and supported the research hypothesis. The results were likely due to COVA2-04 originally being produced to attach to and inhibit SARS-CoV-2, making their surface structure compatibility the highest. SARS-CoV had the second strongest binding to COVA2-04 since it has the highest S protein sequence similarity to SARS-CoV-2.

Physics & Astronomy (HS PHY)

The Effect of Different Blue Light Mitigation Techniques on LED Blue Light Irradiance

Angelica Bain *Washington-Liberty High School*

The purpose of this experiment was to test the different blue light mitigation methods' impact on the amount of blue light energy emitted from the LED screens of smartphones. The amount of research about blue light is growing rapidly, and as more information about the negative health effects emerges, factors that affect the dosage of LED light are gaining importance. The hypothesis stated that if different blue light mitigation techniques are tested for the amount of blue light relative irradiance (w/m^2) using a Spectryx USBVIS spectrometer then the night shift mode will prove to be the most effective at reducing blue wavelength irradiance. Based on the results of this experiment and the conduction of an ANOVA test, the null hypothesis stating that different blue light mitigation techniques would have no effect on the amount of relative irradiance (w/m^2) was rejected. The ANOVA test yielded a p-value of 1.10 x 10^-15, which falls far below the needed 0.05 to prove the independent variable had an effect on the dependent variable. All of the blue light mitigation methods had a significant effect on the amount of relative irradiance emitted the control data set emitted on average around 220.6% more light in the targeted blue light wavelengths as measured by relative irradiance. Although this fact stands, the hypothesis was not accepted because night shift mode was not the most effective in reducing the amount of relative irradiance emitted; the blue light blocking screen filter was. Despite the blue light reduction method, they all significantly decreased the potential retina damage, which just furthers emphasizes the importance of protecting your eyes and using blue light blocking methods.

Spectral Signatures of Simulated Black Hole Accretion

Brian Cate *Central Virginia Governor's School*

The purpose of this study was to determine if changing the electron temperatures of an accreting black hole would cause significant shifts in the emission spectra. The photon simulation code grmonty was used to produce the spectra, and the parameters Theta E and Tp/Te were used to manipulate the electron temperatures in the jet and accretion disk. The spectra were analyzed using a Poisson noise technique to confirm their accuracy, and then visually reviewed to determine the trends in the data. Analysis revealed that changing the electron temperature in both the jet and accretion disk had a statistically significant effect on the luminosity of the spectra. Increasing Theta E, which measures the electron temperature in the jet regions, produced the expected decrease in overall spectral emission. Increasing Tp/Te, which governs the electron temperature in the disk, also produced a downward shift, which was not anticipated. This partially supported the research hypothesis, which stated that if the electron temperatures in the jet and the accretion disk were changed by increasing Theta E and Tp/Te, then increasing Theta E would result in a downward shift in the spectrum and increasing Tp/Te would result in an upward shift in the spectrum.

Honorable Mention

The Effect of Different Parts of the Foot on Distance a Soccer Ball Travels

Madeline Cheatham *Clover Hill High School*

The purpose of this experiment was to determine the effect of the different parts of the foot on the distance a soccer ball traveled. Knowing which part of the foot allows the ball to travel farther means that Coaches and Soccer Players can focus more time into perfecting and understanding the one specific skill. To measure the distances with each foot, a leg apparatus was built to simulate a foot hitting a ball. The five levels of independent variable were control, outside of the foot, toe of the foot, and top of the foot. The distances were recorded into a data table, and this process was repeated until each level had 60 completed trials. The control part of the foot (inside) had an average distance of 31.3 meters (m). The top of the foot resulted in an average distance of 41.8 m. The outside of the foot generates an average distance of 32.2 m. The toe of the foot traveled 37.8 m on average. After the data was collected, an ANOVA test was conducted to test if the data was statistically significant. The results of the ANOVA test stated that there was a statistically significant difference between two of the levels of independent variable. The experimental hypothesis of this experiment was that the top of the foot would cause the ball to travel the farthest. This was supported.

Kinematic Analysis: Transition Skateboarding on Force Components

Brandon Chung *Mills E. Godwin High School*

The purpose of this experiment was to investigate the effects of different skating techniques on the height achieved after traversing the transitional section of a half pipe. Recently, skateboarding became an Olympic event and transitional ramps are one of the many obstacles that will be present. Applying force perpendicular to the direction traveling is known as pumping which is used to increase momentum while skating a ramp. Researching the most efficient technique for pumping will help athletes reduce the work necessary to reach greater heights, ultimately allowing athletes to have increased airtime to complete multiple tricks. The investigation consisted of skating through a half-pipe while studying the effects of alternating the pumping technique used. Each trial began at an 8ft drop on one side of the ramp and a video camera was used to measure the maximum height achieved after reaching the opposite side. The levels of the independent variables consisted of standing up, squatting, a full body extension, and an athletic stance with no upward or downward movement, which was the control. The pumping technique was only applied on the way up the ramp. It was hypothesized that if full body extension was performed then a height greater than 8ft would be achieved while outperforming the other techniques, as it would have the greatest normal force component upward and thus greater momentum. The results revealed that although full body extension achieved the greatest height, there was no statistically significant difference in comparison to standing up results… it is believed the results are due to decreasing the distance from the center of the radial curve to the center of gravity in one's body. … This research could lead to further studies that investigate the timing of when to apply the technique in relation to the curvature of the ramp for further optimization.

Analyzing Dust Grain Sizes in the Protoplanetary Disk HD 163296 Through Different Electromagnetic Wavelengths

Landon Epperson *Central Virginia Governor's School*

The purpose of this study was to analyze high angular resolution data of a protoplanetary disk with concentric dust rings, then produce models to identify different grain sizes, how they distribute, and their effect on thermal emission within the disk. The models and plots were produced in a Python environment using two programs called Radmc-3d and Radmc-3dPy. The results from the models indicated that grain sizes around 1e-1cm (1mm) are the most prevalent within HD 163296 and produced the highest peak brightness temperature, with a value of 7.03K. This temperature is much lower than the true temperature of the disk, suggesting the ring observed is optically thin. In order to analyze and determine the best fit model, a reduced Chi-squared test was run in a Python script. Out of a total of three models with differing grain sizes, they all produced a reduced Chi-squared value greater than 1, suggesting that not all the data was captured. The third model, with a grain size of 1e-1cm, produced the lowest value of 4.79. This results in the third model being the best fit for the original observations made by ALMA (Atacama Large Millimeter Array). These findings supported the research hypothesis that different grains sizes will not be evenly distributed in the given rings of HD 163296. In short, this research provided valuable information on the structure and formation of rings in protoplanetary disks.

The Effect of Different Shin Guards on Force Reflected

Mohnish Gopalan *Mills E. Godwin High School*

The purpose of this experiment was to find what style of shin guard would reflect the most force. In 1990, FIFA passed broad shin guard regulations, requiring all players to wear shin guards during matches. But FIFA did not restrict the players to wear any particular guard, and many players just chose whatever guard they think fits right. Due to this there is no control in this experiment. It was hypothesized that if a ball was bounced off a polypropylene guard, then it would have the least height bounced. A ball was bounced 30cm above the shin guards and the reflectivity was measured in cm. The results showed that the polypropylene guard reflected more force than the other guards tested. T-tests were performed on the data. The t-test revealed that all 3 IV levels were significant. The results did not support the research hypothesis. It is believed that the results are due to the fact that polypropylene is more rigid than a shin pad. This research could lead to further studies on different materials, such as Kevlar, and carbon fiber.

Second Place

Is the Solar System an Outlier? Exoplanetary Orbital Eccentricity and Its Relation to Mass and the Count of Planets

William Graf
Thomas Jefferson High School for Science and Technology

New exoplanets discovered in the past decade show that our solar system is not typical in the attributes or configurations of the planets suggesting a need for a better understanding of the conditions leading to the formation of Earth-like planets. In particular, new-found exoplanets generally have highly elliptical orbits, while Earth and its neighbors have nearly circular orbits. Prior researchers have noted the relationship between the mass of exoplanets and their eccentricity, while others have noted the tendency of multi-planet systems to exhibit lower eccentricity. This research aims to address the seeming anomaly the solar system's uniqueness through deeper inspection of the attributes of the exoplanets and their host star systems. In doing so, the research advances understanding of planetary formation. This study uses regression modeling of exoplanetary mass and the prevalence of multi-planet systems to explain the variation in exoplanet orbital eccentricity using databases compiled from The Extrasolar Planets Encyclopaedia and the NASA Exoplanets Archive. Both linear in levels and power-law relationships were modeled. The models considered and rejected the possibility that the orbital eccentricities of higher mass exoplanets are better explained by accounting for the count of planets in the system. While the solar system is characterized by low orbital eccentricities relative to the known exoplanets, this study found that accounting for the number of planets in the same system as the exoplanet helps explain the apparent difference between orbits of solar system planets and observed exoplanets. The results also extend the literature that suggests a relationship between the eccentricities of the planets and their masses based on modeling of planetary formation.

The Effect of Location on the Amount of Skyglow Detected by a Digital Camera

Ian Hooks *Clover Hill High School*

The purpose of this experiment was to determine the effect of the location on the amount of skyglow detected by a digital camera. This experiment is also intended to bring forth the issue of light pollution to people's attention. To measure the amount of skyglow in the sky, the photos were uploaded to Adobe Photoshop. With Adobe Photoshop, adjustments can be made to a certain image, including the levels or brightness of the photo. The levels were adjusted, so that the results could be taken. The four levels of the independent variable were Ukrop Park, Mary Munford School, Watkin's Landing, and 11918 Kilrenny Road (Backyard). The skyglow photos process was repeated seven different times on seven different nights. The Ukrop Park level produced a mean amount of skyglow of 16.17 EET. The Mary Munford School location had a mean amount of skyglow of 15.94 EET. The backyard location had a mean amount of skyglow of 14.16 EET. The Watkins Landing location had a mean amount of skyglow of 11.87 EET. 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 there was a statistically significant difference between the levels of the independent variable because the p value was less than the level of significance of 0.05. The experimental hypothesis of this experiment was that the Mary Munford School location would have the most amount of skyglow. This was not supported.

Third Place

The Effect of Coronal Mass Ejection Acceleration (km/s^2) In Relevance of Earth's Orbital Position on Gamma Ray Dose Equivalent Rate (nSv/H) in Virginia

Anvita Korrapati *Mills E. Godwin High School*

It's an alien landscape, where tens of thousands of magnetic tornadoes twist upwards. Mysterious dark spots, large enough to engulf the Earth, are prevalent and violent eruptions shoot tons of charged particles into space at colossal speeds. This strange and otherworldly environment is none other than the Sun. Since ancient times, the Sun has provided light and sustenance to humankind, cultivating vitality. But it also has the power to destroy life through its radiating energy. A testament to its dangerous capabilities is the Coronal Mass Ejection (CME), which contains a significant amount of plasma containing very high-energy particles. A CME generated storm can affect the entire technological infrastructure on Earth through harmful levels of gamma radiation. In order to test the exact instance of when the Earth is more exposed to this radiation, a study on the effect of CME accelerations (km/s^2) on Gamma Ray Dose Equivalent Rates (nSv/H) was conducted by gathering data from the SOHO LASCO CME catalog and RadNet gamma radiation database. These data points were averaged to find the highest gamma ray dose equivalent rate during a specific position of Earth in relevance to the Sun, which were split into the four seasons in Virginia (Winter, Spring, Summer, Fall). A permission form was signed by a parent that indicated that they had read and understood the risks and possible dangers involved in the research and they consented to their child participating in this research. The data was found to be statistically significant and demonstrated that the Summer season yields the highest gamma ray dose equivalent rates, which concludes that the Earth's ring current during the Summer is more susceptible to radiation produced by geomagnetic storms in the form of CMEs.

The Effect of Artificial Lighting on the Ability to View the Night Sky

Maya Kaminski *Washington-Liberty High School*

This experiment's purpose was to examine artificial lighting's effect on the ability to view the night sky in summer and fall. Artificial light (light pollution) wastes energy, harms the ecosystem, and interferes with visibility of the night sky. There were two hypotheses: (1) if the light is brighter in a location, then fewer stars will be visible; and (2) if measurements are taken in the fall, then more stars will be seen. Eight locations in Arlington were visited for 33 nights in summer and fall. At each site, the constellation Hercules (summer) or Perseus (fall) was located in the sky and compared to star charts, ranked zero to seven (zero, meaning no stars seen, to seven, meaning a sky filled with stars). Globe at Night, a citizen science program, supplied these charts. A light meter was used at each location to measure the lux (measurement of light) given off by streetlights, as well as a sky quality meter, which measured mag/sq arcsec (measurement of sky quality). Both hypotheses were supported by the results. The first hypothesis was proven: the location with the highest average light measurement had the lowest average star chart ranking, whereas the location with the lowest average light measurement had the highest average star chart ranking. The second hypothesis was also proven: most Perseus (fall) average star chart rankings were higher than those of Hercules (summer). The star chart classifications were entered into the Globe at Night website, giving the world knowledge of Arlington's light pollution.

Quantum Dot Supercapacitors - The Impact of Variation of Supercapacitor Electrolyte Base Material on Capacitance and Supercapacitor Discharge Time

Anika Mukul & Aditi Mukul *Battlefield High School*

In recent years, supercapacitors have been found to be superior to many other energy-storage platforms for a multitude of reasons. However, there is one primary downside to utilizing supercapacitors for energy storage – the most commonly used electrical conductor in supercapacitors, graphene, is very expensive and difficult to obtain, which means that supercapacitors cannot be utilized in their greatest capacity by neither the scientific community nor the general public. The purpose of this experiment was to determine which base material of carbon nanotubes, also known as quantum dots, produced the strongest supercapacitor, as well as had the most similar properties to graphene supercapacitors in order to solve the issues with graphene by using an alternative carbon source. In order to do this, supercapacitors in the form of two sets of coated current collectors, or electrodes, facing each other with a separating material soaked in the electrolyte in between them were created with varying electrolytes. Then, the capacitance and discharge times of each supercapacitor were tested using a variable power supply, breadboard and 1000 Ω resistor. After using the recorded discharge times to calculate capacitance using a capacitance formula and the results were graphed, it was evident that the sucrose-based supercapacitor had the greatest capacitance because it not only had a large range, but it also held that range for a longer relative period of time. This differed from the initial observations and predictions that were based solely on electrical discharge times, as urea had the shortest discharge time before converting, but its comparatively short voltage window had not yet been accounted for.

Honorable Mention

The Effect of Grain Size on Temperature in the Protoplanetary Disk IM Lup

Jillian Nylund *Central Virginia Governor's School*

The purpose of this study was to determine if temperature changes with grain size utilizing the protoplanetary disk IM Lup. The data used was thermal-line imaging collected from IM Lup via the Atacama Large Millimeter/submillimeter Array (ALMA) Telescope located in Chile. This study used a Monte Carlo radiation transfer code, RADMC-3D, to calculate the temperature of a disk with various grain sizes and then compared these to data from an existing paper. Twenty-four data points that related radius and height to temperature were collected for six models at grain sizes ranging logarithmically from .1 microns to 1 centimeter. A reduced chi-square test was conducted to analyze the results. This test found that all models were statistically significantly different as each of their reduced chi values exceeded the delta range, .175, from the reduced chi-minimum value of 21.6768. The research hypothesis, that a larger grain size will have a colder temperature, was partially supported because temperature decreased between the .1 Micron, 1 Micron, 10 Micron, 100 Micron, and 1 Millimeter Models. However, the 1 Centimeter Model having the highest temperature did not support this hypothesis. In summary, the results suggest that grain size in IM Lup is most likely 1 millimeter and that temperature can be used to infer grain size with an inverse correlation between 100 microns and 1 millimeter.

Honorable Mention

The Connection Between Spiral Galaxies and Asymmetry: Analyzing Quadrupole Multipole Asymmetry in Spiral Galaxies and its Relation to other Galactic Characteristics

Simran Patibanda, Kaylyn Nguyen & Trent Schuyler
Governor's School@Innovation Park

Recent astronomical observations have seen large-scale asymmetry in the number of counterclockwise and clockwise spiral galaxies. The purpose of this experiment is to discover if the universe is asymmetrical based on patterns demonstrated through analysis of spiral galaxies' positions and find relationships between the quadrupole multipoles' locations and other galactic characteristics. It is hypothesized that if the galactic coordinate ranges of clockwise and counterclockwise spiral galaxies demonstrate a quadrupole multipole alignment, then a pattern could exist in other characteristics of spiral galaxies further indicating asymmetry in the universe. To test this hypothesis 4,250 galaxy images were obtained from the Sloan Digital Sky Survey (SDSS), and their spin direction was determined using Ganalyzer. Potential axes of asymmetry were found by fitting each right ascension and declination combination to d $|\cos(2\varphi)|$ and $\cos(2\varphi)$ in a chi square goodness of fit test, where d is the spin direction and φ is the angular distance between the geocentric coordinates of the galaxy and the coordinates of the potential axis. The statistical difference between the random and real values of the spin direction represents the probability of a quadrupole axis to exist. A correlation matrix was generated to observe patterns in characteristics of spiral galaxies (velocity dispersion, u, g, r, i, and z color bands, distance, and magnitude) and its relation to probable axes of asymmetry. The results demonstrate a high probability of an axis of asymmetry at (0,-10) and (280,70) as well as a low probability of an axis of asymmetry at (240,10). However, when observing the characteristics of the dataset utilizing a correlation matrix, there are no additional relationships observed besides those already discovered that are not a direct effect of the numerical asymmetry in spiral galaxies, and thus the hypothesis can be rejected.

The Effect of Type of Carbohydrate on a Solution's Refractive Index

Ryan Poquis *Mills E. Godwin High School*

The purpose of the experiment was to determine whether the type of carbohydrate influences the refractive index of a 1 M solution of the carbohydrate. Being able to accurately determine the concentration of sugar in a solution in a cheap fashion is important for both people with type 2 diabetes and small sugar cane farmers who want to create a sugar refinery. To test the effects of carbohydrate type on refractive index, the angles of refraction of solutions with no solvent (control), 1 M glucose, and 1 M sucrose were recorded at ten-degree intervals in order to determine the index of refraction using linear regression analyses. It was hypothesized that if one-molar solutions are made with different carbohydrates as solutes, then the solution with 1 M sucrose will have the greatest index of refraction. During all experimentation, laser-safe goggles, gloves, and an apron were worn to minimize risk, and no food or drink was allowed in the testing environment. The results revealed that the index of refraction for a solution with no solvent, 1 M glucose, and 1 M sucrose were 1.32, 1.44, and 1.49 respectively. Three t-tests were performed on the data which revealed that all of the data collected was statistically significant. The results supported the research hypothesis. It is believed that the results are due to the molar mass of each carbohydrate because the density of a chemical compound is directly proportional to its molar mass, and the refractive index of a medium is directly proportional to its density.

Let’s Play Ball: A Study on How the Material of a Softball Bat Affects the Distance of a Ball Hit

Kelly Taylor *Chesapeake Bay Governor's School*

Softball bats are an important tool within the sport of softball, because of this they range in price, weight, regulations, and popularity. Though, do these parameters actually correlate with performance? This study analyzed how the material of a softball bat affects the distance of a softball hit. This study incorporated the three primary used types of softball bats aluminum, composite, and wooden. In order to test the hypothesis, the mean distance of softball hit from the fence will be greatest from the composite bats, followed by the aluminum bat, and then the wooden bat. Each bat was used to hit 25 premium leather softballs off of a batting tee, then the average distances of said softball were measured from the fence and converted to the overall distance of the ball hit. The data from this study was found to be highly significant, showing that a composite softball bat performed at the greatest rate, the aluminum at the most average, and the wooden with the worst performance. This concludes that the price of a softball bat is indeed worth the cost in correlation with the material of the softball bats performance in regards to distance.

The Effect of Various Wavelengths on the Detection of Point Sources in the Galactic Center

Erum Vohra *Mills E. Godwin High School*

This experiment investigated the Galactic Center Gamma-Ray Excess, a region of the Milky Way that has an abnormally large concentration of gamma-ray emissions. The purpose of this study was to investigate the correlation between gamma-rays and infrared waves in the galactic center. This correlation provided insight into the cause of Gamma-Ray Excess and the validity of current theories, such as the presence of millisecond pulsars and dark matter annihilation. It was hypothesized that if the galactic center of the Milky Way is observed in infrared wavelengths, then there would not be a significant correlation with the gamma ray observations. Gamma rays and infrared waves were compared with data from the Fermi Gamma-Ray Space Telescope and the Two Micron All-Sky Survey. Once data was collected for specific regions of the sky, linear trendlines were established for each region and wavelength. Trendline values were compared between the two wavelengths by subtracting the gamma-ray value from the infrared value. Statistical analysis was performed on this experiment and established that the study was not statistically significant, supporting the hypothesis that there would be no significant correlation between gamma-rays and infrared waves in the galactic center. The results indicated that there is no significant millisecond pulsar source for the Galactic Center Gamma-Ray Excess and that other possible sources should be considered, like dark matter annihilation or cosmic ray bursts.

First Place

The Effect of Constellation on Radio Signal Received at 21cm

Sam Watchman *Arlington Tech*

This study focuses on the spectral line at the 21-centimeter radio wavelength, which is emitted by hydrogen atoms, specifically in the Milky Way. Hydrogen is spread all across the Milky Way galaxy but is concentrated in its different spiral arms. This study examines the amount of power emitted by the hydrogen at this spectral line in different parts of the sky, and also at the Doppler effect frequency shifts in this spectral line caused by the galaxy's rotation which is especially important because by looking at the amount of frequency shift, it is theoretically possible to measure the galaxy's rotation speed and detect its different spiral arms. To detect the 21 cm hydrogen spectral line, this experiment used a 1.5-meter aperture horn antenna to collect and concentrate the signal. The signal was amplified by a Nooelec H1 amplifier and then detected by an RTL-SDR Software Defined Radio. The data was collected in software, and then processed to remove noise and boost the signal itself. The results were that there was more signal in the regions of the sky where the plane of the Milky Way passed through, and that there was a noticeable Doppler shift in the signal in some parts of the galaxy.

Psychology A (HS PSY-A)

The Effect of Visual Messaging on Hand Sanitizer Use

Isabel Baggette *Chesapeake Bay Governor's School*

This study looked at the use of eyes in visual messaging as a way to promote cooperation with posted notices. A chalkboard was set up in the entrance of a restaurant, situated on a table behind a bottle of hand sanitizer. Throughout the study, the board behind the sanitizer displayed the message “please use” surrounded by eyes, only the message “please use”, or was removed entirely. It was shown that people were 60% more likely to use the provided hand sanitizer when the eyes and text were displayed than when there was no messaging at all. There was not a statistically significant difference between the two sign variables, but the results showed that people were 15% more likely to use the sanitizer when the sign included eyes as opposed to only text.

Second Place

The Effects of Classroom Environment on Average Student Participation in a Group Discussion

Sarah Blair *Central Virginia Governor's School*

The purpose of this experiment was to determine the effects of classroom setting, in-person vs. online, on average participation in a group discussion. This experiment was conducted in 2020 at a high school in central Virginia. Two groups of six students were randomly selected from volunteers, and each group participated in an online and face-to-face discussion. Two dependent variables were analyzed for significance: average seconds spoken per student, and average number of times spoken per student. Average seconds spoken per student were recorded out of a total of 600 seconds (10 minutes), and “one time spoken” was defined by an uninterrupted period of speech. Results from both trials were combined and evaluated using matched t-tests with an alpha level of .05. The data revealed a significant difference in average times spoken per student, with a p-value of .0018. However, there was no significant difference in average seconds spoken per student, which was concluded from the corresponding p-value of .052. Ultimately, the research hypothesis, “If students are made to have a group discussion, then an in-person setting will yield greater participation than an online setting,” is partially supported by the data.

Emotional Trauma Caused by The Lack of Sports Due to the Covid-19 Pandemic

Wyatt Brown *Chesapeake Bay Governor's School*

The Coronavirus pandemic forced schools to close in March 2020, causing students to miss their Spring & Fall '20, and Winter '21 sports seasons. Without the influence of sports in student athletes' life due to the Covid-19 pandemic, students accustomed to leaning on sports for social support are likely to suffer mentally. Sports combat depression and anxiety. Sports allow people to improve their body physically, which lets them feel good about themselves, which in turn improves their mental health. There were 122 participants in the survey from high school grades sophomore to senior. The relationship between the percent of time student-athletes play sports to their time spent focused on academics was also analyzed resulting in a p value of .999 which showed significance. Casual and serious athletes are compared based on the average hours students lost to sports due to the Coronavirus pandemic. Casual athletes are considered those who spent less than or equal to 10 hours a week of sports activity while serious athletes are considered to be those who played sports for more than 10 hours a week. This resulted in the serious athletes losing 3.8 more hours than the casual athletes. The percent change of hours of sports played before vs after Covid-19 based on grade was measured resulting in a mean loss of 60.9% of time playing sports. The juniors lost on average 74% of their time in athletics. Seniors lost 59% and the sophomores lost 45% of their time in athletics. On average, there was a loss of 4.3 hours of sports played per student after the Covid-19 pandemic school closures.

How Does the Media Influence Perception of Law Enforcement?

Johannah Caudill *Southwest Virginia Governor's School*

Law enforcement is an institution with applications in many disciplines. A comparative study examining the relationship between pre- and post-surveys was performed. The purpose of this study was to determine if the media has an impact on perception of law enforcement. Data recorded from the pre- and post-surveys was analyzed statistically by a matched-pairs t-test. This test determined if a significant difference between the means of the surveys exists. The test revealed that participant survey responses were significantly different after viewing the survey material: the mean difference was 0.3, and the p-value was 0.0025. The alternative hypothesis for the study was accepted indicating a significant difference between the surveys. Therefore, the fact sheet containing information from the media surrounding the law enforcement institution such as the allotted budget, solved case average, and death rate influenced the study. The study found that the media does reasonably influence perception of law enforcement. This can inform future research in this field by providing information on how great the influence of media is. It is also important in maintaining the media’s responsibility in reporting facts instead of sensationalizing violence.

Honorable Mention

The Comparison of Online Learning Strategies on Information Retention

Kate Devitt *Mills E. Godwin High School*

The arrival of a global pandemic forced education to rapidly shift to digital pedagogy. Many school districts do not have the resources to invest in an array of digital tools, and therefore are greatly disadvantaged. The aim of this experiment is to compare two methods for increasing information retention in online education: gamification and the inclusion of the human face. Participants between the ages of eighteen to twenty-five were taught the translation of twenty Dutch nouns and four nonsense rules for using them via either a Kahoot game or a lecture-style video. The amount of information retained was measured as a percentage of correct answers given on a test administered forty-eight hours after the learning phase. To ensure safety, all contact was done virtually, participants were told they could leave the experiment at any time, and participants were given breaks and practice quizzes to alleviate stress. The video stimulus group demonstrated a higher information retention than the Kahoot group, which had a lower mean accuracy. At a level of significance of 0.05 and a degree of freedom of 10, a t-test indicated the results were statistically significant, and the null hypothesis was rejected. This supported the research hypothesis that the inclusion of the human face would have a greater benefit than gamification. This suggests the inclusion of the human face has a stronger impact on building episodic memory than gamification and therefore further research should be conducted on the applications of this strategy to maximize the effectiveness of digital learning.

Active Versus Passive Virtual Education

Peter Garrison *Central Virginia Governor's School*

The purpose of this study was to determine the best virtual learning environment, whether synchronous or asynchronous. Many schools were forced into a virtual learning environment with the COVID-19 pandemic, and most were torn between setting up synchronous lessons or utilizing asynchronous programs. This study used students from local middle and high schools to determine the best instruction for immediate retention. Using a 10-question quiz following each lesson, a two tailed t-test was performed to determine significance between quiz scores. With an alpha level of .05 and a p value of .7, there was no significant difference. This shows a lack of support for the research hypothesis, which stated that if students who are taught the same material through an asynchronous online lesson as students who learn from an active teacher, then the students who learn from an active teacher will retain more information. This data could be used in the future for online learning decision making, allowing administrators who are split on which remote learning system to use to decide one way or another. Many such choices are close with a few drawbacks to each side and eliminating these could help in the decision making process.

Third Place

Organizational Safety Cultures: Exploring Differences between English & Spanish Workers

Cameron Gilmore *Blacksburg High School*

Historically, production and efficiency has been prioritized over workplace safety in high-risk industries such as mining and construction. One phenomenon introduced to address safety concerns is the concept of safety culture. Although it lacks a standard definition, safety culture can be broadly defined as an organization's values and ideals regarding safety. A robust safety culture has been shown to reduce workplace injury. In companies with large portions of non-English speaking laborers, effectively inculcating a positive safety culture can be challenging. Training materials, policies, guidelines, and other tools are often only delivered in English. This study investigates the difference in how safety culture is perceived between Spanish speaking workers and their English-speaking counterparts. The data analyzed for this project came from a safety culture survey administered to a mid-sized construction company based in California. The company has a sizable population of both English speaking and Spanish speaking employees. Analysis of the pre-existing data consisted of separating responses by language (Spanish & English) and looking for significant differences in their responses to the survey items. Of the 87 items, 26 of them were significantly different, and in all but two cases, the English-speaking employees rated the safety culture more favorably. This is important for two reasons. First, it appears as though the 4 years of safety initiatives undergone by the company prior to the survey were not equally effective for both language groups. This organization may reconsider their safety initiative with a specific focus on their Spanish language employees. Second, these results demand more information. Further studies should be conducted to look for this trend across multiple industries, and multiple types of organizations.

The Correlation Between Dominant/Submissive Personality Traits and the Tendency to Socially Conform

Caitlin Grant *Chesapeake Bay Governor's School*

Social conformity is the unconscious behavior to influence one's decisions based on the environment one is in and the people one is around. This study explored whether a person was more likely to socially conform based on certain dominant personality traits and the genders of the test subject and other participants in the same environment. The experiment, modeled after the famous Asch conformity method, had test subjects among a group of confederates participate in answering a series of category set questions, then individually take a personality survey. In some cases, the test subject would conform to the group response, and in other cases he or she would not show signs of conformity. The use of conformity is known to keep people connected with one another and create stronger relationships, which is why it was predicted that this would make an individual want to conform to the group. It was found that participants who possessed the conformity personality trait would be more likely to conform. In addition, female participants conformed more frequently than males, and both genders conformed more often when in a room full of all male confederates.

The Relationship Between ABO Blood Groups and Certain Personality Types

Sofia Harrison *Chesapeake Bay Governor's School*

The Japanese Blood Type Theory is the concept that blood type is a determinant of a person's personality. This study explored this theory by testing the ABO blood group of participants and three personality types. From previous studies, extraversion, neuroticism, and assertiveness showed a correlation with certain blood groups, and those were the personality types tested in this study. A survey was made using questions from the International Personality Item Pool for each personality type (Goldberg, 1999). Assertiveness and extraversion did not show much difference between the scores of its personality type for the different blood groups. However, neuroticism did show an observable difference between neuroticism scores for the different ABO blood groups. Previous studies have shown that blood groups O and B had high assertiveness scores while A and AB have low scores; and so it was found that this study is consistent with the stated literature, even if the trends were not statistically significant.

Honorable Mention

Ethnicity and Education: Do Gifted Programs Get a Passing Grade?

Kelsey Henry *Chesapeake Bay Governor's School*

Education is by far one of the most vital and important parts in a child's life. It transforms children's lives by allowing them to develop economically, personally, and socially. Throughout the years, there have been numerous questions as to whether or not all students receive equal educational opportunities. Although education is a very important part in every child's life, not all students are given the exact same resources and chances in order to succeed academically. Not only does this study seek to determine if ethnicity plays a factor as to why all students are not treated fairly, this study seeks to determine if there is a correlation between a student's ethnicity and their academic excellence. Specifically, this study strives to determine if there is a correlation between a student's ethnicity and their academic excellence in a gifted classroom.

109 gifted students from elementary to high school age were given a standard survey on their GPA and personal feelings about being in a gifted classroom all sorted by race/ethnicity. The highest average GPA for all students in the gifted program was Caucasian students with an average of 4.1, followed by African American students and finally Hispanic students with an average of 3.8. A p-value of 0.013 indicated a significant difference between in GPA ethnic groups.

The survey that asked how often the students felt unintelligent in their gifted classroom had a p-value of 0.19 meaning that it was trending towards significance. (Table 3) The survey that asked how well the students feel supported or encouraged in their gifted classroom had very similar results with a p-value of 0.068 meaning that it was also trending towards significance. This study shows there is a difference between feelings and success between ethnic groups in gifted programs. Finding ways to make educational resources and gifted program criteria more equitable for all students should be a priority in education.

The Effect of Socioeconomic Status on an Individual's Ability to Swim

Nathan Karnes *Central Virginia Governor's School*

The purpose of this study was to determine whether there was a relationship between socioeconomic status and swimming proficiency. The study was conducted in Central Virginia in the Winter of 2020, with a larger percentage of participants being from rural areas. The study was conducted through an online survey that contained multiple demographic questions regarding socioeconomic status, gender, race, age, and others. There was a total of 19 participants, with 9 being male and 8 being female. After conducting a two-sample t-test, results showed that socioeconomic status and swimming proficiency did not have a statistically significant difference, with a p-value 0.241 compared to an alpha of 0.05. This did not support the research hypothesis that socioeconomic status does have a relationship with swimming proficiency. Research also found that gender, membership to a pool/YMCA, age, and frequency of times swimming during a summer did not have a relationship with swimming proficiency, with p-values of 0.568, 0.369, 0.492, and 0.789 respectively, all compared to an alpha of 0.05. All tests used a two-sample t-test, except age vs. swimming proficiency, where a single factor ANOVA test was used. In summation, even though the data showed no significant findings, it is a possibility that if conducted on a larger scale with a more diverse population of swimmers with varying swimming proficiency and socioeconomic levels, the data would show some significance. Further research in this area could help inform community decisions in regard to water safety.

Honorable Mention

Effect of Social Isolation During the COVID-19 Quarantine on General Mental Health

Eric Kauppi *Central Virginia Governor's School*

The purpose of this study was to determine the relationship between social isolation resulting from the COVID-19 quarantine and symptoms of adolescent mental health issues. This study recruited students from two local high schools in the central Virginia area to complete a survey during November of 2020. The survey contained three sections intended to measure the levels of social isolation, anxiety, and depression that each participant was experiencing. The responses were converted into point values, and the relationship between the social isolation scores and the mental health scores was measured by performing two regression tests between the social isolation scores and both the anxiety and depression scores. At an alpha level of .05, the regression between social isolation and anxiety returned a p-value of .053, and the regression between social isolation and depression returned a p-value of .198. Because neither p-value was lower than the alpha level, the results were not statistically significant and did not support the research hypothesis, which stated that higher levels of social isolation would be correlated with increasing severity of symptoms of mental illnesses. In conclusion, this study found that social isolation during the COVID-19 quarantine did not have a significant impact on adolescent mental health.

Evaluating Loneliness Scales to Assess Loneliness During the COVID-19 Pandemic

Dasol Lee *Blacksburg High School*

Loneliness, the feeling of distress one receives when they perceive their social relationships are less in quantity and quality than desired, is connected to many short and long term physical and psychological issues. Due to their synergistic effect, loneliness and depression are especially harmful to humans. During the COVID-19 pandemic, loneliness and depression has risen due to the forced physical isolation and are amplified by the mass panic and anxiety associated with the pandemic. While there are existing scales to measure loneliness, most of them were specifically created for use in research or clinical settings. Since there was a lack of tools for public use, this research determined the loneliness scale best suited for individuals to use during the COVID-19 pandemic. By evaluating the prominent loneliness scales in existence based on the factors chosen (Accuracy, Language, Loneliness, Answer Options), the best scale for each category of length was decided. From longest to shortest, these include the Version 3 UCLA Loneliness Scale, UCLA 10-item scale, and the single-item question. By establishing a scale for usage by people during the pandemic, people can easily and accurately determine if they are lonely. Mitigating the effects of loneliness and proactively stopping it will result in healthier and happier people, benefiting the greater society. This scale could also be helpful in making the research done during the pandemic efficient and uniform.

First Place

Influence of Virginia State Sentencing Guidelines on Jury Recommended Maximum Sentences

Madison Lilly *Southwest Virginia Governor's School*

The Virginia Criminal Sentencing Guidelines are derived from data relevant to past felony offenses in the Commonwealth and are used as a reference for sentencing judges. Continued 2020 Senate Bill 810 (SB 810) from the VA General Assembly proposes that the proper Guidelines also be presented to a sentencing jury to aid in its decision making, an act that could drastically affect how members of a jury and other criminal court figures perform their roles. Of particular interest in this research is the question of how juror access to the Sentencing Guidelines could affect sentence recommendations, something directly pertinent to the fate of SB 810. Participants in two groups, No Guidelines (NG) and With Guidelines (W/G), were placed in the roles of mock jurors and asked to read two criminal case examples of differing types before providing maximum sentencing recommendations for each and answers regarding Guidelines influence and/or suggestion confidence. Two Sample T-Tests of NG (means 114.88 +/-7.4594764 months for Case 1 and 214.64 +/- 16.44699 months for Case 2) and W/G (means 63.431373 +/- 4.4257052 months for Case 1 and 101.21569 +/- 5.6844 months for Case 2) data yielded $p < 0.001$, indicating differences between the groups for both cases. The Chi-Squared analysis of WG questions regarding Guideline Influence for Case 1 and Case 2 yielded a p-value of 0.9886, indicating that the Guidelines were viewed to be of the same influence for both case types. The other Chi-Squared Analyses of sentence suggestion confidence produced p-values of 0.3617 and 0.9452 for Case 1 and Case 2 confidence respectively, indicating that neither case showed differences in confidence between the groups. The results show that a difference in sentence is present but not viewed as such by participants. Analysis of other case styles including those of a violent nature as well as further research into the psychology of group jury decision making would promote a greater understanding of this topic.

The Effect of Academic Reconditioning on Perception of Connotation

Kylie Maupin *Central Virginia Governor's School*

The purpose of this study was to measure the effect of repetitive academic conditioning of an individual's perception of connotation for specific words. Pretests were used to assess initial perception of connotation of 15 significant words, being either positive or negative. Then, participants were given study guides with content which contradicted their initial perception to see if the material being studied would alter their perception of connotation. This change was assessed weekly by using verbal speed games. The significant words included questioning, use, saving, tenacious, filled, confident, different, old, young, relaxed, thin, economical, adolescent, curious, and talkative. The alpha value was set to .05 and the degrees of freedom was set to 1, which made the chi-square critical value 3.841. The research hypothesis, if students review academic content which contradicts their initial perception of the connotation of a word, then their perception of the connotation will change to match the content of the academic material, was supported in the cases of nine of the 23 results found. Significant chi-square values ranged from 4.00 all the way up to 17.00. One word was significantly changed from negative to positive, four were changed significantly from positive to negative, and two words were changed significantly in both cases. In understanding this much about other people's patterns and methods of thought and communication, we can adapt communication methods to suit specific people, creating a more inclusive and harmonious dialogue for everyone.

How Lifestyle Affects Fast Food Consumption

Benjamin McGuire *Central Virginia Governor's School*

The objective of this study was to determine the relationship between income, demographics, fast food advertising, and frequency of visits to fast food outlets. This was done by recruiting participants from the Central Virginia area to complete a survey asking questions about the previously listed areas of interest. The results were obtained by conducting an ANOVA test, a t-test, and a correlational test using different responses to the differing survey questions. The confidence interval set was .05 and the P-values varied. The ANOVA's P-value was .89, the correlational test's P-value was 0.98, and the t-test's P-value was .00013. The overarching research hypothesis, If the frequency of visits to fast food outlets by lower income families was compared to higher income families, then lower income families' frequency would be higher because they have been more influenced by targeted advertising regarding their income, was not supported by the data. My study concluded that BMI and Income are not related to the choice to eat fast food, but the viewership of fast-food advertisements does affect this choice. Therefore, based on the data of this study, income was not a restriction or significant influencer on the choice to eat fast food.

Psychology B (HS PSY-B)

Is There a Correlation between Anxiety and Trypophobia?

Eleanor McPhatter *Central Virginia Governor's School*

The purpose of this study was to determine whether or not there is a correlation between anxiety and trypophobia. Trypophobia is the fear of tightly compacted holes and bumps. This study was conducted with 35 human participants from a local high school during November of 2020. All participants were required to fill out a Research informed consent form. Each of the participants were asked to complete a survey on anxiety and a survey on trypophobia. The anxiety survey had 13 questions and the trypophobia survey contained a series of photos in which all individuals typed how long they thought they had viewed each photo. To analyze the data from the scores and ratios from all participants for both surveys, a regression test was performed. According to the Critical values of “r” table, for .05 significance, the r-value needed to be above .324 in order to show significance. Since the r-value from the data was .281, that signified there was no significant relationship between anxiety and trypophobia. On a scale from 1 to 20, the average anxiety score was 13.7 and the average trypophobia ratio was 1.07. My research hypothesis which stated that “If I have a number of human participants complete two surveys, then the results will show that the individuals who have a high ratio for the trypophobia test will also show a high score for the anxiety survey,” was not supported. Since the r-value was not negative or was not close to one, my data suggests that trypophobia and anxiety have no direct or indirect correlation with one another.

The Effects of Political Advertisements on Voter Response

Sara Murray *Chesapeake Bay Governor's School*

Research conducted by campaign strategists has led them to believe that political advertisements have a real impact on the outcome of elections. As a result, campaigns spend billions each year creating and distributing these ads. During the 2020 election cycle alone, $8.5 billion were spent on political advertisements. The impact of political ads is still the subject of debate where one study found no correlation between the believability of an advertisement and any demographics, while other studies conclude that specific groups have a higher likelihood to believe a political ad. This study examines the effect of a variety of campaign advertisements on voter sentiment and analyzes trends by demographic, political party and fervor to determine the ability of political advertisements to influence voters' opinions about the 2020 presidential candidates. The data used in this study were obtained using a survey which was shared on social media and through email to attempt to receive at least 100 responses, which was deemed enough to be statistically significant. Data were sorted by other demographic factors, such as male or female, Democrat or Republican, and moderate or extreme political fervor. This was done to indicate political sentiment of respondents and to try to identify groups that are more or less likely to change their minds based on pre-existing political tendencies.

Studying Demographic Trends in Life Quality Based on Maslow's Hierarchy

Alaysia Oakes *Central Virginia Governor's School*

The purpose of this study was to create an accurate assessment to measure the quality of life (QOL) of an individual and identify modern trends. Thirty-two participants were recruited through email from local schools and businesses. Consent forms were completed through Google Forms where an electronic signature was required. The survey consisted of 51 questions that had three main categories: perceived QOL, variable importance, and ideal QOL. I hypothesized that upon determining the previously mentioned, I would be able to estimate life quality and identify current trends. The results supported my hypothesis by having a p-value of .023, meaning the calculated participant QOL was relatively accurate to a .05 alpha value. Paired T-tests were run to access statistical significance because correlating values were from the same participant respectively. The data also showed an inverse relationship between perceived QOL and ideal QOL. Younger participants generally had lower QOL scores and higher ideal QOL scores, whereas older participants had higher QOL scores and lower ideal QOL scores. It was also apparent that all participants were seeking the fifth tier on Maslow's Hierarchy of Needs, self-actualization. Younger participants had more difficulty fulfilling the lower tiers and older participants were farther along, being predominantly in the upper two tiers, self-esteem and self-actualization. In conclusion, my survey was successful at determining QOL to a 95% confidence interval and identifying mainly age based trends that support Maslow's Hierarchy, accompanying the ongoing research on life quality, contributing to creating effective assessments and identifying modern trends.

Third Place

The Effect of Hours of Sleep on Creativity Test Scores

Amanda Powell *Central Virginia Governor's School*

The purpose of this study was to determine if sleep affected creative thinking abilities in high school students. The hypothesis stated that restful sleep would have a negative impact on creativity test scores. Participants were teenagers recruited from local high schools in December 2020. Students were emailed a Google Form that consisted of demographic questions related to sleep and two short creativity tests. The questions included were, “How many hours of sleep did you get last night?” and, “On a rank of 1-10, how tired do you feel right now?”. The tests used were the Remote Associates Test and the Alternative Uses Test. The scores were based on the total points method, and the average scores for each test were 4.0 and 40.5, respectively. After conducting an ANOVA test for both, it was concluded that sleep did not affect the scores. The alpha value was 0.05, and p-values were .94 for the Remote Associates Test and .32 for the Alternative Uses Test. The research hypothesis that fatigued participants would receive higher scores was not supported. Overall, tired students did neither better nor worse on creativity-based tests, suggesting that sleep does not affect creativity, at least in the way these tests assessed creativity.

Honorable Mention

The Effect of Weekly Practice Time on a Violinist's Ability to Sight Read

Elliott Putnam *Central Virginia Governor's School*

The purpose of this research study was to examine the effect of weekly violin practice on a violinist’s ability to sight read music accurately. Participants were asked questions relating to their violin experience and submitted recordings of themselves sight reading assigned musical excerpts. Afterwards, they would answer questions pertaining to their experience and practice habits on violin. Submitted recordings were graded with a fifty-point rubric, allocating ten points each for different aspects of violin playing, such as tone, rhythm, intonation, articulation, and tempo. Every recording was submitted alongside information concerning weekly practice time and total years of experience. From these two quantities, it was possible to create an estimate of each violinist’s total hours of practice. The results of this study indicated a lack of correlation between weekly practice and sight-reading ability, as the p-value ($p = .395$) was greater than the set alpha value of .05. Further regression analysis, however, showed correlations between other data such as the total practice hour estimate to the different subsections of the overall score. Two of these combinations compared the total hour estimate to the articulation and tone scores. The research hypothesis, that greater amounts of weekly practice would result in greater sight-reading ability, was partially supported for this study. This study, while not revealing much about the relationship between practice time and sight-reading ability, had some interesting correlations that could be explored more deeply in future studies.

Honorable Mention

Generational Differences in the Perception of Diabetes Mellitus

Jade Riddle *Southwest Virginia Governor's School*

Diabetes mellitus affects over 463 million people worldwide. Although it is often acknowledged for its severe physiological complications, the psychological burdens of the disease are often overlooked. Previous studies have examined the perceived stigma that diabetics experience, but little to no research has been completed to determine the level of stigma that nondiabetics possess. The purpose of this study was to acknowledge this gap in the research and evaluate the level of diabetes stigma present in different generational groups. The null hypothesis stated that the generational groups would answer in a similar fashion while the alternate stated that they would answer differently from each other. Taking inspiration from previously validated stigma scales for mental health and perceived diabetes stigma scales, a new 16-item stigma survey was developed using Google Forms. The survey employed Likert scale responses and contained subsections on risk factors, treatments, daily life, as well as the preventability and severity of both type 1 and type 2 diabetes. Participants were limited to those who did not have diabetes, did not care for anyone who has diabetes, and did not work with those with diabetes as part of their job. The data were analyzed using a chi-squared test of homogeneity. Most items had a p-value of less than 0.05; however, item 7B possessed a p-value of 0.0282 and item 11B was found to have a p-value of 0.0186. Due to the small sample size of the study (n=15), a Fisher’s exact test was run to verify these results. It was found that item 7B retained a statistically significant p-value of 0.01086 while item 11B did not (0.379). These results suggest that there is not a difference in how different generational groups responded to the stigma survey. However, in the future, this study should be replicated with a larger sample size to verify these results. Additionally, progress should continue to be made on the development of a standardized measure of stigma in order to effectively combat it.

The Effect of Meal Planning and Grocery Lists on the Amount of Food Waste in Households

Leilani Rucker *Central Virginia Governor's School*

The purpose of this study was to determine whether or not grocery lists and meal plans affect the amount of food waste in a household. This study was conducted throughout multiple residences in Virginia during December 2020. Two groups were tested: a group who uses meal plans and grocery lists (Group A), and Group B, who used neither. After about two-and-a-half weeks, the group that did not use meal plans nor grocery lists changed their habits and used grocery lists and meal plans for the remainder of the experiment. Food waste was tracked through a mobile app, and two sample t-tests were conducted to analyze the data. The first t-test conducted was between the group who used grocery lists/ meal plans and the group that used neither. The test resulted in a p-value of .7, with an alpha value set to .05. The other t-test compared the group that did not use meal plans/grocery lists versus the time they did use meal plans and/or grocery lists, resulted in a p-value of .245. These results did not support my research hypothesis which stated that the group who makes grocery lists and meal plans would waste less food than the group that does neither. In conclusion, the results suggested that meal plans and grocery lists do not affect food waste amounts.

The Correlation between Perceiving Faces in Optical Illusions and the Ability to Read Emotional Expressions in Faces

Lindsey Shortt *Chesapeake Bay Governor's School*

Theory of mind, the ability to recognize faces, and the ability to read emotions in facial expressions have been studied over the years. However, the underlying mechanism of such operations, and how they might be connected, is not fully understood. This study explored whether people who are more adept at perceiving emotions in people's facial expressions are also more likely to see faces in optical illusions. Participants were asked to take a two-part survey with describing what they saw in optical illusions and taking a small portion of the Reading the Mind in the Eyes test. It was found that there is no correlation between whether people are able to find the faces in the optical illusions and identifying which emotion is shown in the RMET Test. The main point, I think, is that these two mechanisms of the brain seem to operate independently of one another.

The Effect of Knowing Yourself Better Through the Enneagram on Mental Health

Anna Sloan *Central Virginia Governor's School*

The purpose of this study was to look for a connection between knowing yourself better through the Enneagram (a personality typology) and the general mental health of people. In this study participants completed the researcher's survey once a week for four consecutive weeks. The control group (half of the participants chosen randomly) did not do anything in addition to weekly surveys. After the second survey, the other half of participants were introduced to the Enneagram and took a test that identified their personality type. In the control group, the average scores of weeks 1 and 2 ranged from 24 to 41, and the average scores of weeks 3 and 4 from 27.45 to 39. In the Enneagram group, the average scores of weeks 1 and 2 ranged from 22.5 to 40, and the average scores of weeks 3 and 4 from 26.8 to 44. A paired t-test with an alpha value of .05 was used to compare possible significance between the average scores in the two sets of data. There was no significance in the control group, which had a p-value of .558. However, there was significance in the Enneagram group with a p-value of .022. The research hypothesis was supported by the significance in the Enneagram group data. This study suggests that knowing yourself better through the Enneagram has a positive effect on your general mental health.

How Background Music Affects Concentration and Cognitive Processing

Jonah Snyder *Chesapeake Bay Governor's School*

Streaming platforms like Spotify, Pandora, and YouTube have become increasingly popular in recent years, and even more popular and frequently used since the COVID-19 pandemic began and people were forced to remain at home. In the past, even without a pandemic, students especially listened to music while working on homework and school assignments. Anecdotally, some students claim music is what helps them concentrate while doing homework and other assignments. Others claim they would not be able to complete a single assignment if there were music playing. This study investigated how background music, and particularly the specific characteristics of tempo and presence of lyrics, affect a person's concentration and cognitive processing, primarily related to academic, studious work. Participants were administered three separate sets of math questions, with each question set being administered under a different condition. One condition was no music, while the other conditions varied depending on the characteristic being evaluated. In one sub-study, the characteristic was tempo, fast versus slow, and in the other sub-study it was lyrics, present versus absent. It was found that overall, scores were significantly higher on assessments during which participants were listening to music. However, neither tempo differences nor lyrical differences revealed any significant changes in performance, suggesting that the characteristics of the particular background music chosen can be largely left up to personal taste.

First Place

The Effects of Reading, Listening, and Dual-Modalities on the Comprehension of Different Passages Among High School Students

Alex Taylor *Central Virginia Governor's School*

The purpose of this research was to determine if there were any notable differences in reading comprehension for literature presented in text, audio, and combined text and audio formats. Students volunteered to take part in this research from a number of local high schools in central Virginia. After completing the consent forms, the participants were sorted into three groups (text, audio, and dual) based on their demographic factors to ensure equal distribution of race, gender, age, interest, and education. The sample size for this study was 13, which was a limiting factor. Each participant took a brief 15 question multiple-choice English comprehension quiz containing three high school level passages, and data were collected on the number of questions answered correctly. The mean value for both the text and dual groups were the same at 10.5, while the mean value for the audio group was 10.8. A one-way ANOVA test was conducted. The calculated p-value of .99 was compared with the selected alpha-value of .05, which revealed no statistically significant differences between the three groups. The results did not support the proposed research hypothesis, which stated if high school students were to read, listen to, or read-while-listening to different passages; then those who simultaneously read and listened would have the highest comprehension, while those who only listened would have the lowest comprehension. In summation, this research study suggests that the modality in which literature is presented has little to no impact on the comprehension of information within a high school environment.

The Effect of Relaxation Techniques on Chronic Pain

Hannah Taylor *Central Virginia Governor's School*

The intended purpose of this study was to improve the quality of life of those suffering from chronic pain by testing relaxation techniques that could best decrease pain. The first week participants completed a survey with no relaxation techniques. The following three weeks individuals participated in randomly assigned breathing exercises, listening to music or nature sounds. After completing their weekly technique, they filled out a survey related to their pain scales. Each participant completed all three techniques, three times, for fourteen minutes. Although my analysis showed that my data wasn't statistically significant, there were trends that suggested lower average pain scales on the weeks when participants were completing relaxation techniques compared to the week when no relaxation technique was provided. Trends shown in the data suggest effective relaxation techniques, specifically breathing exercises, may have a positive effect on chronic pain in pediatric patients ages 13 to 17. An ANOVA single factor revealed a p-value of 1.0 between groups and when the alpha value was .05 showed no statistical significance. The study did not support the research hypothesis that if participants with chronic pain participate in three different relaxation techniques, then the instrumental music would be most effective for reducing pain levels. All in all, the results of this study were promising due to the trends suggested in the data. These trends can spark other studies to maximize the quality of life in patients suffering from chronic pain by better managing their pain and stress.

Second Place

The Effect of Increased Blue Light Exposure on Sleep Quality

Lauren Vossen *Central Virginia Governor's School*

The purpose of this study was to provide evidence on whether or not increased blue light exposure during the evening has an impact on sleep quantity and quality. This study was conducted at two local high schools in Virginia during November of 2020. Thirteen participants were recruited in order to conduct this study. Participants were first instructed to fill out proper consent forms. They were then given a survey to fill out every day for two weeks with questions pertaining to their sleep and blue light exposure. A correlation test suggested significance from three of the groups with the set critical value of .1476 and the statistical values resulting in -.189 (sleep quality), .140 (time to fall asleep), -.022 (times woken up during the night), -.187 (alertness), and -.248 (sleep quantity). The groups sleep quality, alertness, and sleep quantity were run through a regression analysis, since there was a suggested negative relationship. With an alpha level of .05, the p-values from each group were revealed to be .0127 (sleep quality), .0137 (alertness), and .001 (sleep quantity). These statistically significant values support the research hypothesis which was that blue light exposure has a significant relationship with one's overall sleep. More specifically, blue light exposure during the evening had a significantly negative relationship between sleep quality, alertness, and sleep quantity.

Honorable Mention

Relationships Between Screen Time and Anxiety and Depression in High School Students

Ella Wesolowski *Central Virginia Governor's School*

The purpose of this study was to examine relationships between screen time and mental and emotional health. Participants were recruited from multiple high schools in Virginia. Consenting participants tracked their screen time in different categories. After one week of tracking screen time, participants reported their average time/day in each category and responded to the Hospital Anxiety and Depression Scale (HADS) survey by means of a digital questionnaire. Participants reported a mean of 11.67 total screen time hours/day, with an average of 2.71 social media hours/day. On a scale of zero to 21, the mean HADS anxiety score was reported to be 9.67, and the mean HADS depression score was 4.33. A correlation test was conducted to look for statistically significant relationships between the different categories of screen time and HADS scores. The critical r-value was determined to be .433, with the alpha set at .05. A statistically significant positive correlation was found between social media screen time and HADS depression scores, with a correlation coefficient of .48. However, a statistically significant correlation was not found between any other categories of screen time and HADS scores. The research hypothesis, stating that if the amount of screen time of a high school student increases, then they will exhibit more anxious/depressive symptoms, therefore worsening their overall mental health, was partially supported. The results of this study suggested that there was a positive relationship between time spent on social media and symptoms of depression.

Gender Morality Differences

Jacob Williams *Central Virginia Governor's School*

The purpose of this study was to determine if morality is shaped by gender. The study was conducted by an online survey with 10 male and 10 female participants. They were given 10 morally challenging questions to monitor the principle of decision-making that is present: utilitarian or deontology. Utilitarian is choosing the best overall outcome while deontology is based on relationships. In the survey, males answered in a 42% utilitarian manner and a 58% deontological manner; females answered in a 53% utilitarian manner and a 47% deontological manner. Four two-sample t-tests were conducted on the groups male and female utilitarian answers; male and female deontology answers; male utilitarian and deontology answers; and female utilitarian and deontology answers. With the alpha value set to .05, the p-values were found to be .14 for both utilitarian and deontology answers of each gender. The test that compared females' utilitarian and deontological answers found a p-value of .21, and the test that compared males' utilitarian and deontological answers found a p-value of .03. Because the p-value was below the alpha for the males, there was statistical significance and suggests males tend to answer in a deontological manner. The overall research did not support the research hypothesis that, if males and females are faced with 10 moral dilemmas, then the females will tend to answer in a deontological mannerism while the males will answer in a utilitarian mannerism. In summation, this study suggests that gender does not usually determine decision-making processes in people.

COVID-19 and Mental Health

Lauren Wilson
Ocean Lakes High School Mathematics and Science Academy

COVID-19 has caused a massive shift in everyone's daily lives, and to protect the physical health of a community, individual mental health may have suffered. For teens especially, COVID and social isolation provided a unique struggle with not seeing friends, not going to school, and a shift in the midst of a vital developmental period. Through this research, the effect of COVID-19 and social isolation on the mental health of high school students was studied. The purpose of this study was to determine and understand which aspects of isolation and this pandemic have the biggest impact on mental health in order to have the best chance at fixing these issues. It was hypothesized that due to the effects of COVID-19 and isolation, there will be more depressive symptoms in high school students compared to last year. Participants were given a survey regarding how their lives were affected by COVID, as well as a depression questionnaire, and also asked about how this has changed from the previous year. It was found that a higher depression scores this year is moderately correlated with the change in the depression score from last year, and these results were found to be statistically significant. However, none of the effects from COVID were found to be correlated with the overall depression score or the depression change. While the conclusion only proved that depression has increased compared to last year, and not what is causing this increase, it is still an important conclusion to be drawn.

Statistical Analysis & Inferences (HS SAI)

Honorable Mention

The Impact of Penalties, Population Density, and Partisanship on Compliance with Stay-at-Home Orders During COVID-19

Colin Berry *Yorktown High School*

Are stay-at-home orders effective during a global pandemic? Although stay-at-home orders should help to slow the spread of contagious diseases (like COVID-19) by reducing person-to-person contact outside a household, these orders are only effective if people actually stay at home. While stay-at-home orders were enacted in many states to help slow the spread of the COVID-1, there hasn't been sufficient analysis of whether people changed their behaviors and remained at home after these policies were enacted. This study uses data on the mobility of (anonymized) smartphones within states before and after the enactment of stay-at-home orders to try to understand the effects of stay-at-home orders on mobility. Using a big dataset, which contains over ten million observations on the movements of smartphones and employing methods that compare outcomes across states with and without the executive orders, the author explored the effects of stay-at-home orders during the spring and summer of 2020 across the US.

The results using a difference-in-difference analysis suggest that stay-at-home orders are associated with a 4.6% increase in the percent of smartphones that remained at home during the late spring/early summer of 2020 across the US. Although there is a statistically significant difference across states with and without stay-at-home orders, it is important to note that the average percent of smartphones that remained at home was 40% in states with stay-at-home orders compared to 36% in states without stay-at-home orders. The results also show that penalties (jail time and fines) had no significant effect on compliance with stay-at-home orders (considering all states with such orders), while compliance with stay-at-home orders in Republican controlled states was 5.3% lower than in Democratic controlled states. States with high population densities had the highest percent of smartphones that remained at home after stay-at-home orders went into effect at 45%.

It can be difficult to enforce stay at home orders and the results in this paper suggest that although these orders have a small but significant impact, studies of individual behaviors and choices will be necessary to understand when and why people may be more or less willing to shelter at home during a global pandemic.

The Effect of the Type of Instruction Received on High School Math Test Scores

Isaiah Bradner *Central Virginia Governor's School*

The purpose of this study was to determine whether the type of instruction a student receives had an effect on math test scores. This study used data gathered from local high schools from August of 2015 to January of 2021. Of the six classes studied, five consisted of accelerated math students. The research hypothesis stated that if students are instructed virtually, then math test scores will be lower than when they are instructed in-person. The data partially supported the research hypothesis; three of the six classes were shown to have a statistically significant difference between math test scores. Six two-tailed t-tests were run to compare the p-values to an alpha value of .05. For Geometry & Trigonometry (the one non-accelerated class) classes, the p-value was 7.3 x 10-11, the p-value for the first group of Calculus 1 classes was .013, and for Calculus 2-3 classes, the p-value was .03. However, for the other three classes, the data was not found to be statistically significant. In the future, if more data points were found for this study, then it is suggested that all of the groups would show statistical significance. This study supports the existing and already compelling research that the use of technology in the learning environment hinders students' academic achievement. This project encourages further research into the relationship between technology and test scores and gives evidence that computers might not be as beneficial to education as previously thought.

The Effect of Natural Disasters on the Severity of Cholera in Africa

Natalia Chahil *Washington-Liberty High School*

The purpose of this project was to find the effect of natural disasters on the severity of Cholera in Africa. The International Disaster Database (EM-DAT) and Human Development Index (HDI) were used. The natural disasters examined: floods, storms, landslides, and droughts from the decades 1990-2010. The hypothesis stated: of all the natural disasters associated with Cholera drought may have the highest severity of Cholera due the decrease of drinking water, causing populations to drink from unknown water. In the dataset, if Cholera happened during the same time of the natural disaster and were in the same year/month/location/state/province, it was assumed linked. A linear regression graph represented each natural disaster's risk of causing Cholera. A mortality rate and infection of Cholera per 1,000 people was used to measure the severity of Cholera per natural disaster, and each selected country's median HDI included in two bubble graphs. The results showed that droughts had the highest historical risk, and the highest probability for these droughts and Cholera to happen in the future, compared to floods and storms. Also, flood-Cholera severity had a higher mortality rate and Cholera infection rate than droughts. Therefore, the null hypothesis and hypothesis were rejected. One reason droughts have a high risk of Cholera because they last for long periods of time and are widespread. Floods may have the highest severity of Cholera because they occur more rapidly than droughts; so, when aid arrives to the affected area, drinking water is contaminated, causing fast-growing cases of Cholera.

The Effect of Aircraft Type on Irregular Operation Rate

Alex Coffman *Mills E. Godwin High School*

An irregular operation (often shortened to IROP), is defined as an event that results in an involuntary change to an aircraft's itinerary. These irregular operations are often a result of circumstances such as mechanical failures and severe weather, which can cause aircraft accidents. The purpose of this investigation was to determine the effects of aircraft model on the irregular operation rate of aircraft. As a result of prior research, it was hypothesized that aircraft with a heavier maximum takeoff weight, such as the Bombardier Global Express, would have a lower irregular operation rate. To determine the impacts of aircraft type on aircraft irregular operation rates, data from a fractional private jet operator with a fleet of various jet aircraft, NetJets, was downloaded from an online flight tracker. A statistical analysis was performed on this data to determine the irregular operation rate for each type of aircraft in the NetJets fleet in Microsoft Access. The Bombardier Global Express and Gulfstream G550 had the lowest irregular operation rates, which supported the research hypothesis. To determine the statistical significance of these results, a chi square was performed, with a level of significance of 0.001. All resulting p-values, with the exception of those produced from the Gulfstream G550 and Bombardier Challenger 650, were below the level of significance value of 0.001, which indicates that the results are statistically significant when compared to all other levels of independent variable.

Third Place

The Effect of Virginia State Budget Allocation on Rates of Incarceration and Recidivism

Bethany Duncan *Central Virginia Governor's School*

This project's purpose was to understand the relationship between Virginia state budget allocation and incarceration/recidivism. Data (total dollar amount of funding, ratio of that dollar amount to the total state budget, demographics of the incarcerated population, and reconviction rates) were recorded onto spreadsheets and then analyzed using regression tests, which found that most correlations between funding for a specific area and incarceration were not statistically significant, with p-values greater than the accepted alpha of .05. This was not in support of the research hypotheses (if the percent of funding in the total budget or the total dollar amount allocated for Public Safety and Homeland Security, the Department of Corrections (VDOC), or the Department of State Police (VSP) increased, then there would be an increase in non-White prisoners and drug crime offenders in Virginia state prison, which would not be mirrored by White prisoners or offenders of different crimes). There was significance for education funding vs. six- and 12-month reconviction rates (p-values .03 and .02), which partially supported the research hypothesis (if the percent of funding in the total budget or the total dollar amount allocated for educated decreased, then there would be an increase in reconviction rates and in the total prison population), as the correlation coefficients were -.98. This project, therefore, did not fully succeed in finding a way to affect the outcomes of the criminal justice system through state funding, but it did find a potentially useful relationship between education funding and recidivism rates.

Use It or Lose It: An Analysis of Unnecessary Spending in Flexible Spending Accounts

Diego Elias *Blacksburg High School*

Americans are spending more than ever on health care. In fact, the Kaiser Family Foundation calculates that the typical family in the U.S. spends around 11% of their income on health services - almost $8,200 per year. One way Americans prepare for these medical expenses is by registering for flexible spending accounts (FSAs). FSAs are a complement to health insurance and are funded by the user's income. They also come with a "Use it or Lose It" policy in which all leftover money at the end of the account life is forfeited. This research attempts to answer the question: How much, if any, unnecessary spending - spending that is driven by the risk of forfeiture primarily, not the medical benefit - occurs in FSAs? With data from 250 Montgomery County Public Schools FSA owners from 2018-2019 and from 2019-2020, the results show that in the last 3 months of the account life, total spending increases significantly. Furthermore, the proportion of spending that occurs on the weekends increases significantly in the final months of the account period - suggesting that the extra spending in those months is less urgent than previous spending.

The Effect of a Student Attending Governor’s School on College Acceptance

Camden Good *Central Virginia Governor's School*

The purpose of this study was to determine whether a student that attended a Governor’s school had a better chance of getting into a high-ranking college than a student who only attended their area base school. This was completed by collecting data on high school alumni from both an area base school and a Governor’s school. They were each asked which college they attended after graduation. Only students who had a 3.8 GPA or higher were included in this study. The data from the students who attended Governor’s school and the base school students were then separated and compared.

For the comparison a two-sample t-test, with an alpha of .05 was used. The resulting p value was .00000265, thus yielding a statistically significant difference in the data. This showed that the Governor’s school students had an advantage over students who only attended their area base school. This finding supported my research hypothesis, which stated that if a student attended Governor’s school, he or she would be more likely to attend higher ranking colleges.

Honorable Mention

Access to High-Quality Child-Care Centers in Rural Countries in Different Virginian Regions

Ellen Habteyonas *Blacksburg High School*

Research has also shown that there are many positive long-term outcomes of having quality early childhood education; children who are enrolled in Early Childhood Education programs achieve more success at school, have better career opportunities, improved health, and lower levels of dependence and crime rates. Families in rural areas face the greatest challenges in finding licensed childcare, with 3 in 5 rural communities lacking adequate childcare supply. Even when childcare is available, finding quality centers is just as important; having choices between licensed, quality centers is often a luxury families living in childcare deserts and poverty don't have. I used the interactive childcare desert map from the CAP to specifically look at two major Virginia cities, Roanoke and Richmond, and their surrounding areas. The Search for Child Day Care engine from the Virginia Department of Social Services' 'Child Care VA' website provided the data of total number of registered centers, licensed centers, and Virginia Star Quality ratings. These were all recorded and analyzed using google sheets and cross tabulation to examine any relationships, similarities, and differences between the rural areas in the two regions. While the licensure rates for both regions were comparable, the counties in southwest Virginia had higher rates of high-quality childcare centers despite having more scarcity than the majority of the rural counties surrounding Richmond. Although Richmond and Roanoke have comparable rates of poverty, Roanoke has less scarcity and more high-quality childcare centers available.

Multiple Regression Modeling to Predict Changes in US GDP Using Stock Market Volatility and Unemployment Rates.

Sania Jain *Maggie L. Walker Governors School*

Government officials, politicians, business owners and individuals are interested in continually assessing the underlying health of the economy. Accurate and timely assessment of GDP can drive timely policy responses to deflationary or inflationary conditions. The calculation of GDP is a challenging and time-consuming exercise. It takes a full month after the end of the quarter for an initial estimate and 3 months after the end of a quarter for accurate GDP information to be available. This is valuable time that can be used for deployment of policy responses. The goal of this study is to predict changes in GDP using a model that leverages stock market volatility, unemployment rates, stock market performance and long-term interest rate. The results showed that GDP has negative correlation to unemployment rates, volatility in the stock market and the S&P 500 index. The GDP is also positively correlated to the interest rate for the 3-month treasury bill. The developed multiple regression model is able to accurately predict the GDP with a coefficient of determination close to 90% and can be calculated at the end of each month rather than waiting a month for the initial estimate.

The Effect of the Occupation on the Difference in Pay Between Males and Females

Rory McAndrew *Washington-Liberty High School*

The purpose of the experiment was to find out if different job industries had varying compensation differences between males and females. The hypothesis was that if the type of industry was being tested, then there would be a difference in the pay gaps between men and women within each industry. The data collected did not support the hypothesis. The null hypothesis, which was that the type of job industry has no effect on the difference in compensation between males and females, was accepted. The data collected did not support existing research regarding occupational influence on the gender pay gap. Existing research suggested that each job industry had a different gender pay gap due to factors such as competitiveness and experience/skill, as well as gender discrimination. However, based on the p-value and standard deviations calculated, there was no relationship between the type of job industry and the compensation difference between males and females. The most likely cause of this conflict was due to the fact that not every existing job in each industry was included - only the most relevant and common jobs.

The Relationship between Gun Law Strength and Homicide Rates

Chandler O'Rourke *Central Virginia Governor's School*

The purpose of this research study was to see if gun law strength has an effect on the homicide rates of states within the United States of America. The study used online resources to determine the states with the strongest and weakest gun laws and those states' correlating homicide rates. The states used for the strong gun law group were California, New Jersey, Connecticut, Maryland, and Massachusetts. The weak gun law group had the states Arizona, Missouri, Idaho, Wyoming, and Mississippi. The control group (medium strength gun laws) contained the states Virginia, North Carolina, Indiana, Nevada, and Tennessee. It was determined that the group with strong gun laws had the lowest mean of homicide rates (four per 100,000), followed by the group of weak gun laws (five per 100,000), and then the control (medium gun law strength) (5.86 per 100,000). With a 95% confidence interval, the control group had the smallest possible error of .74 while the groups with strong and weak gun laws had larger possible errors of 2.17 and 2.8. A single factor ANOVA test was run which produced a p-value of .49 with an alpha of .05. The research hypothesis which stated that the group of weak gun laws would have the lowest homicide rate was not supported. The study suggested that gun laws are not a primary factor for raising or reducing homicide rates and that governments should look to other factors when trying to reduce their homicide rates.

The Effect of Sex, Age, and Geographic Location on Allergy and Asthma Frequency

Jordyn Rollins-Williams *Chesapeake Bay Governor's School*

When the body identifies a molecule shape as potentially harmful, it may trigger an immune response known as an allergic reaction. This data mining study investigated the influence of sex, age, and geographic location on the frequency of allergy and asthma incidences in four regions of the United States. The Northeast and West regions had the largest discrepancies between what was expected and the actual observed values for geographic location frequencies. It was also discovered that females were underrepresented in the West, whereas males were overrepresented in this region. Age affects each region differently overall.

First Place

The Effect of Algorithm Based Neural Network Machine Learning on the Projection of the Basis and Progression of Alzheimer's Disease

Ambica Sharma *Washington-Liberty High School*

This experiment has used neural network machine learning to project the baseline diagnosis and progression of Alzheimer's Disease, a neurodegenerative disease without any known cure. Clinicians believe that if caught early, the progression of Alzheimer's can be decelerated. Machine learning has been commonly used to generate predictions in the biomedical sciences. The research hypothesis had suggested that out of the overlapping eight, eleven, and fifteen Feature (Biomarker) Training Groups, the predicted diagnosis for the fifteen Feature Training Group will have the highest mAUC score (accuracy) because it held the most data points for the machine learning tool to use. An algorithm had been developed, implemented on the machine learning tool, Scikit-learn, and assessed by entering eight, eleven, and fifteen biomarkers for 450 patients to produce a prediction of stage diagnosis (Cognitively Normal, Mild Cognitive Impairment, or Dementia) at various intervals over six years since testing initiation. The 8 Feature Training Group (FTG) had projected an mAUC score of 0.9481 (90% accuracy), the 11 FTG projected an mAUC score of 0.9617 (92% accuracy), and the 15 FTG projected an mAUC score of 0.9754 (94% accuracy). The average accuracy rate across all FTGs was 92%. With this new machine learning algorithm, clinicians have the ability to project diagnoses for patients up to six years, allowing them to be diagnosed during an earlier stage when the growth of Alzheimer's Disease can be potentially arrested.

Correlations Between the Traditional Diets of Different Cultures and the Human Genome's Disease Allele Frequency

Kayli Smith *Chesapeake Bay Governor's School*

Diet has proved to act as a selective pressure with the ability to change the human genome over many generations. This study explored the connections between the allele frequency of gene HLA-DQA1 and the predicted loss of protein function, as well as the connections between high-risk mutations and various populations categorized by their historical diets: largely vegetarian, high seafood content, and high livestock consumption. There was a positive correlation found between the mutation frequency found in the global population versus the probability of harmful effect or the predicted loss of protein function. The mutation frequency of high-risk alleles did differ between the different categories, but there was no distinguishable pattern.

Data Analysis and Evaluation of an Area's Median Household Income on Varying Success in Hospice

Nate Stevenson *Mills E. Godwin High School*

My research intends to determine whether median household income affects the percent patients with a length of stay (LOS) between two and six months ("ideal" range) in a hospice facility based on zip-code. The research hypothesis states that zip-codes with higher median household income will have a larger percent of patients in hospice centers with a LOS in the ideal range. To analyze this, I create income groups of the following ranges: (<$40,000), ($40,001 – $50,000), ($50,001-$65,000), and (>$65,000).

Using Hospice Facility Level data from 2017 and Census Income data (2017), I merge these datasets using the program RStudio. This large dataset is broken into smaller data-frames of different income groups. I assign median household income values to hospice centers based on the zip-code of the hospice facility. Then, I evaluate the relationship between median household income, based on zip-code of facility, against the percent of patients with a LOS in the ideal range.

I perform six t-tests on the data, and four are significant at $\alpha = 0.05$. The research hypothesis is supported by the data. Zip-codes with a median household income of >$60,000 have an average of 1.8% more patients with a LOS between two and six months compared to zip-codes with a median household income of <$40,000. My research implies that higher income areas tend to have more success in hospice when compared to zip-codes of lower income status. This could be due to sparser hospice availability, difficulty in transportation, poorer healthcare, and less frequent doctor's visits.

Second Place

Development of a Machine Learning Algorithm to Detect Amyotrophic Lateral Sclerosis (ALS) in Patients

Ashwitha Surabhi
Thomas Jefferson High School for Science and Technology

Amyotrophic Lateral Sclerosis (ALS) is a common neuromuscular disease worldwide, with an estimated 14,000 to 15,000 ALS patients in America, that results in the death of nerve cells in the brain and spinal cord. As a result, voluntary muscle movement will start to become more difficult for patients. There is no current cure for the disease, but there are methods to prolong lifetime and improve quality of life. Patients have a higher chance of prolonging lifetime and improving quality of life if diagnosed early. However, there is no current method of diagnosing patients in a quick and accurate manner. The current diagnosis process involves having to take various tests, such as blood samples, to eliminate other possible diseases and analyzing patients' behavior over time. Doctors may look for the development of symptoms, such as muscle stiffness, muscle cramps, muscle twitches, slurred speech, and difficulty chewing, over a long period of time to determine if the patient has ALS. The machine learning algorithm can help with the detection of ALS in patients in a quicker and more accurate manner. The model trained on features Lactate Dehydrogenase, Blood Urea Nitrogen, Calcium, Phosphorus, Uric Acid, CK, and Creatinine, which are known to be correlated with ALS to an extent. The models reached 97.7%, 97.6%, and 100% accuracies for predicting ALS in patients using SVMs, Logistic Regression classifier, and Random Forests classifier, respectively. The model's high accuracy can also serve as a reason for further research into treatment with the features used in the model.

Honorable Mention

Classification of Neurons by Activation Stages using an Artificial Neural Network

Eric Xie *Blacksburg High School*

Recent advancements in technology have allowed the gathering of single-cell RNA sequencing data (scRNA-seq). scRNA-seq provides expression profiles of individual cells that allow for the study of differences between gene expression on a cellular level. However, the unique nature of this dataset requires new methods of analysis to be developed in order to extract information from the data. By creating a feed-forward artificial neural network using scRNA-seq data, the activation stage of neurons could be accurately predicted using gene expression data. By comparing the impact of altering the learning rate and the number of neurons in the hidden layer on the overall area under the curve (AUC) of the receiver operating characteristic (ROC) curve, the performance of each program could be determined. The artificial neural network with the highest average AUC of 0.9 had two neurons and a learning rate of 0.01. The program could easily be adapted to analyze other characteristics of cells such as cell development or type. Being able to gather information to this extent through analyzing gene expression data will greatly improve our ability to analyze cells of any type. Further optimizations are required to analyze larger and more complex datasets.

Zoology (HS ZOO)

The Effect of the Type of Recyclable Waste on Vermicompost pH Levels

Elora Burchette *Central Virginia Governor's School*

The purpose of this research project was to identify which compost, from recyclable waste, carried a pH value closest to the average 7.0 pH for standard plant growth. This study used vermicompost, decomposition through the use of (red) worms, as a way to break down recyclable materials, such as paper, plastic, and cardboard waste, into compost. After a week of decomposition, a small amount of compost was removed from each bin, and the pH levels were taken by using a pH paper test strip. Results were collected for 7 weeks in a row, resulting in 7 trials. The final trials of each group were averaged and compared to the suggested 7.0 pH for common plant growth. To continue my data analysis, I ran an ANOVA (two-way without replication) with a set alpha of .05. The resulting p-value came to .186, which was then compared to the alpha value, leading to the null hypothesis being retained. However, the outcome of the research hypothesis did not correspond, as the research hypothesis was not supported. The research hypothesis stated, “If three different recycled materials (paper, plastic, and cardboard) are vermicomposted, then paper will have a pH level closest to that of a 7.0 pH for healthy growth of plants.” This project could help to aid studies in finding an effective way to decrease pollution, while also increasing a healthy state of the environment, in such fields as plant growth.

Prevalence of Mixed Species Herding with Giraffe Calves

Rachel Dickerson *Washington-Liberty High School*

The rapid disappearance of giraffes from the African savanna is an imminent reality, but there is still little knowledge on these famous creatures. Giraffes are known to be found in herds that include other species, such as zebras. The purpose of this investigation was to study whether giraffes were more likely to herd with zebras if there were giraffe calves in the herd. It was hypothesized that the giraffe herds with giraffe calves would herd more frequently with zebras, because the zebras would protect the giraffes from predators, which calves are especially vulnerable to. Using live cameras placed in two locations in the Mpala Research Centre, the giraffe herds were observed over a 30-day span. The total sum of animals observed herding together was recorded in a table under the appropriate herd type (Adult Giraffes Only, Adult Giraffes-Zebras Only, Adult Giraffes-Giraffe Calves Only, and Giraffe Herd-Giraffe Calves-Zebras). The results supported the hypothesis. This is because there was a greater sum of animals observed in the Giraffe-Herd-Giraffe Calves-Zebras herd type than any other herd type. The hypothesis was also proven by the Chi-Square analysis conducted, where the Chi-Square value calculated (17.68) was greater than the critical value. The relationship between zebras and giraffes observed during this investigation, particularly when there were giraffe calves present, could lead to potential further studies on the relationship between the giraffe population size and zebra population size.

The Effect of Colored Feeding Stations on Honeybee Attraction

Jackson Drewry *Clover Hill High School*

The purpose of the experiment was to determine which colors honeybees were attracted to while feeding. In recent years honeybees have become scarcer than in the past decades. That is why if the honeybees were found to be attracted more to certain colors, the hope was to be able to introduce ideas to the agricultural industry. For example, if farmers wanted ways to introduce certain colors into their farms. Thus, more honeybees would pollinate crops and farms would yield more food each year. The research hypothesis was that the honeybees would be attracted towards the yellow-colored feeding stations. Green was the control due to the fact that honeybees are unable to see the color green. During the procedure, different colored feeding stations were placed a certain distance from a hive. Then sugar water was poured evenly into every colored feeding station. After 15 minutes the number of honeybee visits was recorded. The average number of honeybee visits for the control was 7. Yellow had the highest average number of honeybee visits which was 27. The second highest average number of honeybee visits was red with 15. In addition, the average number of honeybee visits for blue was 11, black was 3, and white was 4. The honeybees visited the yellow color feeding station the most on average, so the experimental hypothesis was supported. The null hypothesis was rejected.

The Effect of Water pH on the Heart Rate of Daphnia magna

Anujin Enkhee *Washington-Liberty High School*

This experiment was designed to study the effects of water pH on the heart rate of *Daphnia magna*. The hypothesis was: if *Daphnia magna* are placed in different levels of pH ranging from 6.0 to 9.0, then the heart rate of *Daphnia magna* will decrease at a pH of 6.0, because when organisms are placed in an acidic environment, they become environmentally stressed, there is a decline in health, and the ability to absorb oxygen decreases. The hypothesis was supported because the group placed in 6.0 pH had the lowest mean heart rate of 137.6 bpm, while the group placed in 9.0 pH had the highest mean heart rate of 312.8 bpm. The mean heart rate for the group placed in 7.0 pH was 188.4 bpm and the group places in 8.0 pH had a mean heart rate of 191.6 bpm. To determine if there was statistical significance between the mean heart rates of all the groups, an ANOVA statistical test was calculated and an additional T-test was calculated to compare the mean heart rates between two groups, 7.0 pH and 9.0 pH. The p-value calculated for the ANOVA test was 8.21 x 10-12, while the p-value calculated for the T-test was 1.83 x 10-8. Both p-values were less than the critical value of 0.05, which indicated that the null hypothesis stating that, if *Daphnia magna* are placed in different levels of water pH, then there will be no change in the heart rate of *Daphnia magna*, was rejected.

Second Place

The Effect of Ultraviolet Radiation on the Survival and Hatch Rates of *Artemia salina*

Julie Fitzgerald *Central Virginia Governor's School*

The purpose of this research project is to view the effects of Ultraviolet-B radiation on a specific yet crucial species of brine shrimp, Artemia salina. The data was collected by hatching and raising three separate populations of A. salina, each under different lights with varying levels of UV-B exposure. The fluctuating populations of the brine shrimp were photographically recorded and analyzed in order to determine the effect of the ultraviolet exposure. The results of this study did not display a significant difference in the populations of the A. salina based on how much UV-B light they were exposed to. Two Chi-squared tests of independence were performed: one analyzing the amount of shrimp hatched, and the other analyzing the amount of shrimp that lived to adulthood. For both of these statistical analyses, the alpha value was set at .05. The hatch data gave a p-value of .97, and the survival data gave a p-value of .31. The research hypothesis predicted that the population of the experimental species would decline as the levels of UV-B exposure inversely increased. Based on the data collected, this hypothesis was not supported. In conclusion, the ultraviolet exposure utilized in this experiment did not have a significant effect on the health and population of groups of A. salina. These conclusions most likely suggest that the species' stress resistance is remarkably high, and a higher UV intensity would be required to cause a detrimental effect. However, the increasing levels of ultraviolet radiation is a growing problem today.

Honorable Mention

The Effect of Agricultural Pesticides on *Daphnia magna.*

Shreel Golwala *Mills E. Godwin High School*

The purpose of this experiment was to determine the effects of agricultural pesticides on *Daphnia magna*. Recently, there is a substantial increase in pesticides that are released into bodies of clean water. These chemicals are harmful to the organisms living inside the bodies of water since the compounds of these pesticides are toxic and excessively boost the process of eutrophication. As a result, the initial idea of this experiment was to understand the effects of these chemicals on important crustaceans such as *D. magna*, which would spread more awareness to people about the increase in water pollution, so new ways for the prevention of it can be discovered. A group of 100 *D. magna* were placed in four different groups of 25 Petri dishes. The three of the four groups consisted of three different types of pesticides: an herbicide, fungicide, and insecticide. The last group was the control group consisting of normal spring water. The organisms were observed for five days, and their heart rate was measured every 24 hours. It was hypothesized that the herbicide will negatively affect the heart rate of *D. magna*. Compared to the control (234 BPM), the average heart rate of the organisms in the fungicide, herbicide, and insecticide were 90, 99, and 70 BPM. A t-test was also performed; fungicide vs. control (6.393), herbicide vs. control (6.310), and insecticide vs. control (7.622) all ruled that the research hypothesis was significant. In conclusion, the pesticides did affect the organisms negatively.

Third Place

Analyzing Blue Light on *Dugesia tigrina* Regeneration to Model Human Epidermal Growth Processes

Mrunal Kute *Mills E. Godwin High School*

Skin cancer, a highly prevalent issue in the 21st century, affects approximately 1 in 5 people in the United States. This rapid escalation in cancer rates is attributed to the increasing presence of artificial blue light in the environment, emitted via LED screens. Known to cause biological effects similar to ultraviolet radiation, blue light poses a serious threat to the regeneration processes of epidermal cells. Hence, the purpose of the study was to analyze how different exposure times to blue LED light impact *Dugesia tigrina*, or brown planaria, regeneration rates where *D. tigrina* were used as an invertebrate model to simulate human epidermal growth. Based on the independent variable, a research hypothesis was formulated that if Experimental Group C was exposed to the blue LED lamp for 30 minutes, then the rates of regeneration would be less compared to Experimental Group A (10 minutes), Experimental Group B (20 minutes), and the Control Group (0 minutes). In order to test the dependent variable, regeneration rates were calculated where Experimental Group C regenerated the least at 32.117% in comparison to the other groups, supporting the hypothesis. Based on the t-test conducted, the data was statistically significant, implying that there was less than a 0.1% chance that the results were due to error. In addition, a Pearson Correlation Coefficient (PCC) was further determined, indicating a strong inverse, one-directional relationship between blue light and *D. tigrina* regeneration capabilities. It was thus concluded that the results occurred due to blue light's degradative nature which ensued in the promotion of apoptotic activity, significant alteration to crucial transmembrane proteins, and damage to collagen proteins in the extracellular matrix (ECM), causing tumorigenesis.

First Place

What's All the Buzz? *Drosophila melanogaster* as a Unique Model for Addiction Disorders and Physiology after Traumatic Brain Injury (TBI)

Shan Lateef
Thomas Jefferson High School for Science and Technology

Background: Traumatic brain injury (TBI) is a leading international cause of morbidity and mortality and can significantly disrupt brain physiology resulting in substance use and sleep disorders. Drosophila melanogaster has been validated as a model to explore drug addiction. The goals of this project were to utilize Drosophila melanogaster and determine whether single TBI or concussion and recurrent TBI (rTBI): 1) Cause an increased propensity to consume caffeine containing media and 2) To evaluate whether this addictive behavior can be mitigated by therapeutic hypothermia. Methods: A “high-impact trauma” (HIT) device a was built, which used a spring-based mechanism to propel flies against the wall of a vial, causing mechanical damage to the brain. Caffeine enriched and regular media were presented to flies inside a constructed choice chamber. Hypothermia was induced for 3 minutes in a refrigerator at a temperature of 16o C, after each hit was performed. To prevent any potential accidents with caffeine, goggles were worn. Caffeine, according to safety protocols, was safely disposed of after experimentation (via toilet). Results: Significantly more flies preferred the caffeinated medium, after both single and recurrent TBI. Hypothermia showed some mitigation of the effect of TBI causing caffeine addiction. Conclusion: Recurrent TBI in flies may predispose them to substance use disorders, perhaps due to disrupted physiology in the reward circuits of the brain. Hypothermia offers some protection against such disruptions in brain physiology.

The Effect of Oxygenator Design on the Survival Rate of *Culex tarsalis* Larvae

Emily Lionberger *Mills E. Godwin High School*

Controlling *Culex tarsalis* populations has been a struggle because most methods are detrimental to the environment because they involve invasive destruction. Oxygenators are less damaging and have proven effective in reducing larval and adult *Culex tarsalis* populations. The goal was to study which oxygenator design can prevent *Culex tarsalis* larvae from developing into adults most effectively. A hypothesis was created stating that if different oxygenator designs are tested for their ability to reduce the number of *Culex tarsalis* larvae to enter adulthood, then the floating oxygenator design will have the lowest number of adults as it produces the most surface agitation but minimal amounts of dissolved oxygen. The levels of the independent variable were the air-tube oxygenator, floating oxygenator, air-stone oxygenator, and no oxygenator which was the control to ensure that the results were due not outside factors. A permission form was signed by a parent prior to experimentation that indicated that they had read and understood the risks and possible dangers involved in the research experiment and they consented to their child participating in this research. One hundred *Culex tarsalis* were split into four groups of 25 and added into four tanks with their respective oxygenator. For 21 days the tanks were checked for developed adult mosquitoes and any adults would be recorded and humanely killed. The results showed that the air-stone oxygenator had the least number of adults (1 adult, 24 deceased) followed closely by the air-tube oxygenator (3 adults, 22 deceased). No oxygenator (control) had the most larvae survive (24 adults, 1 deceased) while the floating oxygenator yielded comparable results (20 adults, 5 deceased). The results show oxygenator design does impact *Culex tarsalis* development in the larval stage. This result is likely due to the difference in the water current strength generated by the different oxygenator designs.

The Effect of Nitrate Levels on *Daphnia magna's* Heartrate

Olivia Nguyen *Mills E. Godwin High School*

D. Magna is an organism that plays an important role in almost every aquatic environment. The purpose of this experiment is to find the relationship between number of nitrates in the water and the heart rate of the *Daphnia Magna* inhabiting it. Knowing the relationship will ensure that the population of *Daphnia Magna* will not be greatly affected. Keeping the population consistent in where it needs to be will prevent the food chain aquatic ecosystem from crashing. Groups of *Daphnia Magna* were either treated with water at the nitrate level of 10ppm, 30ppm, or 50ppm. The control was the water that contained 10ppm of nitrate. The hypothesis stated that if the nitrate levels are lower, then it will cause the heart rate of *D. Magna* to slow down more. The results showed that the average *Daphnia Magna* bpm in the 50ppm was lower than the average bpm in the 10ppm. A t-test was performed on the results and it indicated that that all the data was significant. Because of the results, the research hypothesis was not supported. It is believed that the *Daphnia Magna's* heart rate follows similarly to the heart of a human. In a human's heart, nitrates cause the veins to relax so the heart rate is slowed down. Further research could be done on other individual aspects of the environment of the *Daphnia Magna* such as calcium level and food opportunity.

Determining Relatedness of *L. kempii* Nesting Sites Using Bioinformatics

Anooshka Pendyal *Deep Run High School*

Bioinformatics is an interdisciplinary field that focuses on developing and using methods and software to understand large, complex biological data sets. Sequence alignment is a way of arranging sequences of DNA, RNA, or protein to identify regions of similarities that may explain the relationships between the sequences. There have been numerous multiple alignment tools, but one of the most commonly used is MUSCLE, which stands for MUltiple Sequence Comparison by Log-Expectation, which uses computer science structures, such as binary trees to create a draft of the alignment. An issue that has been of interest in bioinformatics is *Lepidochelys kempii's* migratory pattern as well as its recovery as a species. The original cause for the depleted *L. kempii* number was egg harvesting and poaching, but now the primary threats are habitat loss, pollution, and entanglements in shrimping nets. The purpose of this experiment was to determine if there is a population similarity between the *L. kempii* in Florida and the *L. kempii* in Mexico. The results of this project can be used to help conservation efforts of *L. kempii*. This could also reveal that there is a nesting site unknown to humans. The null hypothesis was that the two populations were genetically different, and the alternate hypothesis was that the two populations were genetically similar. The first step in the procedure for this experiment was sample collection. The samples were mitochondrial DNA of *L. kempii* and were collected from Florida and Mexico. The two corresponding files (for the same sequence) were loaded in UGENE. The reversed sequences had already been reversed back to forward during the cleaning process. Then, a built-in alignment algorithm, MUSCLE, was used to align the two sequences. Finally, a final alignment with all the samples was created. With a Fixation index value of less than .05, this experiment was able to reject the null hypothesis and conclude that the populations were genetically similar.

Nectar Feeding Preferences of Ruby-Throated Hummingbirds in the Middle Peninsula

Paula Perez *Chesapeake Bay Governor's School*

The Ruby-Throated Hummingbird, *Archilochus colubris*, is a migratory bird that spends most of the spring and summer months along the east coast of North America. An obstacle they may confront while finding this food energy is the ecological landscape. Ruby-throated hummingbirds readily visit hummingbird feeders put out by locals for the nectar they provide, as the nectar serves as an extra energy resource for their migrations. Although there is controversy on what nectar to use. The purpose of this study is to determine if there is a significant difference in ruby throated hummingbirds' consumption of artificial store-bought nectar (Perky Pet) and homemade nectar made without any extra preservatives. Three sampling sites were identified in the Middle Peninsula region of Virginia which included Saluda, Hartfield, and Shacklefords. At each site there were 3 identical hummingbird feeders that were labeled and contained different solutions: Perky-Pet, Homemade nectar, or Water. At the end of each week, the amount that was left in the containers were put in a measuring cup, individually, and kept track by putting the amount of ounces leftover in the data table. Based on the results on the comparison of Homemade and Perky Pet nectar, the data rejects the null hypothesis, H0: The artificial hummingbird nectar and the homemade will have the same percentage nectar consumed in all the sites. While the data fails to reject the alternative hypothesis, Ha: Hummingbirds will exhibit a preference between homemade nectar and the artificial nectar consumed in Hartfield with p=0.01. The data rejects Ha in Saluda with p=0.06 and Shacklefords with p= 0.64. Based on these findings, Hartfield had the greatest difference in consumption between homemade and artificial nectar. Although in Shacklefords and Saluda there was a low difference between the two nectars. When it comes to comparing the solutions, this knowledge benefits the homeowners who put out the feeders for hummingbirds, so they have an idea of what the hummingbirds prefer.

Honorable Mention

Investigation of Bio-printed Hydrogels for Purification of Danio rerio Habitats During Embryonic Development

Liala Sofi & Alicia Carvalho *Roanoke Valley Governor's School*

Every year, American coal-fired plants generate 110 million tons of coal ash, containing toxic levels of contaminants such as lead, mercury, chromium, aluminum, arsenic, and selenium. Assessing the effects of contaminants in the aquatic eco-environment is critical in protecting wildlife, human health, and the environment. Hydrogels have shown excellent adsorptive performance for water pollutants such as heavy metals. In this research it was hypothesized that coal ash will have a negative effect on the morphological development of Danio rerio and with the creation/usage of bio-printed hydrogels, a purification of the environment along with developmental normalization will occur. Two hydrogels were developed, a 5% Sodium Alginate and 1% Chitosan hydrogel (Hydrogel AC) and a 5% Sodium Alginate, 2% Chitosan, and 100 drops of glacial acetic acid hydrogel (Hydrogel ACA). With the usage of hydrogels, significant drops in turbidity levels of coal ash solutions were found, ranging between a 700% and 1,300% decrease in NTU. Average heartrates of Danio rerio was also found over a span of 72 hours, indicating that with the usage of hydrogels, normality of heartrate was found in treated groups while an increase in heartrate was found for untreated groups. A chi-squared test was then performed on hatched data, resulting in p-values of 0.002 and less than 0.001 at 48 and 72 hours respectively. This indicated that Hydrogel ACA worked significantly better due to the Danio rerio in its treatment having hatch rates similar to the control. Usage of Hydrogel AC resulted in pre-mature development in terms of hatch rates of the Danio rerio indicating a lack in structural ability to purify contaminated environments. Further applications of this project could study reusability of hydrogels, mortality, and neurological responses in embryos.

Honorable Mention

Using the Embryonic-Danio rerio-Stress Response System to Investigate the Toxicity of Metal Oxide Nanoparticles

Uyen Nhi Tran *Roanoke Valley Governor's School*

The purpose of this experiment was to investigate the impact of zinc oxide (ZnO) and titanium dioxide (TiO_2) metal nanoparticles (MNPs) on the stress response system and morphology of *Danio rerio* (zebrafish) embryos. It was hypothesized that if *Danio rerio* were exposed to zinc oxide and titanium dioxide nanoparticles, then expression of the Htr3a, th1, and SERT (5-htt) genes would be altered and/or a change in morphology would be seen. Wild-type Zebrafish embryos (10-12) were placed in solutions of ZnO (60 µg/L), TiO_2 (2.2 µg/L), and a control (no treatment). After five days, heart rate(bpm) data and head size-tail length ratios (morphology) comparison for each treatment group were obtained using video/image analysis. Zebrafish exposed to ZnO had an average heart rate of 45.476 bpm and head-tail ratio of 0.212, TiO_2 had an average heart rate of 47.706 bpm and head-tail ratio of 0.209, compared to the control of 50.666 bpm and head-tail ratio of 0.172. One-way ANOVA tests and subsequent Tukey's Post-hocs showed that the heart rates of treated fish were significantly slower than the heart rates of the control and that the head-tail ratios were significantly larger for treated fish, with treated fish having shorter tails. RNA was extracted and cDNA was made for embryos after five days of treatment. RT-qPCR was performed, but results were not obtained, possibly due to a machine malfunction. Gel electrophoresis of the qPCR samples was conducted, and no amplicons were present. In conclusion, this experiment showed a correlation between MNPs and change in morphology.

Honorable Mention

The Effect of Different Foods on Fruit Fly Preference

Varun Yeri *Mills E. Godwin High School*

This experiment was conducted in order to understand the food preferences of fruit flies (*Drosophila Melanogaster*), as they pose a potential threat to humans as carriers of pathogens such as *Escherichia coli*. Understanding the food preference would help lead to those foods being sealed, thereby preventing infestations and potential disease. 100 Fruit Flies were separately released into a maze and given 1 minute to land on 1 of 3 types of foods in cups: wheat based (honey wheat bread), fruit (banana), leafy vegetable (spinach), and an empty cup as a control to make sure flies don't land on foods for experimentation and only based on smell/taste. Based on project research, it was hypothesized that the fruit flies would largely choose to eat the fruit over the wheat-based food and the vegetable. However, the experiment revealed that fruit flies preferred the spinach over the other food groups. They initially settled on the fruit as it has more sugar, but eventually moved to the spinach. The observed behavior most likely occurred because spinach has the most overall valuable nutrients for the flies, while fruits have mainly sugars. The effects of this experiment may be felt across fields; it may help spawn new research in medicine and the information revealed in it can also help prevent illness in developing countries where fruit flies are common.

The Effect of Silver Nanoparticles on the Heart Rate of *Daphnia magna*

Paul Yang *Mills E. Godwin High School*

The purpose of this experiment was to determine the effects of varying concentration of silver nanoparticles (AgNPs) on the heart rate of *Daphnia magna*. Using *Daphnia magna* as a model organism for other marine life, the negative effects of silver nanoparticles can be evaluated, and regulations can be enforced to reduce those effects. One hundred *Daphnia magna* were exposed to four varying concentrations of silver nanoparticles: 0ppm, .25ppm, .5ppm, and .75ppm. The heart rate of each *Daphnia magna* was measured using a compound microscope. 0ppm of AgNPs was designated as the control and used as a standard of comparison to evaluate the effects of the treatment versus no treatment. It was hypothesized that *Daphnia magna* were exposed to varying concentrations of AgNPs, then .75ppm would have the greatest effect on heart rate. The collected data on *Daphnia magna* was analyzed using t-tests. The null hypothesis was rejected in all three t-tests, and the calculated p value was less than .01 in all tests, so data was overall statistically significant. In comparison to control group (244bpm), the mean heart rates for the other levels of independent variable .25ppm (122.4bpm), .5ppm (108.5bpm), and .75ppm (109bpm) were all drastically lower. The lower heart rates could possibly be a consequence to AgNPs disruption to signal transduction, a process which is important to the survival of a cell. This disruption to signal transduction most likely had an adverse effect on the *Daphnia magna*, thus a drastic decrease in heart rate and physiological damage.

The Effect of Monosodium Glutamate on the Reproduction Rates of *Daphnia magna*

Virginia Trost *Central Virginia Governor's School*

The purpose of this study was to determine if Monosodium Glutamate (MSG) has an effect on the reproduction rate of Daphnia magna. The experiment used three different concentrations of MSG in the water: a control, a low concentration (0.025g/mL), and a high concentration (0.05 g/mL). There were ten daphnia in each beaker and two groups for each concentration level. The daphnia were counted every week, for three weeks, and pictures were uploaded to Adobe Photoshop to analyze their reproduction. A single factor ANOVA test was used to determine if the data was statistically significant. The alpha value of .05 was compared to the p-value of .04, showing there was statistical significance, meaning a post-hoc Tukey test was necessary to analyze which groups held the significance. The Qt value was 3.44 and the Dmin was 4.63. The Tukey test determined that the significance was between the 0.05 g/mL and the 0.025 g/mL group, and the 0.05 g/mL group and the control group, meaning that the highest concentration of MSG impacted the daphnia the most, supporting the hypothesis that If different levels of Monosodium Glutamate are inserted into the daphnia habitat, then the daphnia living in the highest concentration of MSG water will have lower reproductive rates. In conclusion, MSG has an effect on the reproduction rates of daphnia, this study supports the idea that MSG can lead to negative health effects and warrants further study.

FIRST PLACE CATEGORY-SECTION AWARDS

These awards are given to the best papers, as determined by either the Section Judges or, ifmultiple sections, by a group of Honor Judges.

VAS BOTANY AWARD

The award is given by the Botany Section of the Virginia Academy of Science, to the best paper on a botanical subject.

Name (grade)	Beverly Eborn (11)
Title	The Effect of Added Polyamines on Glycine max Responses to Drought
School	Central Virginia Governor's School

Name (grade)	Carson Ray (9) & Daniel Han (9)
Title	The Synergistic Allelopathic Effects of Extracts from Two Invasive Species on Germination and Growth of *R. sativus*
School	Roanoke Valley Governor's School

RODNEY C. BERRY CHEMISTRY AWARD

The Rodney C. Berry Chemistry Award is given for the paper that evidences the mostsignificant contribution in the field of chemistry.

Name (grade)	Julia Brodsky (10)
Title	Optimization of an Electrocoagulation System for the Removal of Polyatomic Ions from Water
School	H.B. Woodlawn

Name (grade)	Thanvi Parupati (9)
Title	The Effect of the Form of Heat Resistant Product on the Heat Damage of the Hair
School	Mills E. Godwin High School

WILLIAM W. BERRY ENGINEERING AWARD

This award is given by Dominion Energy in honor of Mr. William W. Berry who was a past Chairman of the Board of Virginia Power.

Name (grade)	Brock Duma (11)
Title	Whitewater Helmet STAR: Evaluating the Biomechanical Performance and Risk of Head Injury for Whitewater Helmets
School	Blacksburg High School
Name (grade)	Chirayu Nimonkar (11)
Title	The Effect of Rat Brain Phantom Construction on Mimicry of the True Brain Model
School	Mills E. Godwin High School
Name (grade)	Darrah Sheehan (11) & Kimball Sheehan (12)
Title	Investigation of the Tumoricidal Effects of Sonodynamic Therapy in Malignant Glioblastoma Brain Tumors
School	Western Albemarle High School

ANN M. HANCOCK CELLULAR BIOLOGY AWARD

This award is given to the best paper in cellular biology and is presented in memory of Anne M. Hancock who retired from Patrick Henry High School in Hanover County and who gave many years of service to the Jr. Academy not only by teaching but also servingon the Jr. Academy Committee.

Name (grade)	Monona Zhou (9)
Title	The Effect of Coronavirus Species on the Binding Strength to a Neutralizing Antibody
School	Mills E. Godwin High School

MATHEMATICS AWARD

The Mathematics Award is given for the paper that evidences the most significant contribution in the field of Mathematics.

Name (grade)	Lillian Sun (11)
Title	De Novo Prediction of RNA-Protein Interactions for Discovery of Tissue-Specific Binding Sites
School	Thomas Jefferson High School

STATISTICS AWARD

The Statistics Award is given for the paper that evidences the most significant contributionin the field of Statistics.

Name (grade)	Ambica Sharma (10)
Title	The Effect of Algorithm Based Neural Network Machine Learning on the Projection of the Basis and Progression of Alzheimer's Disease
School	Washington-Liberty High School

VABE ZOOLOGY AWARD

This award is presented by the Virginia Association of Biology Educators and is given for outstanding research in the Zoology section.

Name (grade)	Shan Lateef (12)
Title	What's All the Buzz? *Drosophila melanogaster* as a Unique Model for Addiction Disorders and Physiology after Traumatic Brain Injury (TBI)
School	Thomas Jefferson High School

SPECIAL INTEREST AWARDS & SCHOLARSHIPS

Students apply for these awards, and they are evaluated by a special panel of judges from the awarding bodies and/or group of special judges. If any awards are not given, we did not receiveany applications meeting the standards of the award.

CANCER RESEARCH AWARD

These awards are to recognize outstanding science papers related to cancer research. These awards are provided by the American Cancer Society.

Name (grade)	Lillian Sun (11)
Title	De Novo Prediction of RNA-Protein Interactions for Discovery of Tissue-Specific Binding Sites
School	Thomas Jefferson High School

Name (grade)	Anju Natarajan (11)
Title	Comprehensive Computational Genomic Analysis of 1,134 Samples to Understand Genomic Alterations and Their Influence on Outcome in Colorectal Cancer: A Retrospective Study
School	Collegiate School

Name (grade)	Laasya Konidala (10)
Title	A Novel Integrative WSI-Based Framework For Breast Cancer Molecular Classification
School	Mills E. Godwin High School

DR. AND MRS. PRESTON H. LEAKE AWARD IN APPLIED CHEMISTRY

The Dr. and Mrs. Preston H. Leake Award in Applied Chemistry is given to the author of a research paper which best exemplifies how chemicals, chemical principles, or chemistry have been used, are used, or might be used to enhance or even to save life.

Name (grade)	Nishaanth Mulpuru (11)
Title	The Effect of Different Pesticides Containing Heavy Metals on the Transpiration Rate of "*Vigna unguiculata*"
School	Mills E. Godwin High School

ROSCOE HUGHES GENETICS AWARD

The Roscoe Hughes Award is given for the best paper in the field of Genetics.

Name (grade)	London Paige (12)
Title	Investigating Alternatives to Conventional Chronic Kidney Disease Treatment Through Analysis of Differential Gene Expression
School	Roanoke Valley Governor's School

DR. SMITH SHADOMY INFECTIOUS DISEASES AWARD

This award is given to commemorate Dr. Smith Shadomy by the Virginia Chapter of the National Foundation for Infectious Diseases to the paper that evidences outstanding research in the field of infectious diseases.

Name (grade)	Aatish Sethi (11) & Jasmine Agyepong (11)
Title	A New Treatment? An Analysis of the Effect of Known Phytochemicals on SARS-CoV-2 Pathogenesis
School	Governor's School@Innovation Park

SPELEOLOGICAL SOCIETY AWARD

Given by the Richmond Area Speleological Society for outstanding research addressing karst or topics related to speleology (bats, caves, carbonate geology, paleo environments,limestone fossils, sinkholes, etc.

No Award This Year/No eligible applicants

VIRGINIA MUSEUM OF NATURAL HISTORY (VMNH) AWARD

This award is presented by the Friends of the Virginia Museum of Natural History in recognition of a significant contribution in the study and interpretation of Virginia's Natural Heritage.

Name (grade)	Abby Madson (12)
Title	Lichen Abundance and Diversity in Cemetery Environments
School	Chesapeake Bay Governor's School

VIRGINIA SEA GRANT COLLEGE PROGRAM AWARD

This award is given by the Virginia Sea Grant College Program for outstanding marine or coastal research.

Name (grade)	Margaret Collins (12)
Title	A Comparison of *Littoraria Irrorata* Populations Along the Rappahannock River
School	Chesapeake Bay Governor's School

GAMMA SIGMA DELTA AWARD

The Gamma Sigma Delta Award is presented by the Virginia Tech Chapter of the Honor Society of Agriculture. This award is given in recognition of excellence in research dealing with application of new technologies and/or concepts in agriculture forestry, or veterinary medicine.

Name (grade)	Mia Constantin (12) & Elizabeth Quimby (12)
Title	Small Scale Vertical Farming
School	Harrisonburg High School

BETHEL HIGH SCHOOL SCHOLARSHIP

Bethel High School Scholarship - This $1,000 Scholarship Award comes from the interest earned from a $10,000 endowment contributed by the students of Bethel High School, Hampton, Va., over a two year period. This award is based on both the student's presentation and paper.

Name (grade)	Lillian Sun (11)
Title	De Novo Prediction of RNA-Protein Interactions for Discovery of Tissue-Specific Binding Sites
School	Thomas Jefferson High School

HENRY W. MACKENZIE ENVIRONMENTAL SCHOLARSHIP (VEE)

Henry W. MacKenzie Environmental Scholarship - This $5,000 scholarship will be awarded to the student whose paper evidences the most significant contribution in the field of Environmental Science dealing with the James River Basin and Chesapeake Bay. The Virginia Environmental Endowment and VJAS offer this scholarship in tribute to the outstanding and generous services of Judge Henry W. MacKenzie, Jr., one of the founding directors, who has a great interest in the James River and the Chesapeake Bay.

Lynn Tao (10)

The Effect of Impervious Surfaces on Steam Health: a Study of Machine Learning and Multivariate Statistical Analyses
Thomas Jefferson High School for Science and Technology

FRANCES AND SYDNEY LEWIS ENVIRONMENTAL SCHOLARSHIP (VEE)

Frances and Sydney Lewis Environmental Scholarship: A $5,000 scholarship for the best effort by a student in grades 9 to 12 in the field of environmental science. This scholarship is in the name of Frances and Sydney Lewis and is given by the Virginia Environmental Endowment.

Ella Lewis (11)

The Effect of Plastic on the Growth of *Raphanus sativus*
Central Virginia Governor's School

VJAS MIDDLE SCHOOL HONOR AWARDS

These are the highest awards that the Virginia Junior Academy of Science presents. Special panels of honor judges evaluate the projects and determine the awards.

DOROTHY KNOWLTON AWARD

This award is given to the Middle School student presenting the best paper in the life sciences. It is presented in honor of Dorothy Knowlton, the former Science Coordinator of Arlington County, who was instrumental in advancing experimental design within the science curriculum.

Annabelle Van Saun (8)

The Effect of Silver Nanoparticles on The Death Rate Of Adult *Daphnia Magna*
George H. Moody Middle School
I

JOYCE K. PETERSON AWARD

This award is given to the Middle School student presenting the best paper in the physical sciences. It is presented in honor of Mrs. Joyce K. Peterson who has been an outstanding teacher in the Arlington County Schools.

Camellia Sharma (8)

The Effect of Machine Learning Algorithms on Counting the Fish Population
George Moody Middle School

OUSTANDING EIGTH GRADE RESEARCH PROJECT, Grade 8

Given to the eighth-grade student or team presenting the best project. Grade 8 only.

Camellia Sharma (8)

The Effect of Machine Learning Algorithms on Counting the Fish Population
George Moody Middle School

VJAS GRAND MIDDLE SCHOOL AWARD, Grades 7--8

Given to the middle school student or team presenting the best project. Grades 7-8.

Annabelle Van Saun (8)

The Effect of Silver Nanoparticles on The Death Rate Of Adult *Daphnia Magna*
George H. Moody Middle School

VJAS HIGH SCHOOL HONOR AWARDS

These are the highest awards that the Virginia Junior Academy of Science presents. Special panels of honor judges evaluate the projects and determine the awards.

CATESBY JONES AWARD, Grade 12

This award is given to the 12th grade senior student whose paper evidences the most significant contribution to science.

Shan Lateef (12)

What's All the Buzz? *Drosophila melanogaster* as a Unique Model for Addiction Disorders and Physiology after Traumatic Brain Injury (TBI)
Thomas Jefferson High School for Science & Technology

VJAS GRAND HIGH SCHOOL AWARD, Grades 9-12

The top research project by an individual or team of students in grades 9-12.

Shan Lateef (12)

What's All the Buzz? *Drosophila melanogaster* as a Unique Model for Addiction Disorders and Physiology after Traumatic Brain Injury (TBI)
Thomas Jefferson High School for Science & Technology

VJAS DELEGATES TO AJAS, GRADES 9-11

A panel of honor judges selects the honorees from among the students (grades 9-11) who wonfirst place in a senior high section.

Attendance at American Junior Academy of Science (AJAS):

Winners are given a certificate and an invitation to represent VJAS at the annual meeting of theAmerican Junior Academy of Science (AJAS) and to present at a poster session. Students who represent the Commonwealth of Virginia are required to attend all activities and house with thestudents (if applicable).

When VJAS/VAS finances permit, cash awards are given to each individual or a team to help defray expenses. The cash award will be the same for an individual or team, so if a team is selected, they will need to determine who will represent the team, or provide local funding for theother team members. The top four papers are ranked by the judges and VAS/VJAS will provide cash awards in this order when VAS/VJAS finances permit. VAS/VJAS will attempt to fully cover the expenses of the winners followed by the alternates.

Winner Meenakshi Ambati (11)

Identification of Fluoxetine as a direct NLRP3 inhibitor to treat atrophic macular degeneration: Molecular modeling, mechanism, morphometry, and meta- analysis(Year 2)
Albemarle High School

ABSTRACT

The atrophic form of age-related macular degeneration (dry AMD) affects nearly 200 million people worldwide. There is no FDA-approved therapy for this disease, which is the leading cause of irreversible blindness among people over 50 years of age. Vision loss in dry AMD results from degeneration of the retinal pigmented epithelium (RPE). RPE cell death is driven by accumulation of *Alu* RNAs, which are noncoding transcripts of a human retrotransposon, amyloid ◆? deposition, and iron overload. *Alu* RNA, amyloid ◆?, and iron induce RPE degeneration by activating the NLRP3-ASC inflammasome. In new data, I report that fluoxetine, an FDA-approved drug for treating clinical depression, binds NLRP3 in silico, in vitro, and in cells. In new data, I also report that Fluoxetine inhibits NLRP3 ATPase activity. In an extension of last year's work which focused solely on *Alu* RNA, I provide new data that fluoxetine blocks RPE degeneration induced by oligomerized amyloid ◆? and iron in mice. In a substantive expansion of last year's work in which I studied a single health insurance database comprising 25 million people, I present new data by analyzing three health insurance databases comprising more than 130 million Americans, which identify a reduced hazard of developing dry AMD among patients with depression who were treated with fluoxetine. In addition, new analysis from a random-effect meta-analysis model employing propensity score matching and confounder

adjustment demonstrates a pooled risk reduction of 17% for fluoxetine users. A prediction interval analysis based on these three databases estimates a >95% probability of a future clinical trial identifying a benefit of fluoxetine in reducing the risk of dry AMD. Collectively, these interdisciplinary studies provide strong support for testing fluoxetine as a potential drug repurposing candidate for dry AMD, which causes blindness in millions of people in the United States and across the world.

INTRODUCTION

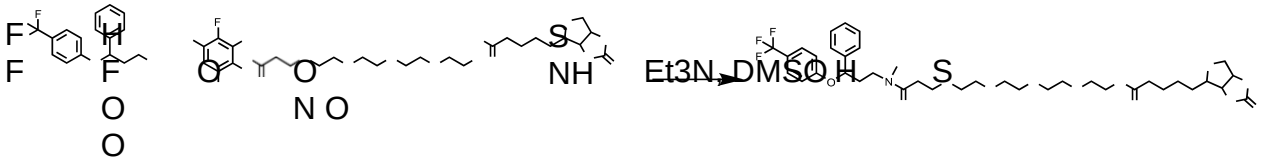
Age-related macular degeneration (AMD) is the leading cause of irreversible blindness among those over 50 years of age around the world (Mitchell et al., 2018). The dry form of AMD is characterized by degeneration of the retinal pigmented epithelium (RPE), a specialized monolayer of cells lying external to the retinal photoreceptors (Mitchell et al., 2018). Progressive RPE degeneration in the central portion of the retina known as the macula leads to photoreceptor cell death and consequent vision loss over several years (Mitchell et al., 2018). Dry AMD, which

accounts for approximately 90% of the 200 million global cases of AMD (Wong et al., 2014), has no FDA-approved therapy (Mitchell et al., 2018). In dry AMD, areas of RPE degeneration display accumulation of *Alu* repetitive RNAs, amyloid β, and iron (Kaneko et al., 2011; Johnson et al., 2002; Hahn et al., 2003). These substances are cytotoxic as they activate the NLRP3-ASC inflammasome (Tarallo et al., 2012; Gelfand et al., 2015), a multiprotein complex that acts as a danger sensor that responds to a diverse set of inflammatory stimuli (Latz, 2010). In response to various danger signals, the proteins NLRP3, ASC, and pro-caspase-1 assemble into a macromolecular platform known as the ASC speck (Masumoto et al., 1999). The defining molecular event of inflammasome activation is auto-cleavage of pro-caspase-1 into active caspase-1, which cleaves interleukin IL-1β from an inactive pro-form to a mature, active form. Active IL-1β, which is elevated in dry AMD, is a pro-inflammatory cytokine that is cytotoxic in dry AMD (Eandi et al., 2016).

Despite dozens of clinical trials over two decades, no treatment has yet proven effective for dry AMD (Mitchell et al., 2018). I sought to identify a novel therapy for dry AMD by employing the concept of drug repurposing (Boguski et al., 2009). Specifically, I hypothesized that an existing drug that is FDA-approved for another disease and that shares structural similarity to a known inflammasome inhibitor might be effective against dry AMD. In addition to testing its efficacy in preclinical models, I also sought the ability to determine whether patients using this drug had a reduced hazard of developing dry AMD by analyzing health insurance claims databases.
Therefore, I focused on a prevalent, chronic disease that has multiple treatment options: clinical depression. Here I demonstrate that fluoxetine, which is FDA-approved for clinical depression, contains a structural moiety present in a known NLRP3 inhibitor, and that it directly interacts with NLRP3 and inhibits its assembly and activation. Further, fluoxetine inhibits RPE degeneration in mice. I also present evidence from three health insurance databases that fluoxetine use is associated with reduced incident dry AMD, suggesting it could be repurposed.

METHODS AND MATERIALS

Synthesis of Biotinylated Fluoxetine: Fluoxetine (0.211 mmol, 65.5 mg, 4 eq; **1**) and TPF-PEG3- Biotin (0.052 mmol, 33.5 mg, 1 eq; **2**) were reacted to produce biotinylated fluoxetine (**3**): mass spectrum using electrospray ionization (m/z calculated for 783.3, found = 783.3).



1 **2** **3**

Purification of Myc-tagged human NLRP3 protein: HEK293T cells were transfected with plasmid encoding Myc-tagged human NLRP3 using Lipofectamine™ 3000 (ThermoFisher) myc-tagged NLRP3 was purified using anti-c-Myc magnetic beads (ThermoFisher).

Streptavidin pull-down assay: To assess fluoxetine-NLRP3 interaction, LPS-primed THP-1 cell lysates or purified NLRP3 were pre-cleaned using streptavidin magnetic beads (ThermoFisher) to remove nonspecific binding. Pre-treated proteins were incubated with biotinylated fluoxetine and free (unbiotinylated) fluoxetine for 1 h on ice. Then, samples were incubated with pre- activated streptavidin magnetic beads overnight at 4°C. The beads were washed with lysis buffer three times and boiled with SDS sample buffer (ThermoFisher) for further analysis.

Molecular modeling and docking of fluoxetine-NLRP3 complexes: The cryo-EM structure of Sharif et al. (2019), pdb file 6NPY, was used to model NLRP3 interactions with fluoxetine. This structure features an NLRP3 monomer bound to ADP and NEK7, which were deleted from the structure. The hook-shaped leucine rich repeat (LRR) domain to which NEK is predominantly bound was also deleted, leaving the NACHT domain, which has the nucleotide binding domain near its center. Using that definition of the binding region of interest, docking of the S enantiomer of FLX in and around the nucleotide binding cavity of the truncated NLRP3 structure was performed using the HADDOCK2.4 web server (van Zundert et al., 2016). PRODIGY LIGAND (Kurkcuoglu et al., 2018; Vangone et al., 2019) was used to calculate the free energy of binding of FLX to NLRP3 from the HADDOCK output PDB file of the docked complex.

NLRP3 ATPase Activity: NLRP3 ATPase activity was measured using ADP-Glo Kinase Assay kit (Promega). Purified NLRP3 (2.0 ng/µl) was incubated with fluoxetine in reaction buffer at 37°C for 60 min. Ultra-Pure ATP (50 µm) was added, mixed with NLRP3, and incubated at 37°C for 30 min. ADP conversion was measured (Cytation 5 Cell Imaging, BioTek).

Amyloid oligomer preparation: Oligomeric Aβ was prepared using human lyophilized, synthetic Aβ1–40 (BACHEM) as previously described (Barghorn et al., 2005; Lambert et al., 2001).

Cell culture studies: All cell culture experiments were compliant with University of Virginia Institutional Biosafety Committee regulations. Mouse bone marrow derived macrophages (BMDMs) were cultured in Iscove's modified Dulbecco's media (IMDM) with 10% FBS and 20% L929 supernatants. Cells were maintained at 37 °C in a 5% CO2 environment.

ASC speck imaging: BMDMs seeded on chambered coverslips (30,000 cells/well) for 12 h were pretreated with fluoxetine (10 µM) or 0.1% DMSO (control) for 2 h. Cells were treated with oligomeric Aβ for 12 h. 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 goat serum; 1 h at 4 °C), incubated with anti-ASC antibody (Adipogen) with blocking buffer, and visualized with Alexa Fluor 555 (Invitrogen). DAPI-stained slides were mounted using Fluoromount-G (Southern Biotech) and imaged by confocal microscopy (Nikon A1R).
Immunoblotting: Cells were treated with LPS and oligomeric Aβ and pre-treated with fluoxetine (10 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 13000g 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 Immobilon-FL PVDF membranes (Millipore). The transferred membranes were blocked with 5% nonfat dry skim milk for 1 h at room temperature and then incubated with primary antibody 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. The primary antibody was anti-mouse caspase-1 antibody (AdipoGen).
Animal Studies: Animal experiments were approved by the University of Virginia Institutional Animal Care and Use Committee. All animal procedures and euthanasia were performed by a University of Virginia scientist for a purpose other than this research, and the retinal tissue was supplied to me.
Induction of RPE degeneration and drug treatments: C57BL/6J mice (The Jackson Laboratory) were anesthetized with ketamine hydrochloride and xylazine. Oligomerized Aβ1-40 (BACHEM) was injected into the subretinal space. Fluoxetine (Cayman Chemical; 1 mM in 0.5 µl) or vehicle control (PBS) was injected into the vitreous humor 24 h before and immediately after Aβ injection. Animals were euthanized 7 days after Aβ iron injection, and eyes were enucleated. Assessment of RPE degeneration: RPE health was assessed by immunofluorescence staining of zonula occludens-1 (ZO-1) on RPE flat mounts. Flat mounts were fixed with 2% PFA, stained with rabbit polyclonal antibodies against mouse ZO-1 (Invitrogen), visualized with Alexa Fluor 594 (Invitrogen), and imaged (A1R Nikon). Images were graded as healthy or degenerated in

masked fashion. Proportions of eyes with degeneration were compared using Fisher's exact test. Polymegethism quantified by morphometry was compared using two-tailed Student t-test (Kerur et al., 2018).
Health Insurance Claims Databases Analyses: Health insurance database information contains de-identified data that are 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) 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 2018; 2) PearlDiver Mariner database, which contains data on health care claims and medication usage for persons in provider networks over the time period 2010 to the second quarter of 2018; 3) PearlDiver Patient Records Database, which captures health care claims and medication usage for persons in the Humana network between 2007 and the first quarter of 2017. Sample Selection: Patients were included in the analysis if they had continuous enrollment in the plan for at least 1 year and were at least 50 years of age at baseline. Individuals with pre-existing dry AMD (z1 medical claims prior to diagnosis of depression) were excluded. Disease claims were identified by International Classification of Diseases (ICD)-9-CM and ICD-10-CM codes.
Independent Variable: Exposure to fluoxetine – the independent variable – was determined by whether patients filled ≥1 outpatient pharmacy prescriptions for generic or brand versions, either in sole form or as a combination medication, as identified by National Drug Codes.
Dependent Variable: Time to initial diagnosis of dry AMD was the dependent variable.
Analyses: Analyses were performed with the use of R software, version 3.6.1 (the R project [https://www.r-project.org]). To analyze the risk of dry AMD between fluoxetine users and fluoxetine non-users, an adjusted Cox proportional hazards regression analysis was performed, and the hazard ratio was analyzed by the likelihood ratio test. The restricted maximum-likelihood estimator method was used to estimate the between-study variance. This adjusted model included confounding covariates that influence dry AMD risk: age, sex, smoking, body mass index, and Charlson comorbidity index. Kaplan-Meier survival plots were analyzed by log rank test.
Statistical tests were 2-sided. P values < 0.05 were considered statistically significant.
Propensity score matching: To evaluate the robustness of the findings and mitigate any possible residual confounding, I estimated propensity-score models including use of fluoxetine and no use

of fluoxetine. The individual propensities for starting fluoxetine treatment were estimated with the use of logistic regression. As predictors, the propensity-score models included the set of variables which displayed P values < 0.1 in logistic regression analyses. I used the R package MatchIt to perform matching in a 1:1 ratio using greedy nearest neighbor matching. In addition, to control for any residual covariate imbalance, I estimated the relative hazard in the propensity score-matched groups using the multivariable Cox models that included the covariates from the multivariable regression analysis employed for the original unmatched group analyses. Statistical tests were two-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. Variability among databases was evaluated by Cochran's Q-test. 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 and of the pooled results, and of the 95% PI.

RESULTS

Fluoxetine interacts with NLRP3

The small molecule CY-09 inhibits the NLRP3 inflammasome (Jiang et al., 2017). By examining the structure of various FDA-approved drugs, I observed that fluoxetine, which is indicated for clinical depression, shared structural similarity to CY-09L a (trifluoromethyl)phenyl moiety (Fig. 1A). Interestingly, several other FDA approved drugs for clinical depression did not share this similarity. To test whether fluoxetine binds NLRP3, a biotin conjugate of fluoxetine was synthesized and used an affinity reagent. Biotinylated fluoxetine was incubated with LPS-primed human THP-1 monocytes lysates. Fluoxetine-associated protein complexes were precipitated by streptavidin pull-down and found to contain NLRP3 by western blotting. These data suggest that fluoxetine directly interacts with NLRP3 or with proteins complexed with NLRP3 (Fig. 1B). In contrast, GAPDH was not detected in the same lysate pull-down, indicating that fluoxetine did not non-specifically bind random proteins in this assay (Fig. 1B). Next, a competition assay was performed by incubating the protein lysate and biotinylated fluoxetine with increasing amounts of excess unlabeled fluoxetine. Increasing ratios of unlabeled to labeled fluoxetine resulted in reduced abundance of NLRP3 detected in the precipitate (Fig. 1B). Ratios of 10-fold and higher

excesses of unlabeled fluoxetine resulted in undetectable levels of NLRP3. These data provide support for the specificity of the presumed interaction between fluoxetine and NLRP3.

To determine whether CY-09 interacts with NLRP3 directly, recombinant myc-tagged NLRP3 protein was purified. When this purified NLRP3 protein was incubated with biotinylated fluoxetine, a direct interaction was observed (Fig. 1C). Excess amounts of unlabeled fluoxetine (5–10 fold) successfully competed against this interaction, confirming the specificity of this interaction (Fig. 1C). Thus, similar to CY-09, fluoxetine directly binds NLRP3.

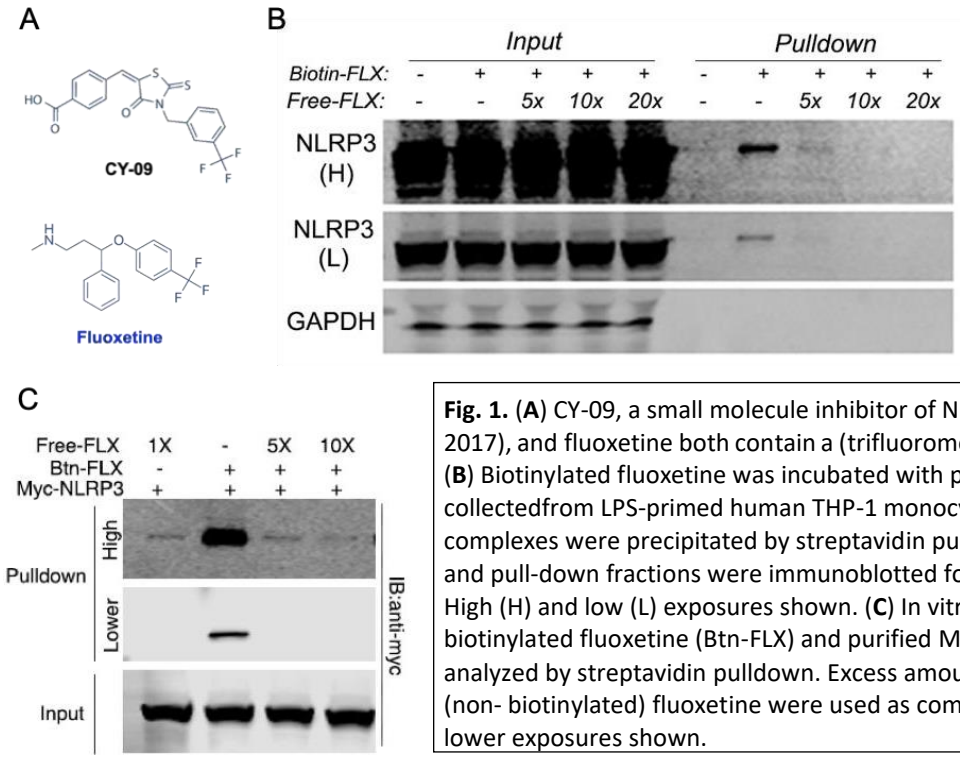


Fig. 1. (**A**) CY-09, a small molecule inhibitor of NLRP3 (Jiang et al., 2017), and fluoxetine both contain a (trifluoromethyl)phenyl moiety. (**B**) Biotinylated fluoxetine was incubated with protein lysate collectedfrom LPS-primed human THP-1 monocytes. Protein complexes were precipitated by streptavidin pull-down. The input and pull-down fractions were immunoblotted for NLRP3 or GAPDH. High (H) and low (L) exposures shown. (**C**) In vitro interaction of biotinylated fluoxetine (Btn-FLX) and purified Myc-NLRP3 protein analyzed by streptavidin pulldown. Excess amounts (5–10x) of free (non- biotinylated) fluoxetine were used as competitors. High and lower exposures shown.

Molecular modeling of fluoxetine binding to the NLRP3 NACHT domain

The nucleotide ATP binds to the NACHT domain of NLRP3 and undergoes hydrolysis into ADP via the ATPase activity of NLRP3. This enzymatic reaction provides the energy required for NLRP3 inflammasome assembly (Duncan et al., 2007). I hypothesized that fluoxetine interacts with NLRP3 via structural mimicry of ATP because the strong electronegativity of fluorine in its trifluoromethyl (CF3) group could be an effective mimic for the phosphate group of ATP. Thus, I tested the hypothesis that fluoxetine could bind in the same structural region as ATP, a site that is deeply buried in the NACHT domain of NLRP3 (Sharif et al., 2019). The structure of NLRP3 was extracted from the cryo-electron microscopy structure of NLRP3 complexed with NEK7 and

nucleotide (6NPY; PDB) (Sharif et al., 2019). This extracted NLRP3 structure and the structure of fluoxetine (SFX; PDB) were subjected to a protein-ligand docking study using HADDOCK (van Zundert et al., 2016). The highest ranked docked pose identified by HADDOCK was one in which fluoxetine was inside the void of the nucleotide binding cavity of NLRP3 (Fig. 2A) lined on one side by basic (positively charged) amino acid residues (Fig. 2 B and C). Using PRODIGY LIGAND (Kurkcuoglu et al., 2018; Vangone et al., 2019), the free energy of binding of NLRP3 to fluoxetine ΔG = –8.9 Kcal/mol, which corresponds to a dissociation constant (*K*D) of ~0.53 μM at 37°C, using ΔG = –RT ln *K*D. This value is similar to the *K*D of CY-09 for NLRP3 (0.5 μM; Jiang et al., 2017). These data suggest fluoxetine binds to the ATP-binding site of NLRP3.

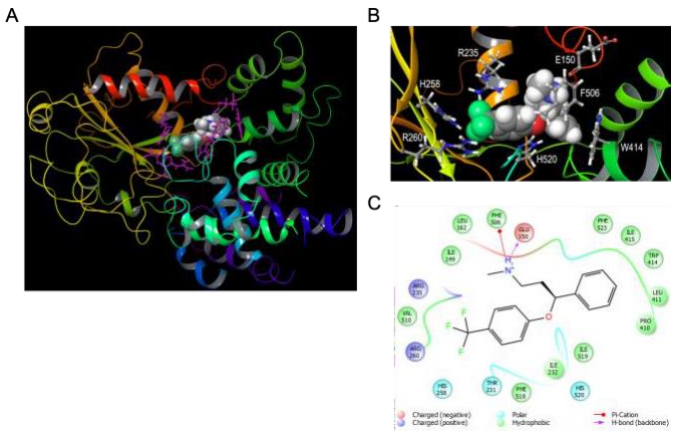


Fig. 2. (**A, B)** The best docked pose of fluoxetine fully inside the nucleotide binding cavity of NLRP3 as identified by HADDOCK. Ribbon diagrams of NLRP3in complex with fluoxetine shown in sphere rendering. The conformation of the complex is shown along with interacting sidechains (in magenta, **A**). (**B**) A magnified view of the complex shows that these interacting sidechains include a triad of basic residues (R235, H258, R260, using the numbering system of 6NPY.PDB), two nitrogenous aromatic amino acids (H520 and W414), and two residues that engage the fluoxetine amino group in hydrogen bonding (E150) or cation-π interaction (F506). The binding energy of this complex was calculated as 1'G = –8.9 Kcal/mol, using the PRODIGY-LIGAND web server. **C.** A complete schematic interaction diagram for the complex of

Fluoxetine inhibits NLRP3 ATPase, assembly, and activation

Fluoxetine was tested for inhibition of NLRP3 ATPase activity. There was a dose-dependent inhibition of the ATPase activity of purified NLRP3 (Fig. 3A). Last year, I found that fluoxetine disrupts *Alu* RNA-induced inflammasome assembly, which was monitored by assessing ASC speck formation in mouse bone marrow derived macrophages (BMDMs). As an extension of that study, in new experiments, I found that ASC speck formation was robustly induced by oligomerized A[illegible] and this was decreased by fluoxetine treatment to baseline levels (Fig. 3 B to D). Inflammasome activation was assessed in BMDMs by monitoring caspase-1 activation via western blotting and IL-1β secretion via ELISA. Caspase-1 cleavage was induced by A[illegible] and reduced by fluoxetine (Fig. 3E). IL-1β release was robustly induced by A[illegible] in BMDMs and reduced by fluoxetine (Fig. 3F). These data demonstrate that fluoxetine inhibits inflammasome activation.

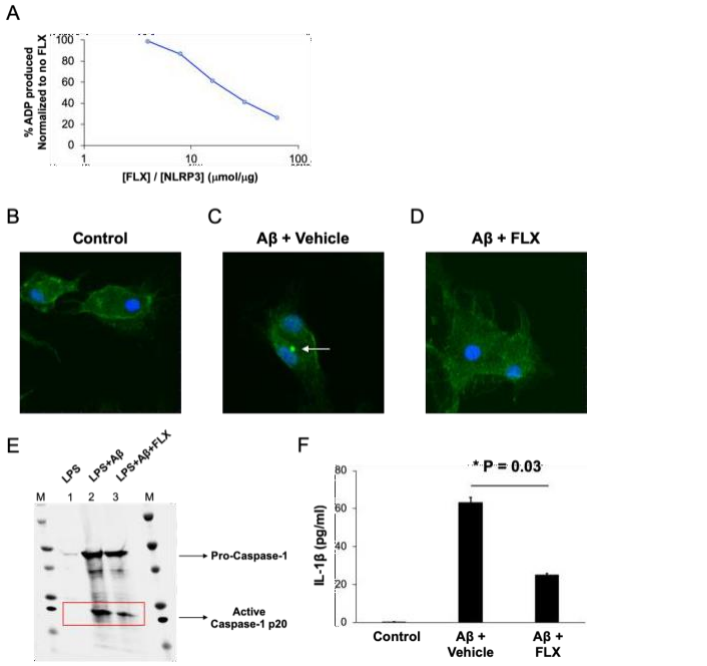


Fig. 3. (A) Dose-dependent reduction of NLRP3's ATPase activity (hydrolysis of ATP to ADP) by fluoxetine (FLX). Values normalized to no fluoxetine. (**B–D**) Representative immunofluorescent images of wild-type mouse bone marrow-derived macrophages (BMDMs) stained for anti-ASC antibody (green). Cell nuclei stained blue by DAPI. (**D**) No ASC speck formation in control cells. (**C**) ASC speck formation (green circular aggregate; white arrow) is induced by oligomerized A1-40 (A). (**D**) FLX inhibits ASC speck formation induced by A. (**E**) Representative western blot image shows that FLX inhibits caspase-1 cleavage (active caspase-1 p20 fragments enclosed by red rectangle) induced by A in LPS-primed BMDMs. Marker (M) lanes and the three treatment lanes are labeled. (**F**) ELISA-based quantification shows that FLX inhibits A-induced IL-1 secretion in BMDMs.P value for A + vehicle vs. A + FLX group comparison using Student's two-tailed t test. Mean andSEM

Fluoxetine inhibits RPE degeneration

Last year, I found fluoxetine protected against *Alu* RNA-induced RPE degeneration in mice. New studies were performed using A and iron in *in vivo* mouse models. Subretinal injection of oligomerized A or iron induced RPE degeneration, whereas fluoxetine treatment conferred profound protection against these toxicities (Fig. 4 A to D). These data demonstrate a powerful inhibitory effect of fluoxetine in two new human disease-relevant animal models.

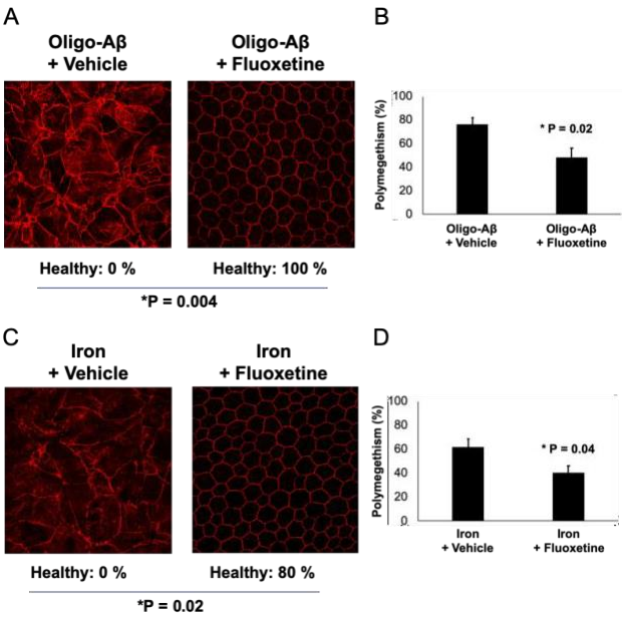


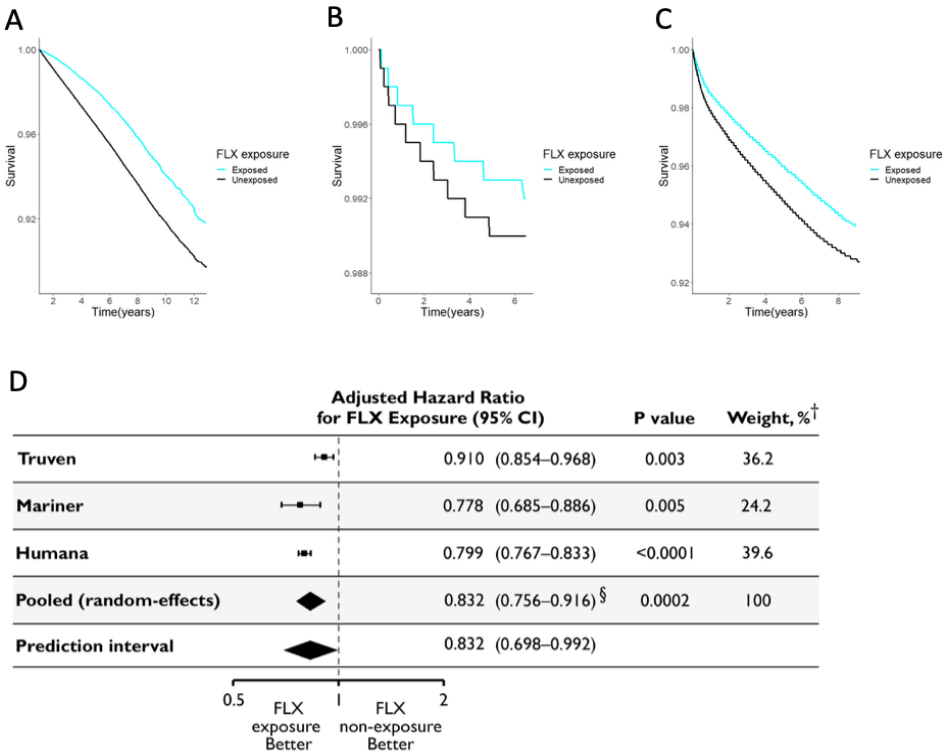
Fig. 4. (**A–D**) Fluoxetine inhibits RPE degeneration induced by subretinal administrationof oligomerized Aβ1-40 (oligo Aβ(**A, B**) or iron(**C, D**). (**A, C**) Representative flat mounts stained for zonula occludens-1 (ZO-1; red). Loss of regular hexagonal cellular boundaries in ZO-1 stained flat mounts is indicative of degenerated RPE. The percentage of RPE flat mounts assessedas Healthy by binary grading was statistically analyzed using Fisher's exact test. N = 5 per group. (**B, D**) Morphometric quantification of RPE degeneration, assessed by the variation in cell area (polymegethism) expressed as a percentage, is presented as mean±SEM and was statistically analyzed using

Fluoxetine associated with reduced development of dry AMD

I performed a retrospective, longitudinal cohort analysis among patients with depression aged 50 or older (the population at risk) to assess the risk of dry AMD. Last year, I studied the PearlDiver Humana database (25 million Americans from 2007 to 2017) and found a reduced risk of dry AMD development among fluoxetine users. In a substantive expansion from prior work, I studied two new databases: Truven Marketscan Commercial Claims (90 million Americans from 2010 to 2018) and the PearlDiver Mariner (15 million Americans from 2010 to 2018).

I performed Kaplan-Meier survival analyses to estimate the probability of developing dry AMD: fluoxetine use was associated with a significantly slower rate of developing dry AMD in the Truven, Mariner, and Humana databases (Fig. 5 A–C). Next, I performed Cox proportional hazards regression analyses to estimate the hazard of dry AMD in relation to fluoxetine use. Patients in these databases were not randomly assigned to fluoxetine 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 dry AMD: age, sex, smoking, and body mass index, and Charlson comorbidity index, a measure of overall health. These adjusted Cox proportional hazards regression models in the propensity-score-matched populations also showed a protective association of fluoxetine use (Fig. 5D). In Truven, fluoxetine exposure was associated with a 9% reduced hazard of developing dry AMD (adjusted hazard ratio (aHR), 0.910; 95% CI, 0.854 to 0.968; P = 0.003). In Mariner, fluoxetine exposure was associated with a 22% reduced hazard (aHR, 0.778; 95% CI, 0.685 to 0.886; P = 0.005). In Humana, fluoxetine exposure was associated with a 20% reduced hazard (aHR, 0.799; 95% CI, 0.767 to 0.833; P < 0.0001).

Next, I estimated the combined hazard in the three databases based on an inverse- variance-weighted meta-analysis using a random-effects model. I chose this model for two reasons: (1) a substantial amount of the variance between the studies could be attributed to heterogeneity (I^2 = 82.8%; 95% CI, 34.6% to 99.6%); (2) the Truven, Mariner, and Humana databases represent populations whose underlying true effects that are likely different (DerSimonian & Laird, 1986). The meta-analysis identified a protective effect of fluoxetine against incident dry AMD (pooled adjusted hazard ratio = 0.832; 95% CI, 0.756, 0.916; P=0.0002) (Fig. 5D). The pooled hazard ratio (0.832) and confidence interval (0.756 to 0.916) 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 et al., 2016). The 95% prediction interval was 0.698 to 0.992 (Fig. 5D), implying a future clinical trial has a >95% probability of identifying a protective effect (hazard ratio < 1.0) of fluoxetine against dry AMD.



† Influence of studies on meta-analysis using random-effects model
Test for heterogeneity: χ^2=12.4924, df=2, P=0.0019; τ^2=0.0056, 95% CI, 0.0006 to 0.2759; I^2=82.8%, 95% CI, 34.58% to 99.58%
§ Test for overall effect: z=3.75, P=0.0002

Fig. 5. Risk of developing dry age-related macular degeneration is reduced with fluoxetine exposure. (**A–C**) Kaplan-Meier survival curves showing the probability of not developing dry AMD (survival) over time for subjects in the Truven Marketscan (**A**), PearlDiver Mariner (**B**), and PearlDiver Humana (**C**) databases based on fluoxetine (FLX) exposure or non-exposure. Difference between fluoxetine (FLX) exposure or non-exposure groups was significant (P < 0.0001 by log rank test) all three databases. **(D)** Hazard ratios for developing dry AMD 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. Diamonds show the pooled estimate of the adjusted hazard ratio and the 95% confidence intervals for meta-analyses using an inverse-variance-weighted random-effects. The broken vertical line represents an adjusted hazard ratio of 1, which denotes equal risk between fluoxetine exposure and non-exposure. Horizontal bars denote 95% confidence intervals (CI). P values derived from z statistics for individual databases are reported. The estimates of heterogeneity (2), results of the statistical test of heterogeneity using the chi-square (2) test statistic and its degrees of freedom (df) are shown below the plot. The Higgins I^2 statistic and its 95% CI are presented. The results of the statistical tests of overall effect, the z test statistics, and corresponding P values are presented.

DISCUSSION AND CONCLUSIONS

These studies demonstrate that fluoxetine binds NLRP3 and inhibits both NLRP3 inflammasome assembly, ATPase, and activation. The docking results for fluoxetine are consistent with the experimental results of binding and ATPase inhibition, as predicted by the modeling of fluoxetine interacting in the ATP-binding domain of NLRP3. The *K*D of ~0.5 μM predicted by the docking simulations is compatible with the inhibition of inflammasome activation observed experimentally at 10 μM. Fluoxetine also blocks RPE degeneration in multiple disease-relevant preclinical models and is associated with a reduced risk of developing dry AMD in people. The circulating concentration of fluoxetine and its structurally similar bioactive metabolites in patients taking fluoxetine reaches 8 μM (Preskorn et al., 1991), which indicates that fluoxetine levels are sufficient to exert activity against dry AMD. Collectively, these findings provide a rationale for launching a prospective randomized clinical trial of fluoxetine for dry AMD.

A strength of the insurance database analyses is the replication in three cohorts that comprise half of all U.S. adults. In addition, I adjusted for confounders and performed propensity score matching, which increases the validity of the conclusion. However, because there was no randomization in this retrospective study, there could be residual confounding or selection bias. In addition, this study, like all observational health insurance claims studies, has inherent limitations in assessing the accuracy of coding and clinical phenotyping. These studies do, however, provide a rationale for performing randomized controlled trials of fluoxetine for dry AMD, which can provide insights into causality. Demonstrating fluoxetine's benefit for dry AMD in a such a prospective trial could benefit millions suffering from the risk of irrecoverable blindness. Unmatched analyses revealed a 30–41% risk reduction in the three databases, whereas the propensity-score-matched and confounder adjusted analyses revealed a 17% risk reduction in the summary meta-analysis. Given that the overall burden of dry AMD is approximately 200 million worldwide, the potential benefits of even a 17% risk reduction are profound. Despite numerous advances into the mechanisms of dry AMD, there is still no approved therapy for this disease. Traditional approaches to drug development are expensive and time-consuming: on average, a new FDA-approved drug takes 10–12 years and $2.8 billion to develop (DiMasi et al., 2016). The identification of the unrecognized therapeutic activity of an existing FDA-approved drug using Big Data mining, coupled with its efficacy in disease-relevant models could greatly

accelerate and reduce the cost of drug development. It would also be interesting to determine whether fluoxetine is beneficial in other inflammasome-driven diseases such as Alzheimer's disease, Parkinson's disease, and diabetes (Heneka et al., 2018; Masters et al., 2011).

COMPETING INTEREST STATEMENT

I am named as an inventor on two patent applications (US patent 62/972,848; International patent PCT/US2021/017663) on fluoxetine and dry AMD filed by the University of Virginia.

LITERATURE CITED

Barghorn, S. et al. Globular amyloid β-peptide1-42 oligomer - A homogenous and stable neuropathological protein in Alzheimer's disease. J Neurochem 2005; 95:834–47.

Boguski, M. S., Mandl, K. D., & Sukhatme, V. P. Drug discovery. Repurposing with a difference. Science 2009; 324:1394-1395.

DerSimonian, R and Laird, N. Meta-analysis in clinical trials. Control Clin Trials 1986; 7:177- 188.

DiMasi, J. A., Grabowski, H. G., & Hansen, R. W. Innovation in the pharmaceutical industry: New estimates of R&D costs. J Health Econ 2016; 47:20-33.

Duncan, J.A. et al. Cryopyrin/NALP3 binds ATP/dATP, is an ATPase, and requires ATP binding to mediate inflammatory signaling. Proc Natl Acad Sci U S A 2007; 104(19):8041-8046. Eandi, C. M. et al. Subretinal mononuclear phagocytes induce cone segment loss via IL-1�. Elife 2016; 5:e16490.

Fowler, B. J. et al. Nucleoside reverse transcriptase inhibitors possess intrinsic anti-inflammatory activity. Science 2014; 346:1000-3.

Heneka, M. T., McManus, R. M., & Latz, E. Inflammasome signalling in brain function and neurodegenerative disease. Nat Rev Neurosci 2018; 19:610-621.

IntHout, J., Ioannidis, J. P., Rovers, M. M. & Goeman, J. J. Plea for routinely presenting prediction intervals in meta-analysis. BMJ Open 2016; 6:e010247.

Jiang, H. et al. Identification of a selective and direct NLRP3 inhibitor to treat inflammatory disorders. J Exp Med, 2017; 214:3219-3238.

Johnson LV, Leitner WP, Rivest AJ, Staples MK, Radeke MJ, Anderson DH. The Alzheimer's A�-peptide is deposited at sites of complement activation in pathologic deposits associated with aging and age-related macular degeneration. Proc Natl Acad Sci U S A 2002; 99:11830-5.

Kaneko, H. et al. DICER1 deficit induces Alu RNA toxicity in age-related macular degeneration. Nature 2011; 471:325-330.
Kurkcuoglu Z. et al. Performance of HADDOCK and a simple contact-based protein-ligand binding affinity predictor in the D3R Grand Challenge 2. J Comp Aid Mol Des 2018; 32:175-185 Lambert, M. P. et al. Vaccination with soluble Aβ oligomers generates toxicity-neutralizing antibodies. J Neurochem 2001; 79, 595–605.
Latz, E. The inflammasomes: mechanisms of activation and function. Curr Opin Immunol 2010; 22:28-33.
Masters, S. L., Latz, E., & O'Neill, L. A. The inflammasome in atherosclerosis and type 2 diabetes. Sci Transl Med 2011; 3:81ps17.
Masumoto, J. et al. ASC, a novel 22-kDa protein, aggregates during apoptosis of human promyelocytic leukemia HL-60 cells. J Biol Chem 1999; 274:33835-33838.
Mitchell, P., Liew, G., Gopinath, B., & Wong, T. Y. Age-related macular degeneration. Lancet, 2018; 392:1147-1159.
Preskorn, S.H., Silkey, B., Beber, J., Dorey, C. Antidepressant response and plasma concentrations of fluoxetine. Ann Clin Psychiatry 1991; 3:147-151
Rosenbaum, P.R. and Rubin, D. B., The central role of the propensity score in observational studies for causal effects. Biometrika 1983; 70:41-55
Sharif, H. et al. Structural mechanism for NEK7-licensed activation of NLRP3 inflammasome. Nature 2019; 570:338-343.
Tarallo, V. et al. DICER1 loss and Alu RNA induce age-related macular degeneration via the NLRP3 inflammasome and MyD88. Cell 2012;149: 847-859.
van Zundert G. C. P., et al. (2016). The HADDOCK2.2 webserver: User-friendly integrative modeling of biomolecular complexes. J Mol Biol 2016; 428:720-725
Vangone A. et al. Large-scale prediction of binding affinity in protein-small ligand complexes: the PRODIGY-LIG web server. Bioinformatics, 2019; 35:1585-1587.
Wong, W. L. et al. Global prevalence of age-related macular degeneration and disease burden projection for 2020 and 2040: a systematic review and meta-analysis. Lancet Global Health 2014; 2:e106-116.

Winner Cameron Sharma (11)

The Effect of Surface Dynamics on Atmospheric Water Harvesting Mills E. Godwin High School

The Effect of Surface Dynamics on Atmospheric Water Harvesting Abstract

The global water crisis is a well-documented fact. It affects all regions and demographics. Atmospheric water harvesters (AWHs) have not been explored well as an option for freshwater. An estimated 12,900 km^3 of water remains suspended in the air, while according to the World Health Organization only 0.075 km^3 meets the daily water requirement of one billion people.
Aero2Aqua, an AWH presented here is a novel invention. It harvests ground level vapors without using external energy. It combines three diverse bioinspired methods of atmospheric water harvesting into a complementary system. The three methods are

hydrophilic and hydrophobic surfaces of the darkling beetle, the water trapping ridges of the cactus spines and the water channeling “liquid diodes” on the skin of Texas horn lizard. A device was designed, built and tested incorporating these three components. Hydrophilic disks with diameters of 10, 15, 18, 20 and 25 mm were the levels of independent variable (IV). There was no control. The amount of water harvested was the dependent variable. It was hypothesized that the AWH using 25 mm disks would collect the most water. Mean values measured for the IV were 3.323, 5.028, 7.475, 15.753 and 24.889 grams. The related t-values were higher than the table t-value of 2.011. Therefore, the null hypothesis was rejected, and the data was significant. The results supported the hypothesis. Future enhancement could include computer optimized designs that would maximize water collection. The project was done under adult supervision using safety gear.

Introduction

The scarcity of freshwater is a global crisis. Over two billion people reside in areas with high water stress. Agricultural land serving 3.2 billion humans is under high to very-high water shortage. (Liu et al., 2017). AWHs are by far one of the most under explored options. An AWH, as the name implies, collects water from in the air. An estimated 12,900 km^3 of water remains suspended in the air (Qadir et al., 2018), That is a significant quantity. According to the World Health Organization only 0.075 km^3/day meets the daily water requirement of one billion people (Ohno et al., 2018). The invention of Aero2Aqua was motivated by the author’s passion for helping the environment and pursuing novel solution that make a difference.

Water is suspended in the atmosphere in all three phases, i.e., vapor (ambient moisture, fog and clouds), liquid (raindrops) and solid (ice crystals). Condensation occurs at temperatures below the dew point (i.e., at relative humidity = 100%). Aero2Aqua harvests ground level vapors

without requiring the formation of dew, i.e., from unsaturated air. Moisture can be separated from the dry air by absorption or adsorption. (Jarimi et al., 2020). Water binds through strong hydrogen bonds in absorption. Energy required to break the bond is relatively high (90-400 kJ/mol), which mandates an external energy source. On the other hand, adsorption involves weak van der Waals forces between the adsorbate and adsorbent. The process is readily reversible, requiring 20 kJ/mol or less (Zhou et al., 2020). Aero2Aqua works by adsorption of ambient moisture on hydrophilic surfaces and then using gravity to separate the adhering water droplets.

The rate and mode of condensation of water on a hydrophilic surface depends on its wettability. Condensing droplets produce an order-of-magnitude higher heat transfer rate than the formation of film (Niu and Tang, 2016). Therefore, the hydrophilic surfaces of Aero2Aqua were conditioned to promote droplet formation and to conduct heat away from the exposed areas.

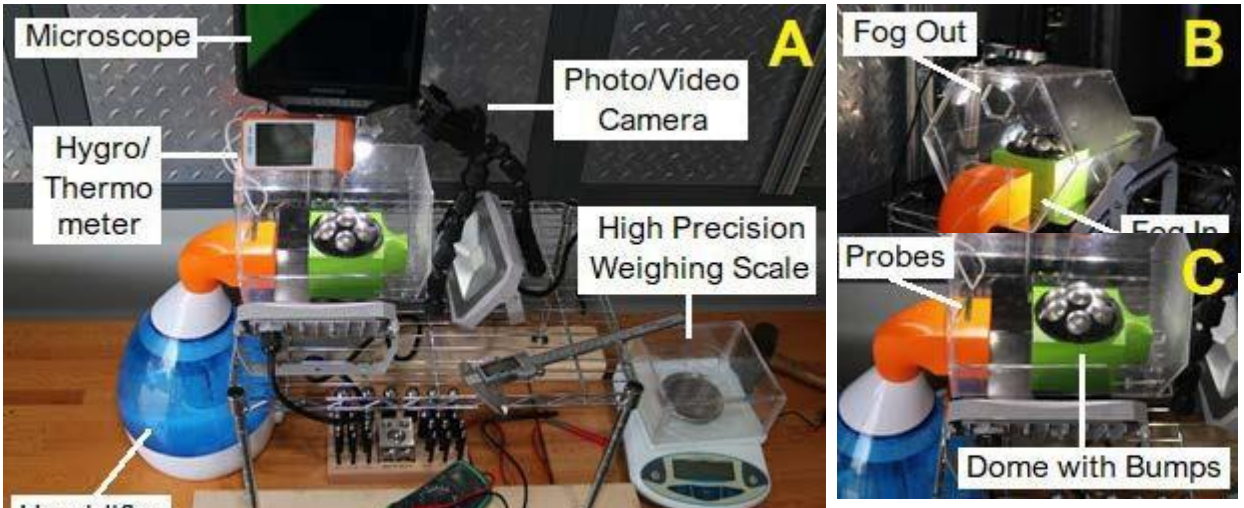

Fig. 1. Namibian desert beetle *Cactus spines* *Texas horned lizard*
(reducedplanckconstant.wordpress.com/tag/namibian-desert-beetles/) (Malik et al., 2015). (tpwd.texas.gov/huntwild/wild/species/thlizard)

Biomimicry is the scientific process of creating solutions that are inspired by the systems occurring in nature. Aero2Aqua has leveraged three such natural structures, 1) Namib desert beetle (*S. gracilipes*), 2) spines of cactus spines and 3) Texas horned lizard (*P. cornutum*). The beetle has hydrophilic bumps on its elytra that attract water and hydrophobic flat areas where the condensate drains to its mouth, assisted by gravity (Yin et al., 2017) (Fig.1). Unlike beetle, the moisture adheres mechanically to rough micropillars of the cactus spines. It sits atop the spine in a Cassie-Baxter state, which is the phenomenon of trapping an air cushion between the liquid and surface (Malik et al., 2015). The Gibbs free energy then propels the water droplets along the increasing diameter of the tapered spine, towards the plant. Amazingly, the drops can even move against gravity (Liu et al., 2015). Integumentary capillary system of the lizard has microchannels that transport water to its mouth via “liquid diodes”. Engineers have used it for such diverse tasks as cooling buildings (Badarnah, 2016) and channeling lubricants (Comanns et al., 2016).

Diameter of the superhydrophilic disks was the independent variable (IV). The levels of IV were 10 mm, 15 mm, 18 mm, 20 mm and 25 mm disks. There was no control because

Aero2Aqua is a novel invention and there are no standards for the AWHs. The amount of water collected was the dependent variable. A custom fog chamber was designed and built. The constants included fog chamber, meters, 3D printed parts, cameras, etc. It was hypothesized that if AWHs with different sized disks were used, then the one with the 25 mm disks would collect the most water. The hypothesis was in alignment with other researchers who found a correlation between surface area and amount of water collected (Qadir et al., 2018; Yao et al., 2018).

Methods and Materials



F hamber.

The experiment setup is shown in Fig. 2. There were three key components of the device,

1) hydrophilic stainless-steel bumps (inspired by the beetle) and copper spikes (cactus), 2) water draining hydrophobic dome (lizard) and 3) fog chamber. *Due to space limitation, the physics and detailed analysis of copper spikes and dome have not been presented here*. The bumps were made from 0.8 mm thick stainless-steel stampings of 10 mm, 15 mm, 18 mm, 20 mm, and 25 mm Φ (Φ : diameter). The spherical bumps were fabricated from the flat stampings on a one-ton press using high-carbon steel punch and die (Fig. 3A, 3B). Bumps were 1) cleaned with acetone,
2) sprayed with Harland's Lubricent UV Hydrophilic Coating and 3) spun at 1,000 rpm for 2 minutes in a centrifuge to even out the coating. Tapered spikes with alternating hydrophilic and hydrophobic bands were made from 2.59 mm Φ annealed copper wires. A 108 mm Φ dome was designed with Autodesk Inventor's engineering module and built on a 3D printer. Surface of the dome was textured to mimic the "liquid diode" channels on the lizard's skin so that the water flowing off the bumps and spikes was channeled to the collection

area and prevent any localized slowdown. The dome was 1) cleaned with CoroTech Oil & Grease Emulsifier, 2) coated with polydimethylsiloxane (PDMS, 10:1 wt% of Sylgard 184 silicone elastomer base) and 3) spun at 2,000 rpm for 2 minutes. PDMS is hydrophobic.

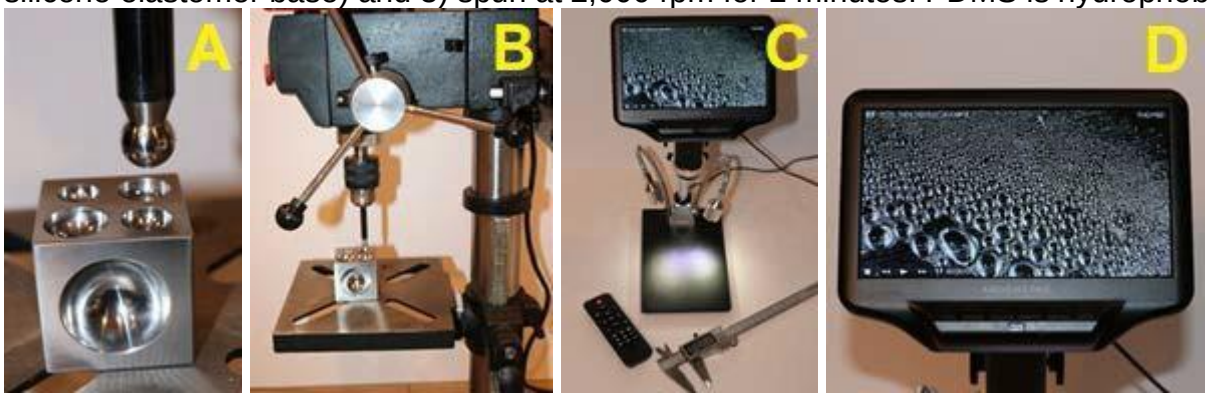


Fig. 3. A. Punch and die. B. Press. C. Microscope. D. Microscope screen showing microbeads.

It was important to carefully prepare the surfaces and evenly coat them. As explained in the Appendix, the energy freed during coalescing of water drops is a key mechanical driver of the atmospheric water harvesting. Microdroplets should coalesce together repeatedly to maximize the motive energy. Therefore, any filming must be avoided by prepping the surfaces.

A 20 cm long fog chamber was fabricated from 2.15 mm thick acrylic sheets. The chamber had an inlet and outlet for humid air to model the naturally blowing fog. A consumer grade humidifier was used for creating the fog which was directed into the chamber (Fig 2B). Multiple components were designed with Autodesk Inventor and fabricated on a 3D printer.

AWH with 25 mm Φ bumps was weighed and placed in the fog chamber. The humidifier was run for 2 minutes. The AWH was retrieved from the fog chamber and weighed. It was dried with a blow dryer because wiping could compromise the hydrophilicity/phobicity. The step was repeated with runtimes of 4, 6, 8 and 10 minutes. Ten such trials were conducted. The process was repeated for the AWHs with 10 mm, 15 mm, 18 mm and 20 mm Φ bumps for a total of 300 measurements. Additionally, 25 trials were done for each of the five AWHs with a runtime of 2 minutes to collect the data for the t-tests.

A high precision scale was used for weighing. It was accurate to one milligram, i.e., it could measure a water bead that is 100 microns cubed or 5.75 micron in diameter. The humidity and temperature of the fog chamber were monitored with a combo hygro/thermometer (Fig. 2B). A 1,000x microscope was used to measure and monitor microbeads during condensation. The meters and microscope had a USB feed to continuously record the data on a computer (Fig. 3D).

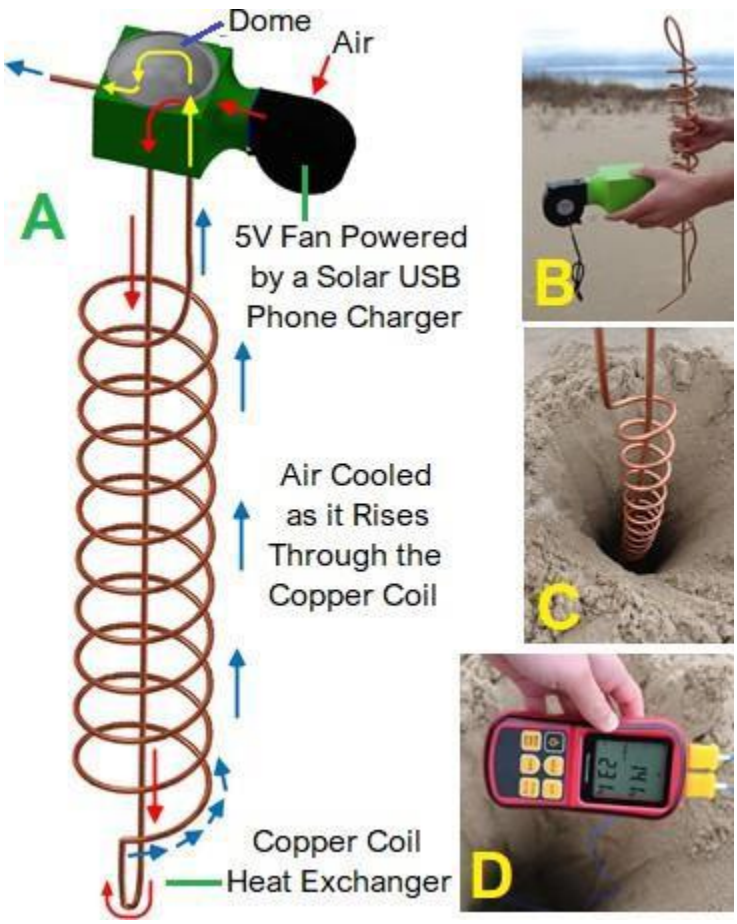


Fig. 4. A. Coiled copper heat exchanger. B. Components before assembly. C. Coil being buried. D. Dual thermo.

Performance of the water harvester was improved by geothermal cooling. A heat exchanger was built by coiling a 5 mm Φ copper tube. The diameter was selected for its high surface area to volume ratio. A centrifugal fan pushed ambient air through the central tube (Fig. 4A). Keeping in the environment friendly theme, fan was solar powered. To introduce the turbulence and increase heat loss. steel wool was inserted in the tube prior to making the spiral. The cooled air was circulated in the green chamber below the dome to cool the hydrophilic bumps (yellow arrows in Fig. 4A). The heat exchanger was tested at depths over one meter. The temperature differential was large and effective. The meter in Fig. 4D is showing the temperature above (23.1 °C) and one meter below ground (14.1 °C). The green chamber in Fig.4 and its internal components were 3D printed. All physical models were built and tested under adult supervision while wearing protective gear. *Once again, the thermodynamics and detailed analysis of the heat exchanger design and operation have been omitted due to space constraints*.

Results

Fig. 5. Micrographs of water droplets in various stages of formation on the bumps and spikes.

Extended videos and photographs were taken of the water microbeads forming on the hydrophilic bumps and spikes but not included here due to the format limitations. Fig. 5A shows the coalescing of microbeads into three larger drops. The drop on the top left is about to roll off. A drop in the process of similar movement can be seen in the top right of Fig. 5B. As explained in the Appendix, successive coalescing of droplets generates the crucial motive force that allows Aero2Aqua to work without an external energy source. Droplets similarly formed on the spikes (Fig. 5C). The coalesced drops even moved against the gravity (≤ 5° upslope). Results like Fig. 5 showed that the hydrophilic surface had been conditioned effectively to avoid film formation.

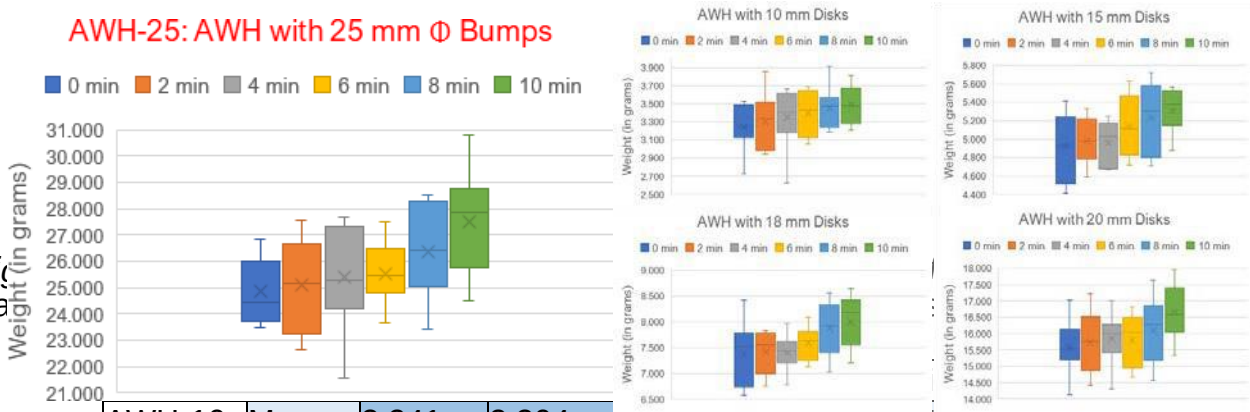


Fig
Ta

AWH-10	Mean	3.241	3.304	3.353	3.392	3.455	3.490
	SD	0.230	0.278	0.309	0.230	0.210	0.190
AWH-15	Mean	4.928	4.981	4.963	5.131	5.233	5.306
	SD	0.345	0.225	0.226	0.299	0.354	0.237
AWH-18	Mean	7.371	7.421	7.399	7.589	7.869	7.998
	SD	0.573	0.386	0.327	0.302	0.479	0.491
AWH-20	Mean	15.589	15.720	15.843	15.789	16.082	16.667
	SD	0.798	0.923	0.775	0.744	1.003	0.840
AWH-25	Mean	24.843	25.085	25.400	25.547	26.366	27.489
	SD	1.208	1.615	1.866	1.162	1.673	1.790

The result of 300 measurements (5 AWHs x 6 time intervals x 10 readings/interval) are summarized in Fig. 6 and Table 1. For example, value in top left of the table (= 3.241 g) is the average weight of the AWH with 10 mm Φ bumps when it is dry. The value 3.304 is the weight of AWH-10 after 2 minutes in the fog chamber and so on. There are some anomalies that can be attributed to the experimental error, e.g., AWH-18 collected less water after 4 min than 2 min.

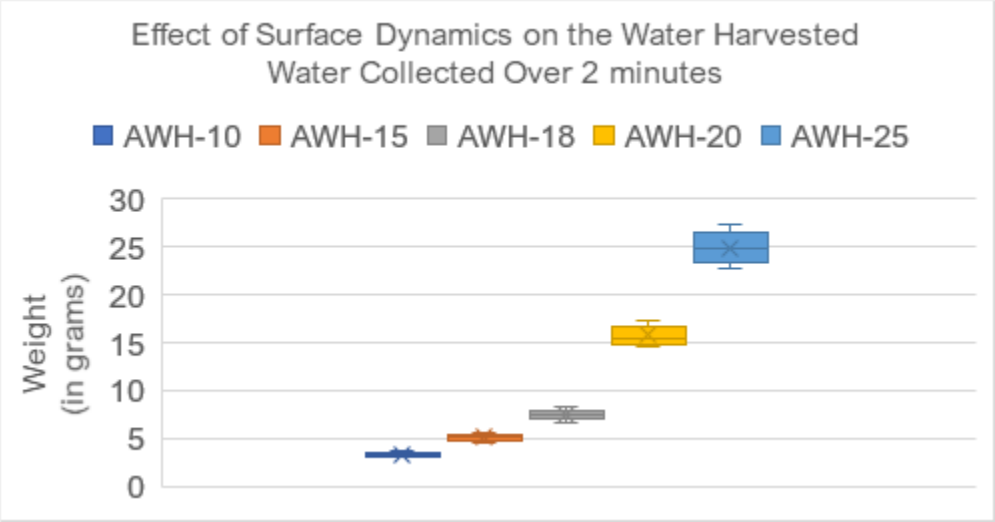


Fig. 7. Data summary: The Effect of Surface Dynamics on Atmospheric Water Harvesting

Table 2. Stat analysis: The Effect of Surface Dynamics on Atmospheric Water Harvesting (All values other than count in grams)

Stats	Atmospheric Water Harvesters				
	AWH-10	AWH-15	AWH-18	AWH-20	AWH-25
Mean	3.323	5.028	7.475	15.753	24.889
Range	0.602	0.920	1.624	2.610	4.550
Max Min	3.614	5.497	8.202	17.230	27.304
Variance	3.012	4.577	6.578	14.620	22.754
SD	0.037	0.085	0.189	0.836	2.309
1 SD	0.193	0.291	0.435	0.914	1.520
2 SD	3.130-3.516	4.737-5.319	7.040-7.910	14.839-16.667	23.369-26.409
3 SD	2.936-3.710	4.445-5.611	6.605-8.345	13.924-17.582	21.850-27.928
N	2.743-3.903	4.154-5.902	6.170-8.780	13.010-18.496	20.330-29.448
	25	25	25	25	25
Sample results of the t-test @ df = 48; α = 0.05; t = 2.011 for significance AWH-10 vs. AWH-15 t = 23.892 p < 0.05 AWH-15 vs. AWH-18 t = 22.896 p < 0.05 AWH-18 vs. AWH-20 t = 40.052 p < 0.05					

Table 3. Results of all paired t-tests @ df = 48; α = 0.05; t = 2.011 for significance

	AWH-10	AWH-15	AWH-18	AWH-20	AWH-25
AWH-10	–	-23.892	-42.722	-65.163	-68.973
AWH-15	23.892	–	-22.896	-54.757	-62.888
AWH-18	42.722	22.896	–	-40.052	-53.975
AWH-20	65.163	54.757	40.052	–	-25.238
AWH-25	68.973	62.888	53.975	25.238	–

Next an AWH was placed in the fog chamber for 2 minutes and weighed. The process was repeated for 25 trials of each of the AWHs for a total of 125 measurements. The 25 trials were done so that the dataset was large enough for reliable statistical analysis. The summary of the data distribution and statistical analysis are in Fig. 7 and Table 2. As noticeable in Fig. 7, the range of values for each AWH is in its own distinct band. That observation combined with t-tests proved that the data was statistically significant. There were no outliers for any of the levels of the independent variable, which was defined by the values that were outside the ($\mu \pm 2\sigma$) range.

A comparison of the means showed that the 25-mm disks harvested the most amount of water (Table 2). The results supported the research hypothesis. All values of the t-tests were further away from zero than the table t-value of 2.011 (Table 2). Therefore, the null hypothesis was rejected. From that, it can be inferred that the probability of the results being due to chance is less than 0.05 and were most likely caused by the independent variable. The data was statistically significant because the null hypothesis was rejected.

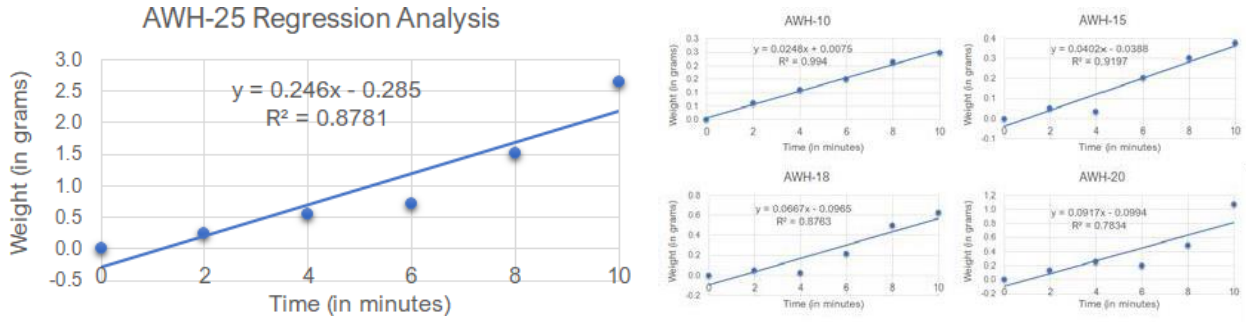


Fig. 8 Regression analysis of the water harvested by AWHs.

Table 4. Rate of water harvested by AWHs (in liters per hour per m^2)

	AWH-10	AWH-15	AWH-18	AWH-20	AWH-25
Slope	0.0248	0.0402	0.0667	0.0917	0.2460
Intercept	0.0075	-0.0388	-0.0965	-0.0994	-0.2850
Water/hour	1.4925	2.3732	3.9067	5.4050	14.4750
L/hour/m^2	2.715	1.918	2.193	2.458	4.213

The final step addressed the question, it is understandable that AWH-25 harvests the most water because it has the largest hydrophilic disks (25 mm Φ), but is it also the most efficient?

That can be resolved by calculating the water collected per hour per sq meter. Therefore, a regression analysis was performed on the mean values from Table 1. The table has gross weight (i.e., weight of the AWH and water harvested). The regression analysis in Fig. 8 and Table 4 was

done on the net weight of water collected (i.e., after subtracting the weight of dry AWH from the gross weight, table not shown here). The slope and intercept of the fitted lines from Fig. 8 are listed in Table 4. Those were used for estimating the water collected per hour and then the rate (in L/hour/m^2). There is an interesting scenario in Table 4. The water collected per hour by AWH-10 is lower than that of AWH-15. However, the situation reverses in the rate of collection. That is because of the smaller area of the bumps in AWH-10 (area α $radius^2$). Also looking at the trend in the bottom line of Table 4, AWH-10 seems to be an outlier because the water is steadily increasing with the increase in the diameter of the hydrophilic bumps in the other four cases.

Discussion and Conclusions

The purpose of this experiment was to identify the best surface dynamics for harvesting atmospheric water by using different sizes of hydrophilic disks and spikes. The research hypothesis was that a larger-sized disk would harvest more water. The research hypothesis was supported because a comparison of means of each of the five levels of the independent variable showed that the 25 mm diameter harvested the most water. The data was significant because all t-values were further away from zero than the table t-value.

Numerous time-elapse videos were recorded showing the growth of water droplets and their movement on the bumps and spikes. However, those could not be presented here due to the format restrictions. The analysis of spikes was also not presented for the same reasons.

Many researchers have worked in past on similar topics. They have utilized diverse technologies such as absorbing moisture into gels and then extracting water from the gel using energy (Zhou et al., 2020) or harps of wires (Qadir et al., 2018). Aero2Aqua presented here is a novel invention that does not require external energy. Instead, it relies on the dynamics of the hydrophilic and hydrophobic surfaces and the energy freed during coalescing of water droplets.

Though the objective of Aero2Aqua was to harvest water without using any external energy, a copper heat exchanger was built as an addon option. The option is still environment friendly because the 5 Volt fan is driven by a solar USB battery charger. The heat exchanger was viable because the ground is significantly cooler than air even 1-2 meter below the surface. That is especially true in arid areas with stony or sandy soil. The cost of heat exchanger was under
$25. The analysis of heat exchanger has been omitted due to the space constraints.

Linear regression was conducted on the data from all five AWHs. The result was used for calculating the projected collection by each AWH in liters/hour/m^2. Once again, the AWH with

25 mm disks performed the best. There was a direct correlation between the amount of water collected and the size of the disk. It would be interesting to investigate the optimum disk size beyond which any increase in size would reduce the rate of water collection. That would be an important factor in scaling up Aero2Aqua to a commercial product. There are numerous potential sources of error. Passive water collection is an inexact science. In can be inferred from the overlapping boxes in Fig. 6 that AWHs collected lesser water in more time in many cases. However, there was a clear trend in Fig. 6 and Table 1 that the average water collected increased with time and bump sizes. There were also scope for human error in repeated coating of the hydrophobic and hydrophilic surfaces. The experiment was conducted over several weeks due to the large number of time-consuming measurements (e.g., 10 trials x 10 minutes x 5 AWHs = 500 minutes, not including setup, weighing and cataloging time). However, such an effort was needed for thoroughness of the results.

The experiment could be improved in future by using different sized disks together. The 25 mm disks shown in Fig. 2C packed the dome quite tightly. However, smaller disks, especially the 10 mm Φ had more open spaces. Also, the disks could be arranged in patterns other than a rosette. Another step would be to run computer simulations. Many such apps are available commercially (e.g., COMSOL-Metaphysics) and freely (Surface Evolver). The modeling would help optimize the design, which could then be compared against the physical trials.

Literature Cited

Peer Reviewed:

Badarnah, L. (2016). Water management lessons from nature for applications to buildings. *Procedia Engineering 145*, 1432 – 1439.

Comanns, P., Winands, K., Pothen, M., Bott, R., Wagner, H. and Baumgartner, W. (2016). The Texas horned lizard as model for for passive directional transport of cooling lubricants. *Proc. SPIE 9797, Bioinspiration, Biomimetics, and Bioreplication 2016, 979711*

Demakov, S., Loginov, Y., Illarionov, M., Ivanova, M. and Karabanalov, M. (2012). Effect of Annealing Temperature on the Texture of Copper Wire. *The Physics of Metals and Metallography, 113(7)*, 681–686.

Deng, S., Shang, W., Feng, S., Zhu, S., Xing, Y., Li, D., Hou, Y. and Zheng, Y. (2017). Controlled droplet transport to target on a high adhesion surface with multi-gradients. Nature Scientific Reports, 7(45687) 1-8.

Guo, L. and Tang, G. (2015). Experimental study on directional motion of a single droplet on cactus spines. *International Journal of Heat and Mass Transfer 84*, 198-202.

Hay, C., Lee, J. and Silvester, D. (2019). Formation of 3-D gold and copper microelectrode arrays for enhanced electrochemical sensing applications. *Nanomaterials 9(1170)*,

Liu, J., Yang, H., Gosling, S., Kummu, M., Fiorke, M., Shang, C., Alcamo, J. and Oki, T. (2017).
Water scarcity assessments in the past, present and future *Earths Future 5(6)*, 545-559.

Liu, C., Xue, Y., Chen, Y. and Zheng, Y. (2015). Effective directional self-gathering of drops on spine of cactus with splayed capillary arrays. *Nature Scientific Reports 5(17757)*, 1-8.

Malik, F., Clement, R., Gethin, D., Beysens, D., and Parker, A. (2015). Dew harvesting efficiency of four species of cacti. *Bioinspiration & Biomimetics, 10(036005)*, 1-16

Niu, D. and Tang, G. (2016). The effect of surface wettability on water vapor condensation in nanoscale. *Nature Scientific Reports 6(19192)*, 1-6.

Norgaard, T., Ebner, M. and Dacke, M. (2012). Animal or Plant: Which Is the Better Fog Water Collector? *PLoS ONE 7(4)*, e34603 1-4.

Ohno, K., Asami, M. and Matsui, Y. (2018). Is the default of 2 liters for daily per-capita water consumption appropriate? A nationwide survey reveals water intake in Japan. *WHO Journal of Water and Health 16(4)*. 562-573.

Qadir, M., Jimenez, G., Farnum, R., Dodson, L. and Smakhtin, V. (2018). Fog Water Collection: Challenges beyond Technology. *Water 10(4)*, 372-381.

Schneider, J., Stocker, A., Franke, A. and Kawalla, R. (2018). Effects by the microstructure after hot and cold rolling on the texture and grain size after final annealing of ferritic non- oriented FeSi electrical steel. *AIP Advances 8(04760)*, 1-14.

Vahabi, H., Wang, W., Mabry, J. and Kota, A. (2018). Coalescence-induced jumping of droplets on superomniphobic surfaces with macrotexture. Science Advances 4(3488), 1-7.

Yao, Y., Aizenberg, J. and Park, K. (2018). Dropwise Condensation on Hydrophobic Bumps and Dimples. *Applied Physics Letters 112(15)*.

Yin, K., Du, H., Dong, X., Wang, C., Duan, J. and He, J. (2017). A simple way to achieve bioinspired hybrid wettability surface with micro/nanopatterns for efficient fog collection. *The Royal Society of Chemistry Nanoscale 9*, 14620–14626.

Zhong, S., Wang, Y., Wang, M., Zhang, M., Yin, X., Peng, R. and Ming, N. (2003). Formation of nanostructured copper filaments in electrochemical deposition. *The American Physical Society, Physical Review E67(061601)*, 1-9.

Zhou, X., Lu, H., Zhao, F. and Yu, G. (2020). Atmospheric Water Harvesting: A Review of Material and Structural Designs, *American Chemical Society Materials 2(7)*, 671-684.

Books:
Callister, W. and Rethwisch, D. (2015). Fundamentals of Materials Science and Engineering: An Integrated Approach (5th ed.). Wiley Publishers

Cengel, Y. and Ghajar, A. (2014). Heat and mass transfer (5th ed,). McGraw Hill

Appendix

A. Design of Hydrophilic Surfaces: Thermodynamics of Coalescence Energy of Waterdrops

A favorable energy gradient due to the coalescing of water drops is one of key drivers that enables an atmospheric water harvester to run without an external energy source. Merger of smaller droplets into larger ones is thermodynamically favored because it is exothermic (Vahabi et al., 2018). Water has the highest surface tension of all naturally occurring liquids (other than mercury, which is a pure metal). As explained below the amount of energy harnessed from the surface tension made Aero2Aqua feasible without an external energy source. By conservation of energy, the surface energy released after coalescing is

$\Delta Es = \gamma_{lv} \bullet \Delta A_{lv} + \gamma_{sl} \bullet \Delta A_{sl} + \gamma_{sv} \bullet \Delta A_{sv}$ [A.1]

where, γ_{lv}, γ_{ls} and γ_{sv} are the surface tension at the liquid-vapor, solid-liquid, and solid-vapor interfaces, respectively and ΔA_{lv}. ΔA_{sl}, and ΔA_{sv} are the change of area of liquid-vapor, solid- liquid and solid-vapor interfaces due to coalescing. By the conservation of mass principle, the decrease in the area of the solid-liquid interface is equal to the increase in the solid-vapor interface area, i.e., Asl = −Asv. Then, Equation [A.1] can be rewritten as

$\Delta E_s = \gamma_{lv} \bullet \Delta A_{lv} + (\gamma_{sl} - \gamma_{sv}) \bullet \Delta A_{sl}$ [A.2]

Since the condensation forms waterdrops without any wetting, A_{sl} is effectively zero. Then,

$\Delta E_s = \gamma_{lv} \bullet \Delta A_{lv}$ [A.3]

If two drops of radii r_1 an r_2 coalesce to form a drop of radius r_3, then the following holds true because the total volume remains unchanged (volume of sphere = $4/3\ \pi\ r^3$)

$r_1^3 + r_2^3 = r_3^3$ [A.4]

Using Equation [A.4], Equation [A.3] can be rewritten in terms of radii as

$\Delta E_s = \gamma_{lv} \bullet [4\pi r_1^2 + 4\pi r_2^2 - 4\pi (r^3 + r^3)^{2/3}]$, or

$\Delta E_s = 4\pi\gamma_{lv} \bullet (r_1^2 + r_2^2 - (r_1^3 + r_2^3)^{2/3})$ [A.5]

From Eqation [A.5], it can be inferred that

1. *The coalescence energy is higher when larger drops merge because r1 and r2 are larger.*
2. *The increased energy release would propel the drop faster towards the hydrophobic surface.*
3. *Most energy is released when two similar sized drops merge. Repeatedly adding tiny drops to a growing drop is inefficient. If a tiny drop of radius r2 is added to a growing large drop of radius r1, then r1 >> r2. So, r2 is effectively zero as compared to r1 in Equation [A.5].*

That results in ΔEs ≈ 0*.*

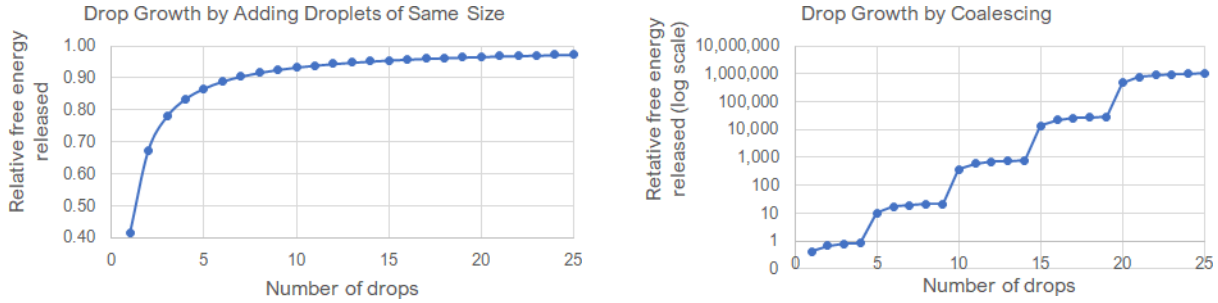


Fig. 9. Free energy released during coalescing, using Equation [A.5]. In the lefthand case, same sized droplets are being added to a growing drop. In the righthand case, the drops coalesce in the intermediate steps. *The energy released on the right is 1,036,900 times that of the left*!

Therefore, great care was taken when prepping the hydrophylic surfaces of Aero2Aqua so as to promote microbead formation, growth and coalscing and avoid filming. It increased the water harvest. The bead formation was monitored by the microscope shown in Fig. 2. Advanced nanocoatings would be used in the commercial version of Aero2Aqua.

B. <u>Shape of the Condenser: Heat Dissipaton in the Spherical Aero2Aqua Bumps</u>

The specific latent heat of condensation of water is 2,260 kJ/kg. This is the heat emitted (or absorbed) when vapor changes to liquid (or vice versa). In the temperature range −25 °C to 40 °C, it is approximated by the following empirical formula (source: Book by Cengel and Ghajar).

$L_{water}(T) \approx (2500.8 - 2.36T + 0.0016T^2 - 0.00006T^3)$ kJ/kg [B.1]

where T is the numerical value of temperature in °C. In case of the Aero2Aqua dome, the latent heat was emitted as water condensed onto the hydrophilic surfaces. The design of Aero2Aqua had to account for removing the heat away from the surface. In a steady state operation, the rate of heat transfer into the disk equals the rate of heat lost. Then according to Fourier's law, the heat conduction through a spherical layer is as follows.

where, 1) Qdot is the r te of heat transfer at radius r (in W); 2) T is the temperature at radius r (in K); 3) A a of sphere = $4\pi r^2$ (in m^2) and 4) k, coeff of thermal conductivity, (in $W \cdot m^{-1} \cdot K^{-1}$)

$$\dot{Q} = -kA\frac{dT}{dr} \quad [B.2]$$

The hydrophilic bumps were constructed as segments of spheres. For a hollow sphere with inner and outer surface temperatures at T1 and T2 and inner and outer radii of r1 and r2, Equation [B.2] can be integrated over the thickness of the shell by the separation of variables.

$$\int_{r=r_1}^{r_2} \frac{Q}{A}\, dr = -\int_{T=T_1}^{T_2} k\, dT \qquad [B.3]$$

Substituting $A = 4\pi r^2$, integrating and rearranging the terms gives

$$\dot{Q} = \frac{T_1 - T_2}{R} \qquad \text{where,} \qquad R = \frac{r_2 - r_1}{4\pi r_1 r_2 k} \qquad [B.4]$$

From equation [B.4], it can be deduced that for a given temperature differential (T1 – T2), the heat conduction (Qdot) is directly proportional to (r1• r2 / (r2 – r1)). *The disks used for this experiment were 0.8 mm thick, i.e., (r2 – r1) = 0.8 mm.* Therefore, the Qdot could be increased by

1. Increasing r2 (and therefore r1, because r2 – r1 was fixed at 0.8 mm and/or
2. Using a material with a higher value of k

Theoretically, r2 will be max for a flat disk (i.e., r2 = ∞). But, that conflicted with the constraints

1. Water should drain off the bumps under gravity and
2. The available surface area must be maximized.

These opposing engineering criteria were balanced to pick the radii of curvature of the bumps. The solver feature of Excel was used to optimize the Equations C.1, C.3 and C.4. It was determined that making a spherical bump with the same diameter as the disk was optimal. For example, the 10 mm Φ disk was formed into the segment of a sphere 10 mm in diameter. There were more precise solutions such as making paraboloid bumps, similar to the paraboloid dome. However, that would have needed an advanced manufacturing facility, which was not feasible.

The metal disks were pressed into spherical bumps with a one-ton press (Fig. 3). The disks represent the gray segment in Fig. 10. The diameter of the disk was the same as the dia[illegible] and die used in the press. From Fig. 10, θ = 2R / 2πR * 360° = 11[illegible] ere close to being hemispheres, which optimized the draining and increased surface area, as mentioned above. Stainless

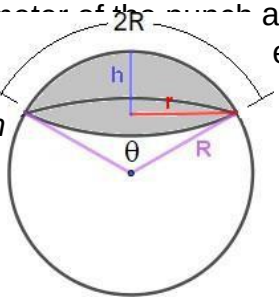


Fig
bum

steel was chosen for fabricating the bumps even though its coefficient of thermal conductivity (k = 14 $W \bullet m^{-1} \bullet K^{-1}$) is lower than other avaiable metals such as copper (k = 413 $W \bullet m^{-1} \bullet K^{-1}$). Steel was picked because of its durability, abundance and low cost.

Alternate Lynn Tao (10)

The Effect of Impervious Surfaces on Steam Health: a Study of Machine Learning and Multivariate Statistical Analyses
Thomas Jefferson High School for Science & Technology

ABSTRACT

Impervious surface area is projected to triple within the next three decades as a direct consequence of proliferating urbanization. Impervious surfaces, which are man-made architectural features that prevent absorption of water such as buildings and roads, play a profound role in affecting surface runoff and physio-chemical properties of stream systems. Thus, quantifying and studying impervious surfaces is crucial to understanding the breadth of anthropogenic influence. However, current methods of quantifying impervious surfaces require complex procedures, expensive software, and experienced personnel. As an alternative, we designed a novel machine learning approach that utilizes Google Maps and a K-Nearest- Neighbors (KNN) supervised algorithm to quantify the percentage of impervious surfaces (PoIS) surrounding 21 urban stream sites in Fairfax County, VA. Non-metric Multidimensional Scaling (nMDS) was conducted to analyze the relationship between PoIS and 10 water quality parameters based on the Bray (Sorenson) distance matrix. Permutational Multivariate Analysis of Variance (PERMANOVA) was used to detect the strength of dissimilarities among stream sites. Our research demonstrates that impervious surfaces are negatively correlated with the ecological health of Fairfax County streams. In addition, the developed machine learning algorithm used to quantify PoIS may serve as a useful tool to identify high risk streams, or areas that should be monitored. The algorithm will help better understand our urban stream environment, serving as a foundation for cost-effective water-resource management.

INTRODUCTION

The US Cities Factsheet projects the combined urbanized land area to triple within the next three decades [1]. Urbanization results in an increase in impervious surfaces, surfaces

covered by impenetrable materials [2], which results in significant changes in the biological, physical, and chemical conditions of local freshwater ecosystems by influencing the structure of macroinvertebrate communities, reducing natural landscape complexity, and diminishing sustainable drainage to water bodies [3][4].

These impacts are especially evident in areas with large population growth. Fairfax County, Virginia, has seen more than a 10-fold increase in population size in the past 70 years, from 98,255 in 1950 to 1,147,532 in 2019 [5]. Consequently, most streams in Fairfax County show symptoms of “urban stream syndrome”, the consistent ecological degradation of stream ecosystems [6]. Unfortunately, the balance between urbanization and preservation is thin; research into the consequences of urban development is essential to cost-effective water-resource management [7].

Current methods of quantifying impervious surfaces, such as using ArcGIS or ISAT, require complex procedures, expensive software, and experienced personnel. In addition, although various statistical techniques such as Cluster Analysis, Principal Component Analysis, and Multidimensional Scaling (MDS) were used to investigate the anthropogenic impacts on the water ecosystems [8][9], impervious surface has not been employed as a quantifiable measure in these analyses. This is likely because the relationship between impervious surfaces and stream health factors is not well understood.

Thus, the present study had a two-fold purpose. First, we wanted to develop a user- friendly method to quantify impervious surface area around a sampling site that was both efficient and accurate. Second, we used this method to test whether there was a significant relationship between impervious surfaces and biological and physio-chemical stream health factors in Fairfax County. We first designed a novel K-Nearest-Neighbors (KNN) supervised

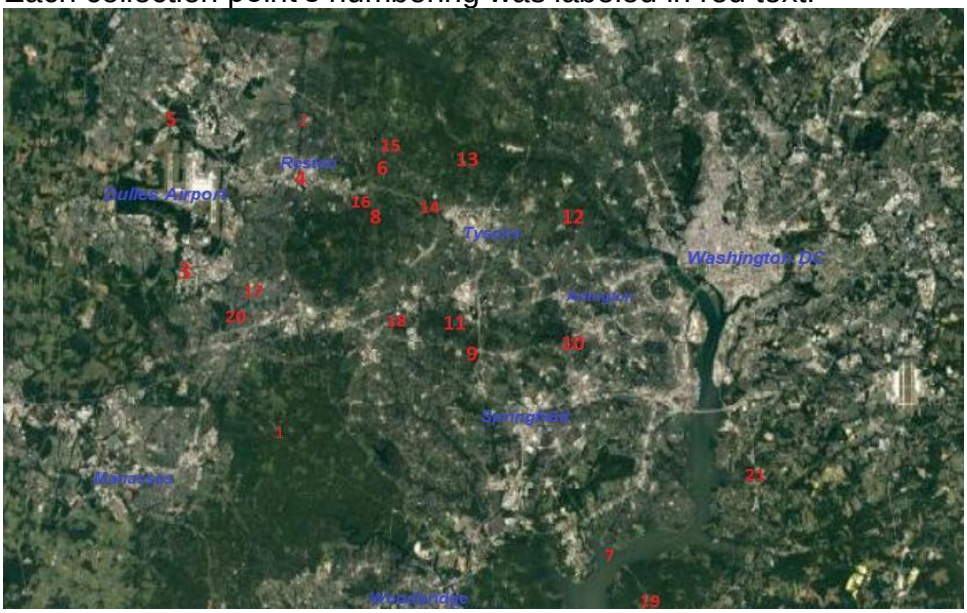
machine learning (ML) algorithm to classify the satellite image pixels as either impervious or pervious. This algorithm extracted statistical profiles from supervised training sets and stored these profiles in three-dimensional cluster centers, then calculated Euclidian distance from unknown image pixels to these cluster centers to determine the class membership using votes from the K nearest neighbors. Then, we applied this ML algorithm to satellite images of Fairfax County streams (n = 21) and quantified the surrounding impervious surfaces. We incorporated the percentage of impervious surfaces (PoIS) as a numerical variable in statistical analyses. We found that impervious surfaces in Fairfax County had a significant negative correlation with ecological stream health score, i.e., as impervious surface area increased, stream health declined.

METHODS AND MATERIALS Water sample collection Streams in Fairfax County (n = 21) were assessed based on the Virginian Save Our Streams
(VASOS) protocol during the Autumn of 2019 as part of the Integrated Biology, English, and Technology (IBET) program at Thomas Jefferson High School for Science and Technology (**Table 1**). These data sampling points were labelled on a satellite image (**Figure 1**). Physical, chemical, and biological data were collected including a multi-metric index based on macroinvertebrate richness, in addition to *E. coli* growth, pH, alkalinity, chloride, dissolved oxygen, phosphate, nitrates, and the number of riffles, water temperature, and transparency.
Selected streams had also been previously categorized as “healthy”, “moderate”, or “unhealthy” by the Fairfax County Park Authority and had an overall health score assigned following the protocols of the Virginia Department of Environmental Quality.

Table 1. Numbered experimental streams (n = 21) in Fairfax County, VA. Health category data is from the Fairfax County Park Authority (FCPA).

Sample Points	Stream Name	GPS Locations		Sampling Time		Health Category
		Latitude	Longitude	Date	Time	
1	Popes Head Creek	38.777785	-77.392512	10/26/19	14:30-18:25	Healthy
2	Follylick	38.990033	-77.382770	11/23/19	12:16-17:00	Unhealthy
3	Cub Run	38.891667	-77.470556	11/4/19	10:30-15:00	Semi-healthy
4	Sugarland Run	38.965735	-77.371122	11/24/19	10:30-13:00	Unhealthy
5	Horsepen Run	38.991776	-77.469719	11/16/19	13:50-16:30	Unhealthy
6	Colvin Run	38.967000	-77.295266	11/16/19	14:30-16:30	Semi-healthy
7	Sugarland Run	38.993056	-77.143628	11/23/19	8:24-12:00	Unhealthy
8	Difficult Run	38.931800	-77.297200	10/27/19	13:00-16:32	Semi-healthy
9	Accotink Creek	38.832500	-77.220862	11/10/19	11:45-15:15	Unhealthy
10	Holmes Run Stream	38.841284	-77.143628	10/12/19	10:45-14:00	Unhealthy
11	Accotink Creek	38.842620	-77.230470	11/3/19	15:00-17:30	Unhealthy
12	Pimmit Run	38.932700	-77.157700	10/21/19	17:11-19:10	Unhealthy
13	Difficult Run	38.976500	-77.249300	11/2/19	12:02-17:30	Healthy
14	Wolf Trap Creek	38.932400	-77.263200	11/17/19	10:55-14:18	Healthy
15	Difficult Run	38.968872	-77.280598	10/12/19	17:30-20:00	Semi-healthy
16	Snakeden Branch	38.937340	-77.324400	11/16/19	11:00-13:00	Unhealthy
17	Frog Branch Stream	38.877477	-77.410879	10/26/19	15:00-18:00	Unhealthy
18	Daniel's Run	38.851700	-77.289700	10/19/19	15:37-17:45	Unhealthy
19	Difficult Run	38.911111	-77.317500	11/9/19	10:57-14:37	Healthy
20	Big Rocky Run	38.868618	-77.405575	10/26/19	10:10-14:15	Unhealthy
21	South Run	38.751719	-77.290788	11/2/19	7:45-10:10	Semi-healthy

Figure 1. Data Collection Points on a Satellite Image. Major cities were labeled in blue text. Each collection point's numbering was labeled in red text.



A health score, also called a stream ecological number or multi-metric score, is an important parameter for water quality monitoring and is part of VASOS standard protocol. It is a weighted sum calculated based on what percentage of various macroinvertebrate groups live in a tream using the Rocky Bottom method following the field guide to aquatic macroinvertebrates. The resulting ecological number defines stream health into three categories: Acceptable Ecological Condition (9–12), Ecological conditions cannot be determined at this time (8), and Unacceptable Ecological Condition (0–7) [10].

Machine Learning (ML) Supervised Classification

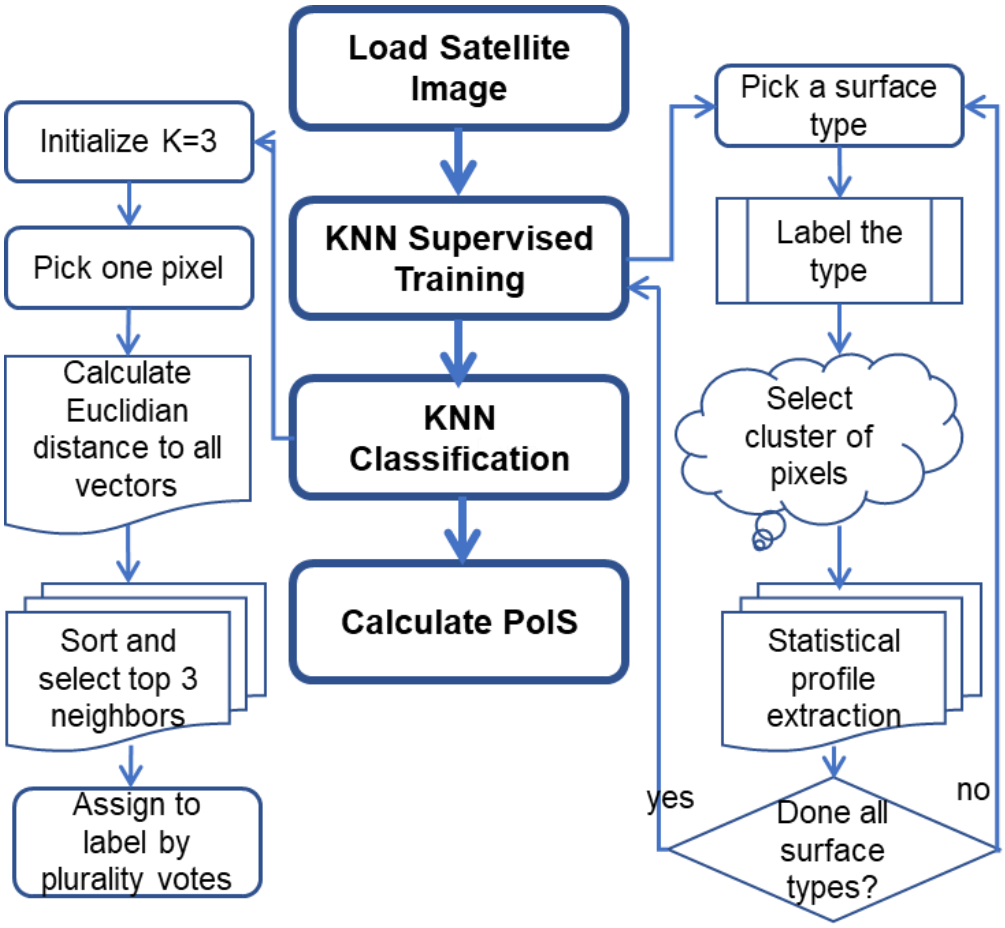
ML supervised classification was used to calculate PoIS from satellite imaging near each water sample collection point (Figure 2). Impervious surfaces were defined as man-made architectural features that prevent absorption of water, e.g., buildings, roads, parking lots, sidewalks, brick and asphalt. Pervious surfaces include surfaces composed of vegetation, water bodies, and bare soil. KNN, K-Nearest-Neighbors

The k-nearest neighbors (KNN) classifier is a supervised ML algorithm that assigns an unknown object with a feature vector to a known class membership by a plurality vote of its neighbors. The object is assigned to the class most common among its k nearest neighbors. KNN involves a supervised training phase and classification phase [17].

Supervised training phase: a software program was developed in this study to assist collecting training samples of well-known impervious surface or pervious surface types. The statistical profiles of these training examples were extracted and stored in three-dimensional feature spaces (RGB) as vectors. To improve accuracy and reduce noise/outliers of the sample data, the cluster center of each distinct type was calculated and used as the training sample vector.

Classification phase: Each satellite image pixel was processed and its Euclidean distance to all the cluster centers of these sample vectors was calculated. The pixel was then classified as either impervious or pervious based on the plurality vote of its *k* nearest neighbors. In our usage of KNN based on distinct surface types, the *k* value chosen was 3.

Figure 2. Flow Chart of KNN Supervised Machine Learning Classifier



Statistical Analysis

Two multivariate statistical techniques and a regression analysis were used to study the relationship of PoIS with the stream health factors.

Non-metric Multidimensional Scaling (nMDS) Analysis

MDS is a powerful tool for dimensional reduction. It achieves this goal by mapping the original data into a distance space where their distances correspond to the similarities of the objects [11][12]. NMDS uses repetitive process in finding the optimal transformation to minimize the stress, which is calculated as below:
stress =

$$\frac{\sum ij\ (\cancel{dij - Dij})2\ \sqrt{}}{\sqrt{\sum ij\ Dij2}}$$

where *dij* is dissimilarity of sample *i* to *j* and *Dij* is the distance between samples *i* and *j* in the Cartesian space of the ordination.
During nMDS analysis, all the data were first standardized to avoid misclassification due to wide differences in dimensionality. A scree test was then performed to decide an appropriate number of dimensions. The goodness-of-fit of the mapping was assessed with Shepard diagrams. All procedures were performed using R vegan functions.

PERMANOVA Analysis

Permutational Multivariate Analysis of Variance (PERMANOVA) is used to test whether groups of objects are significantly different. It is popular for ecological studies due to its less restricted data assumption [13]. The test statistic is a pseudo-F-ratio:

$$F = \frac{SSA \div (a-1)}{SSW \div (N-a)}$$

where SS_W is the sum of squared dissimilarities within groups, SS_A is the sum of the squared dissimilarities among groups, *a* is the number of groups, and *N* is the total number of objects. The significance of this ratio is usually used to indicate the strength of dissimilarity, as in this study.

Regression Analysis

Linear regression was used to model the relationship between PoIS versus each of the physio-chemical and biological stream variables.

RESULTS

KNN Supervised Classification

Evaluation of the K-Nearest-Neighbors (KNN) supervised classification is done using precision, recall, and accuracy calculations. In the context of impervious surfaces, precision measures the percentage of KNN classified-impervious surface that is true positive impervious. On the other hand, recall measures the percentage of actual impervious surface that was true positive. Accuracy represents the percentage of correct analyses.

$$\text{Accuracy} = \frac{tp+tn}{tp+tn+fp+fn}$$

$$\text{Precision} = \frac{tp}{\text{Predicted}} = \frac{tp}{tp+fp}$$

$$\text{Recall} = \frac{tp}{tp+fn}$$

	Actual Classification	
Classification	*tp* # True Positive	*fp* # False Positive
	fn # False Negative	*tn* # True Negative

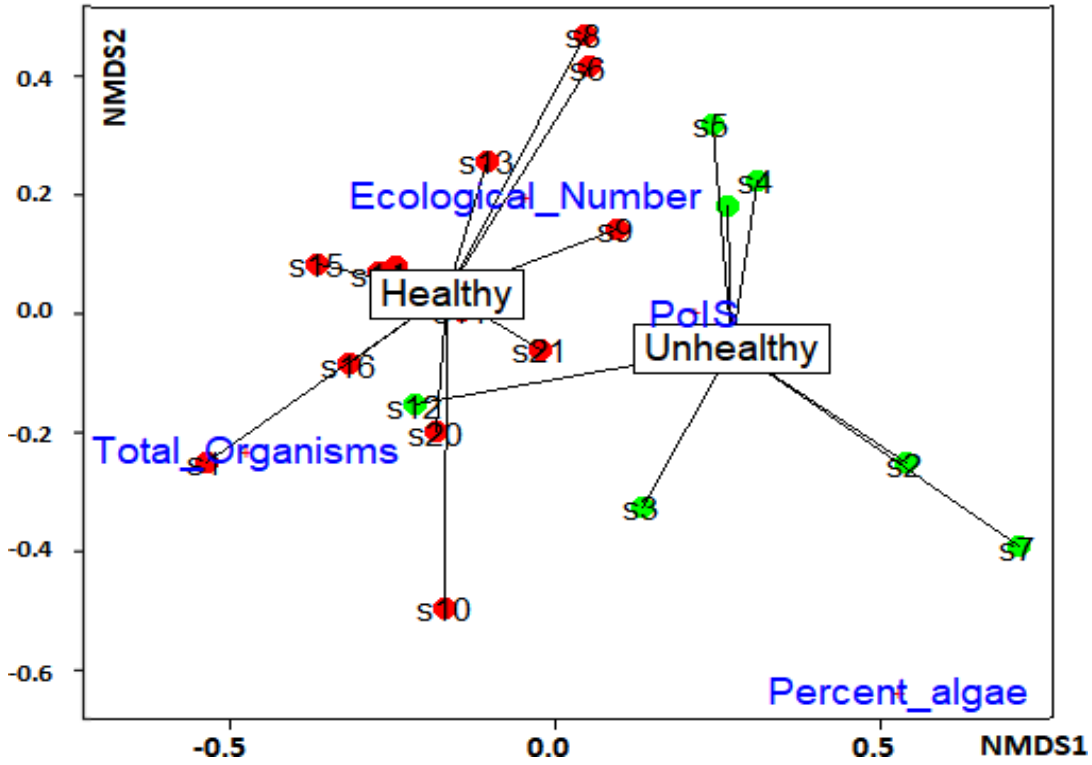
One hundred random pixels were chosen from each of the satellite images around the stream sites. These pixels covered various impervious and pervious surface types. We were able to achieve an overall classification accuracy of 88% (**Table 2**).

Table 2. Accuracy, precision and recall of the KNN algorithm

	Impervious Surface (IS) Types	Pervious Surface (PS) Types
Precision	94%	82%
Recall	84%	93%
Accuracy	88%	88%

nMDS Analysis and PERMANOVA Analysis

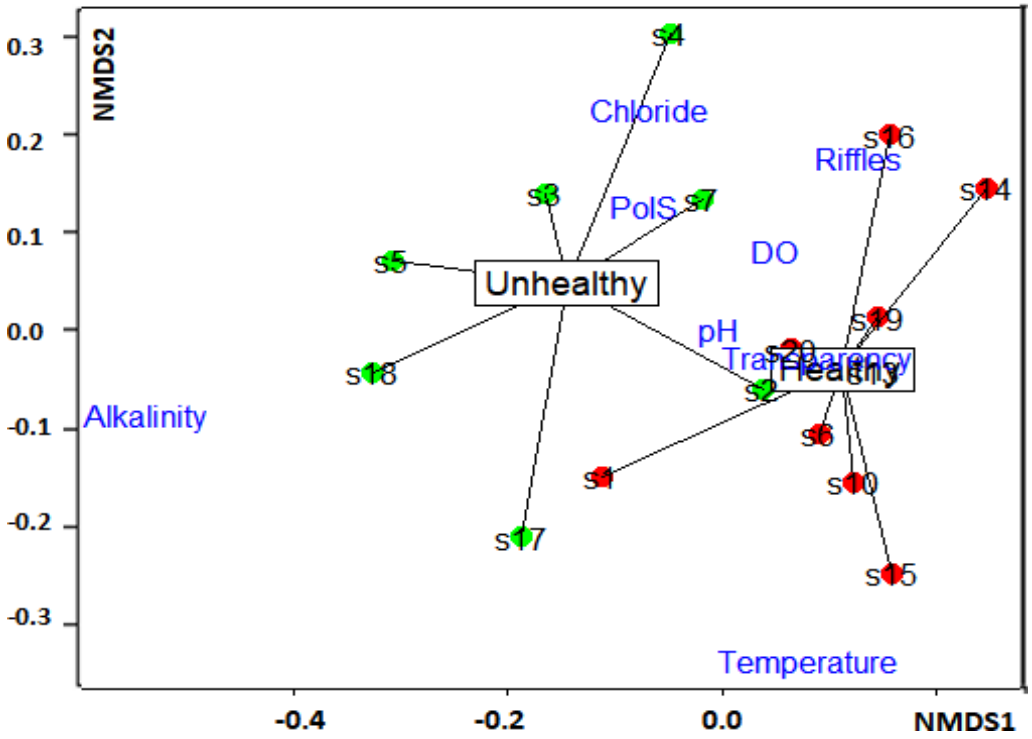
The sample water quality parameters were analyzed using non-metric Multidimensional Scaling (nMDS) analysis to find the relationship between impervious surfaces and the other variables. The dataset collected was organized into two sets, biological or physio-chemical.
NMDS (Stress = 0.16, Bray Curtis as the distance measure) and Permutational Multivariate Analysis of Variance (PERMANOVA) were conducted for each set of data (**Figure** 3& 4).
Figure 3. Multidimensional scaling analysis of PoIS and biological water variables. Bray Curtis is the distance measure option.



NMDS analysis (**Figure 3**) revealed several interesting facts. Impervious surface was close (or similar) to stream ecology number. This was further confirmed by the result of the later regression analysis. Stream ecology number was a little distance away from the total organism count, though both were based on macroinvertebrates. This result made sense because the stream ecology number was calculated with various weight factors for different species of macroinvertebrates instead of just the count. When stream health category was used as the env-

fit variable, streams fell nicely into two clusters, healthy and unhealthy, based on PoIS and other biological conditions. PERMANOVA analysis showed these two groups were significantly different to each other with Pr = 0.043.
When associated with physio-chemical parameters (**Figure 4**), impervious surface was close to most variables such as DO, PH, chloride, riffles, and transparency. Comparatively, it was not as close to alkalinity and water temperature. Alkalinity levels may be particularly affected by the existence of Dulles Airport on the west side of Fairfax County. Different physio- chemical conditions placed the streams sites into two separate groups, healthy and unhealthy. PERMANOVA showed these two groups were significantly different with Pr = 0.038.

Figure 4. Multidimensional scaling analysis of PoIS and water physio- chemical variables. Bray Curtis is the distance measure option.



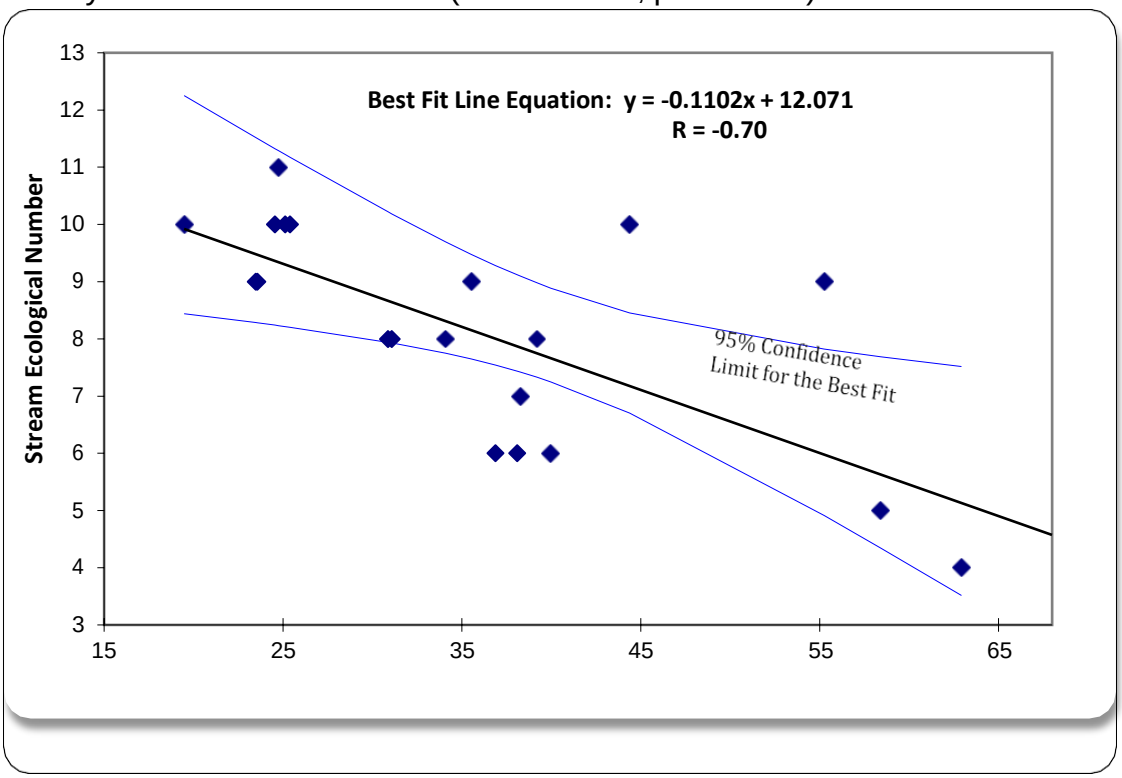
Regression Analysis

Impervious surfaces showed a relatively strong linear correlation with stream biological factors. Total organism count displayed a negative correlation with PoIS, with a coefficient of

correlation of 48% and a p-value of 0.04631. A positive correlation was found between PoIS and algae growth as well as between PoIS and *E. coli* bacterial density. These results were consistent with the above nMDS analysis.

Though nMDS analysis indicated a closeness between PoIS and stream physio-chemical parameters, this was not a linear relationship. Analyzing PoIS for these physio-chemical parameters produced low coefficients of correlation and insignificant p-values.

Figure 5. Correlation of PoIS and stream ecological number. Data points represent PoIS (x-axis) and the stream ecological number (y-axis) (n=20). Similar linear regression conveyed a correlation of -70% (SE=1.41739, p=0.00062).



Overall stream health had the most significant correlation with impervious surface percentage, confirming the closeness between the impervious surface and stream health score on the prior nMDS analysis (**Figure 5**). This high correlation and significance suggest that the linear regression equation can be used to model the Fairfax County stream health score based on the measures of PoIS. The equation is as follows:

*Stream Health Score = -0.110242 * PoIS + 12.07060*

DISCUSSION & CONCLUSION

In this study, we designed an effective and efficient ML algorithm to calculate the percent of impervious surfaces (PoIS) based on any satellite image. We then applied our K- Nearest-Neighbors (KNN) algorithm for Fairfax County streams and performed data analyses.
We found that PoIS showed a significant correlation with almost all biological factors, which is consistent with previous studies [14][15], and supports the theory that urban development is a major contributor to the degradation in stream ecosystems [16]. We also found a trend between PoIS and stream physio-chemical factors, but the relationship was nonlinear and unclear but warrants further investigation.
Past research showed that chemical and physical features are impacted by a wide variety of factors related to catchment area, such as stream current, varied precipitation, and regional (not just local) urbanization [15]. As a result, physio-chemical data would need to be collected across multiple seasons and multiple years to reveal more information. Comparatively, macroinvertebrate diversity and the VASOS multi-metric index are more stable over time and thus serve as better indicators of stream health. This is why macroinvertebrate diversity is so valuable when assessing stream health.
A few potential sources of error could have limited the present study. Some water parameters were unavailable for a few collection sites, so the sample size was smaller than intended for some variables and thus may have carried less statistical weight. Furthermore, differences in timing and weather may have affected readings of some stream parameters such as temperature and transparency. In the future, multiple trials of stream parameters could be taken and averaged to reduce the chance of outliers. In addition, collecting samples across multiple seasons and years at larger spatial scales would reduce environmental and human-induced error

in the data. Further exploration of machine learning algorithms would further improve the performance and accuracy in classifying impervious surfaces from satellite images.
Our study found that the VASOS stream health score had the most significant correlation with PoIS. Their closeness on the non-metric Multidimensional Scaling (nMDS) plots was confirmed by their high correlation in regression analysis, which also produced a linear model. The model could be used as a basis for a quick and inexpensive way to estimate stream health score from the PoIS in its surrounding area. The computer program developed in this study can be used to identify high risk streams, or areas that should be monitored. Future research could look into its application as a mechanism for determining the impact of proposed construction projects on the environment.

BIBLIOGRAPHY

[1] Center for Sustainable Systems, University of Michigan. (2020). *U.S. Cities Factsheet.* http://css.umich.edu/factsheets/us-cities-factsheet

[2] Obiakor, M. O., *et al*. (2012). Effects of vegetated and synthetic (impervious) surfaces on the microclimate of urban area. *Journal of Applied Science & Environmental Management*, 16(1), 85-94. https://search.proquest.com/docview/1347624562?accountid=34939

[3] McGrane, Scott J. (2016). Impacts of urbanization on hydrological and water quality dynamics, and urban water management: a review. *Hydrological Sciences Journal*, 61:13, 2295-2311. DOI: 10.1080/02626667.2015.1128084

[4] Peipoch, M., *et al*. (2015). Ecological Simplification: Human Influences on Riverscape Complexity. *BioScience*, 65(11). https://doi.org/10.1093/biosci/biv120

[5] U.S. Census Bureau. (July 1, 2019). *QuickFacts: Fairfax County, Virginia.* https://www.census.gov/quickfacts/fairfaxcountyvirginia

[6] Jastram, J. (2014). Streamflow, Water Quality, and Aquatic Macroinvertebrates of Selected Streams in Fairfax County, Virginia, 2007–12. *U.S. Geological Survey Scientific Investigations.* http://dx.doi.org/10.3133/sir20145073.

[7] Parece, T., & Campbell, J. (2015). Identifying Urban Watershed Boundaries and Area, Fairfax County, Virginia. *Photogrammetric Engineering & Remote Sensing*, 81(5), 365- 372. https://doi.org/10.14358/PERS.81.5.365
[8] Wu, M., et al. (2011). Investigation of Spatial and Temporal Trends in Water Quality in Daya Bay, South China Sea. *International Journal of Environmental Research and Public Health*, 8, 2352-2365. doi:10.3390/ijerph8062352
[9] Akbulut, M. (2010). Assessment of Surface Water Quality in the Atikhisar Reservoir and Sarýçay Creek. *Ekoloji* 19, 74, 139-149.
[10] Virginia Save Our Streams. (Spring 2020). *Biological Monitoring Data Form for Muddy Bottom Streams*. https://vasos.org/wp-content/uploads/Rocky-Example-Datasheet.pdf.
[11] Holland, S. (2019). *Non-metric multidimensional scaling (NMS)*. http://strata.uga.edu/8370/lecturenotes/multidimensionalScaling.html.
[12] Letten, A. (2017). *Multidimensional scaling*. http://environmentalcomputing.net/
[13] Joshuaebner, V. (2018). *Permutational Multivariate Analysis of Variance (PERMANOVA) in R*. https://archetypalecology.wordpress.com/2018/02/21/permutational-multivariate-analysis-of-variance-permanova-in-r-preliminary/
[14] Jacobson, C. R. (2011). Identification and quantification of the hydrological impacts of imperviousness in urban catchments. *Journal of Environmental Management*, 92(6). https://doi.org/10.1016/j.jenvman.2011.01.018
[15] Sponseller, R. A., *et al*. (2008). Relationships between land use, spatial scale and stream macroinvertebrate communities. *Freshwater Biology*, 46(10). https://doi.org/10.1046/j.1365-2427.2001.00758.x
[16] Gaffield, S. J. *et al.* (2003). Public health effects of inadequately managed stormwater runoff. *American Journal of Public Health*, 93(9), 1527-1533. https://ajph.aphapublications.org/doi/pdf/10.2105/AJPH.93.9.1527
[17] Cover, T. M. & P. E Hart. (1967). Nearest neighbor pattern classification. *IEEE Trans. Inform. Theory*, vol. IT-13, pp. 21-27.

Alternate Brock Duma (11)

Whitewater Helmet STAR: Evaluating the Biomechanical Performance and Risk of Head Injury for Whitewater Helmets
Blacksburg High School

Abstract

There are more than 6 million people who participate in whitewater kayaking and rafting in the United States each year. Of these 6 million participants, there are over 50 whitewater related deaths each year, which makes it have one of the highest fatality risks of all sports. As the popularity in whitewater activities grows, the number of injuries, including concussions, also increases. The objective of this study was to create a rating system for whitewater helmets by evaluating the biomechanical performance and risk of head injury of whitewater helmets using the Summation of Tests for the Analysis of Risk (STAR) system. All watersport helmets that passed the EN: 1385: 2012 standard, and that were clearly marketed for whitewater use were selected for this study. A total of 21 helmets were found, and 2 models of each helmet were tested. A custom pendulum impactor was used to test the helmets under conditions which are known to be associated with the highest risk of head injury and death. The struck head consisted of a NOCSAE head and Hybrid III 50th percentile neck, with the head form instrumented with three linear accelerometers, and a triaxial angular rate sensor. For this study, 126 tests were performed at six different configurations. The helmets were tested at 3.1 m/s and 4.9 m/s with impacts to the front, rear, and side for each speed. The velocities were chosen given that the highest recorded flow rate in a whitewater river is 5 m/s, which implies that it is very unlikely that any underwater head impact will have a head impact speed greater than 5 m/s. Each helmet's STAR value was calculated using the combination of exposure and injury risk that was determined by the linear and rotational accelerations. The resulting head impact accelerations predicted a very high risk of concussion for all impact locations with the 4.9 m/s impact speed. The STAR values varied between helmets, indicating that some helmets provide better protection than others. Overall, these results show a clear need for improvement in whitewater helmets, and the methodologies developed in this research project should provide manufacturers a path to improving their products.

Introduction

There are over 6 million people who participate in whitewater kayaking and rafting in the United States every year (Figure 1) (Spittler, et al., 2020). Of these 6 million participants, there are more than 50 whitewater related deaths each year, which gives the sport one of the highest fatality risks of all sports (Spittler, et al., 2020; Sayour, et al., 2019). As the popularity in whitewater

activities grows, the number of injuries, including concussions, also increases. The majority of injuries attained in these activities are acute, and they account for approximately 58% of all whitewater injuries (Spittler, et al., 2020). Acute head injuries occur in these sports from either contact with objects from outside the boat such as rocks, or from contact with other paddler's equipment (Spittler, et al., 2020; EN 1385: 2012). Head, neck, and face injuries are frequent among paddlers and are considered to be the most severe. Of all possible injuries, head injuries are the most life threatening. These dangerous head injuries can cause a participant to become unconscious, which often leads to death due to drowning. The head injuries are so severe that 77% of participants who sustain head injuries require medical attention (Schoen & Stanto, 2002).

Figure 1: Whitewater rafting is one of the most dangerous sports in the United States with over 50 fatalities each year. *(Photo used with permission from Michael Spinelli and Austin Funk and photo was taken by "Adventurers on the Gorge")*

The most common mechanism of whitewater head injuries is contact against underwater objects with the frontal/forehead area and the side of the eye socket (EN 1385: 2012). This occurs when a participant either capsizes or falls out of their vessel. Once out of their vessel, the fast moving rapids paired with hidden rigid rocks beneath the water's surface pose a high risk of head injury and death. The highest recorded flow rate in a whitewater river is 5 m/s, which implies that it is

very unlikely that any underwater head impact will have a head impact speed greater than 5 m/s (EN 1385: 2012). Because of the high head injury risk, there is an extremely high helmet usage rate among whitewater sports (Spittler, et al., 2020).

EN 1385: 2012 Whitewater Helmet Standard: One of the world's largest certification bodies, the British Standards Institute, created the only standard of testing for whitewater helmets known as EN 1385: 2012. The standard evaluates the helmet's impact protection, durability, and retention. To evaluate the impact protection, helmets are dropped from a height that simulates at least 15 Joules onto the center of a fixed anvil. The standard requires a tridirectional accelerometer to be fitted in the headform, a head impact acceleration recording apparatus, a system to guide the falling helmet, and a non-fixed system that supports a helmeted metal headform that is small through large in size. If a medium sized headform, named 575-J, is being used, the drop height is 0.326 m and the impact speed is 2.53 m/s. The impact speed ranges from

3.11 m/s to 2.22 m/s for the smallest to the largest of the five headform sizes. The mass of the medium headform is 4.69 kg while the masses range from 3.10 kg to 6.09 kg for the smallest to the largest headforms. The circumference of the medium headform is 0.575 m while the circumferences range from 0.495 m to 0.625 m for the smallest to the largest headforms. Upon impact with the anvil, the headforms cannot exceed a measured acceleration of 250 g after data processing and filtering for any of the impact tests and configurations. In order to evaluate durability, additional tests are performed that involve heating and cooling helmets, a water immersion configuration, and radiation exposure. The standard also performed retention tests which evaluate the helmet's ability to stay on participants. Overall, the standard provides many useful and important evaluation processes; however, advances in impact testing could provide more information and an improved characterization of the helmet impact response.

Linear and Rotational Head Acceleration Components: The whitewater helmet standard is like most historical helmet standards in that the impact test only evaluates linear acceleration (EN 1385: 2012). However, both linear and rotational acceleration occur during head impacts, and many researchers have demonstrated the importance of rotational acceleration relative to brain injury. An example of such researchers is Dr. Post and his colleagues at the Neurotrauma Impact Science Laboratory at the University of Ottawa. By using computational models of the

brain, Dr. Post and his research team have shown that rotational acceleration increases the amount of brain deformation (Post, et al., 2013). Recently, helmet testing devices and standards have been created to evaluate both linear and rotational accelerations by the National Operating Committee on Standards for Athletic Equipment (NOCSAE), the National Football League (NFL), and the Virginia Tech STAR helmet rating systems (Bailey, et al., 2020; Pellman, et al., 2006; Bland, et al., 2019; Campolettano, et al., 2020). New algorithms have been created to calculate injury risk from these new tests. For example, the combined probability of injury equations determines risk of concussion by analyzing the peak linear and rotational accelerations (Rowson & Duma, 2013). By lowering both linear and rotational acceleration in laboratory tests, it has been shown that brain injury risk is lowered in real-world head impact events (Rowson, et al., 2014; Bailey, et al., 2020). Given the serious head injuries observed in whitewater sports, both linear and rotational acceleration measures should be analyzed when evaluating the biomechanical performance of whitewater helmets (Schoen & Stanto, 2002).

STAR Helmet Evaluation System: A new helmet evaluation system has been developed by leading researchers at the Virginia Tech helmet lab, who have been testing helmets in a multitude of sports for the past ten years (Rowson & Duma, 2011; Rowson, et al., 2015; Bland, et al., 2019). This method they created combines extensive impact testing that includes the use of an injury risk function as well as exposure data to generate a complete summary of the helmet performance (Rowson & Duma, 2011). This system is called the Summation of Tests for the Analysis of Risk (STAR). For most sports, the system uses the medium NOCSAE headform mounted on a Hybrid III neck. Instrumentation inside the headform measures linear acceleration and rotational velocity, and the latter is used to determine rotational acceleration. Impact tests are performed at a range of impact locations and energy levels that include both centric and non-centric impact directions. For each impact test, the peak linear and rotational acceleration values are inserted into a brain injury risk function, and that risk is multiplied by exposure to get an overall incidence number (Rowson & Duma, 2013). The STAR equation aggregates all of this data into one number that is used to set the helmet ratings STAR value, with five stars indicating the best available protection. Helmets with higher star ratings do a better job of managing the impact energy and ultimately lowering the linear and rotational acceleration values the head would experience for a given impact. The STAR rating system has been utilized for

many sports, such as hockey, soccer, cycling, football, youth football, and flag football (Rowson & Duma, 2011; Rowson, et al., 2015; Bland, et al., 2019; Campolettano, et al., 2020). The appeal of the STAR system is that it clearly differentiates complex helmet performance into usable information for consumers. Moreover, on-field studies have shown brain injury reduction rates in athletes who wear higher rated helmets (Rowson, et al., 2014; Bailey, et al., 2020).

Objectives: There are serious head injuries in whitewater sports and the current standard of testing is very limited. An advanced whitewater helmet rating system is needed to help improve product design and reduce injury risk. The current standard of testing for whitewater helmets provides important evaluation of the helmet's retention and durability, but the impact tests are limited. The maximum head acceleration limit of 250 g in the drop test is very high for a relatively low 15 J impact event. Also, rotational acceleration should be taken into consideration for this standard, because both linear and rotational acceleration are proven to contribute to head injuries like concussions (Post, et al., 2013). As of now, the consumer has no information to differentiate between helmets that have passed the standard, so a publicly available rating system for these helmets is necessary. This new rating system will facilitate the purchase and use of more protective helmets which could decrease the amount of head injuries in whitewater activities. The objective of this study is to create a rating system for whitewater helmets by evaluating the biomechanical performance and risk of head injury of whitewater helmets using the STAR system.

Methods and Materials

A total of 21 helmet models were purchased from five different manufacturers (Table 1). Two samples of each helmet were purchased for testing for a total test matrix of 42 helmets. The watersport helmets that were chosen for this study were required to be clearly marketed for whitewater use. This was determined through each manufacturer's website and helmet descriptions. The size of each helmet purchased was chosen to match the circumference of the medium NOCSAE head form of 57.6 cm. If two of the sizes for a given helmet overlapped across this value, the larger helmet was chosen. The price and mass of each helmet were recorded before experimentation.

Manufacturer	Helmet Model	Price ($)	Mass (g)	Legend
Shred Ready	Fullface Whitewater Helmet	149.95	705	FF
Shred Ready	Outfitter Pro Helmet	49.00	360	O
Shred Ready	Shaggy Helmet	179.95	535	SH
Shred Ready	SESH Helmet	54.95	495	SE
Shred Ready	Halfcut Whitewater Helmet	99.95	505	H
Shred Ready	Fullcut Whitewater Helmet	110.00	585	FC
Shred Ready	Super Scrappy Whitewater Helmet	89.95	485	SS
WRSI	Trident Composite	199.95	565	T
WRSI	Moment Fullface	179.95	805	M
WRSI	Current Pro	139.95	715	CP
WRSI	Current	119.95	595	C
NRS	Chaos Side Cut Helmet	79.95	565	CS
NRS	Chaos Full Cut Helmet	69.95	510	CF
NRS	Havoc Livery Helmet	49.95	420	HL
Sweet Protection	Rocker Fullface Helmet	329.95	730	RF
Sweet Protection	Rocker Helmet	229.95	530	R
Sweet Protection	Strutter Helmet	199.95	515	ST
Sweet Protection	Wanderer Helmet	149.95	580	W
Sweet Protection	Sweet Rocker - Dagger Edition	259.99	530	SR
Gath	Gath Gedi	189.00	430	G
Gath	Gath RV	209.00	550	RV

Table 1: All 21 helmet models purchased for testing with their respective price and weight.

Every helmet used in this study was certified to the EN: 1385: whitewater helmet standard. This ensures that regardless of the outcomes of this research, the helmets still passed the range of basic safety tests included in the standard. This is consistent with previous studies conducted in other sports that benchmarked all helmets tested to other available standards. For example, all football helmets rated have passed the NOCSAE standard (Rowson & Duma, 2011), all hockey helmets rated have passed the Hockey Equipment Certification Council (HECC) standard (Rowson, et al., 2015), and all bicycle helmets rated have passed the Consumer Product Safety Commission (CPSC) standard (Bland, et al., 2019).

A custom pendulum impactor was used to test the helmets under conditions simulating the highest risk of head injury in whitewater kayaking and rafting (Figure 2). The pendulum consists of an arm, pivot point, and an impactor surface. The pendulum provides an extremely repeatable system with an arm composed of 10.16 x 5.8 cm rectangular aluminum tubing and a 16.3 kg

impacting mass at its end. The length of the arm from the center of its pivot point to the center of its impacting mass is 190.5 cm. The pendulum arm has a total mass of 36.3 kg and a moment of inertia of 72 kg m^2. The impactor face is constructed of nylon and has a diameter of 20.3 cm and a radius of curvature of 12.7 cm. This contact surface is designed to mimic a rock or other rigid surface a whitewater participant might impact, while also maximizing repeatability and reproducibility of the tests.

Figure 2: The front impact condition is shown on the right with the pendulum system.

The headform was connected to the data acquisition system to the left of the device. The pendulum impactor arm was elevated by using a winch system fixed to an electromagnet that could hold or release the pendulum arm. The height of the pendulum head corresponded to either the 3.1 m/s impact speed or the 4.9 m/s impact speed. This speed was determined by the angle of the pendulum arm. An angle of 30 degrees correlated to a 3.1 m/s impact speed and an angle of 60 degrees correlated to a 4.9 m/s impact speed. The impact speed was validated using a speedometer positioned directly before the impact site.

Each whitewater helmet was positioned on a medium NOCSAE headform according to each helmet's respective manufacturer fitting guidelines. The NOCSAE headform was utilized because its shape allows for a very realistic fit between the helmet and headform. The headform was mounted to a Hybrid III 50th percentile neck using a custom adapter plate that provided the anatomically accurate relative locations of the occipital condyle pin and headform center of gravity (CG). The mass of the adaptor plate was made to be equal to the material removed for this modification. The head and neck assembly was mounted on a sliding mass that was designed to simulate the effective mass of the torso during a head impact, thus providing the best biofidelic impact configuration. This sliding mass was mounted to an adjustable table commonly used for impact testing (Biokinetics, Ottawa, Ontario, Canada). In contrast to most standard certification tests, this pendulum system allows and accounts for linear and rotational motion.

To measure the head impact kinematics, the headform was instrumented with a six degree of freedom sensor package consisting of three accelerometers and three angular rate sensors (6DX-Pro, DTS, Seal Beach, CA). Data was sampled at 20,000 Hz and filtered using a 4-pole Butterworth low pass filter according to SAE J211, with a cutoff frequency of 1650 Hz (CFC 1000) for accelerometer data and 256 Hz (CFC 155) for angular rate sensor data. The angular acceleration values were determined by differentiating the angular rate data. Resultant values were calculated for linear (g) and rotational (rad/sec^2) acceleration.

Six impact configurations were used to test the helmets. These configurations were defined by three different impact locations at two different speeds. The front, side, and rear helmet sites were impacted to cover the range of the possible impact locations for a whitewater helmet (Figure 3). Two impact speeds of 3.1 m/s and 4.9 m/s were selected to replicate a medium and high impact. The velocity of 4.9 m/s was chosen as the high impact speed because the highest recorded flow rate of a river is 5 m/s (EN 1385: 2012). Each helmet was only impacted once at each site to ensure that any deformation caused by testing did not affect any future tests.This resulted in six tests per helmet model for a total test matrix of 127 tests. The laboratory's mandatory safety guidelines were followed for each test. These guidelines included safety lockout procedures to ensure the safety of all participants involved.

Figure 3: Front (left), side (middle), and rear (right) impact conditions.

Similar to previous STAR systems in other sports, each helmet's STAR value was calculated using the resultant linear and rotational acceleration for each respective test (Equation 1). For this equation, E represents exposure; L represents the impact locations; V represents the impact velocity; and R represents the risk of concussion defined by the linear (a) and angular (α) head acceleration for each configuration.

$$\textbf{Whitewater STAR} = \sum_{L=1}^{3} \sum_{V=1}^{2} E(L, V) * R(a, \alpha) \quad Eq. 1$$

The risk of concussion for a given test was calculated through the risk function using the resultant linear and rotational head accelerations observed (Equation 2). The risk function used in this equation includes both linear and rotational head acceleration because they are both correlated and predictive of concussion (Rowson & Duma, 2013). This function was developed from high school and collegiate football head acceleration data. A multivariate logistic regression analysis modeled risk as a function of linear and angular head acceleration. The validity of this function was confirmed using the National Football League (NFL) head impact reconstructions in addition to the impacts used to generate the function. Using this risk function enhances the data analysis by increasing the importance of the higher acceleration impacts. Once the risk is calculated, the risk is then multiplied by the exposure for a given configuration. Exposure is equivalent to one for whitewater activities because participants typically only undergo one major head impact annually (Spittler, et al., 2020). This is done for each testing configuration, and each value is then summated together to create the STAR value. The STAR

value for each helmet is then used to determine its STAR rating. It is important to note that the STAR value is different from the star rating. Lower STAR values represent a lower risk of concussion and are then assigned to higher star ratings. The star rating ranges up to five stars for the best available helmets. Consumers are familiar with the star ratings.

$$R(a,\alpha) = \frac{1}{1 + e^{-(-10.2 + 0.0433 * a + 0.000873 * a - 0.000000920 * a\alpha)}} \quad Eq.\ 2$$

Results

Higher linear acceleration values were observed for the front impact conditions, and higher rotational acceleration values were observed for the side impact conditions. The linear regression relating linear and rotational acceleration was strongly correlated (r^2=0.71). However, there was a low correlation between helmet price and STAR value (r^2=0.11), and there was also a low correlation between helmet mass and STAR value (r^2=0.03).

In the 3.1 m/s front impact condition the 21 helmeted tests resulted in a range of 30.2 –

131.2 g, and 1601 - 5036 rad/sec^2. In the 4.9 m/s front impact condition the 21 helmeted tests resulted in a range of 82.0 – 282.5 g, and 4024 - 13069 rad/sec^2 (Figures 4 and 5).

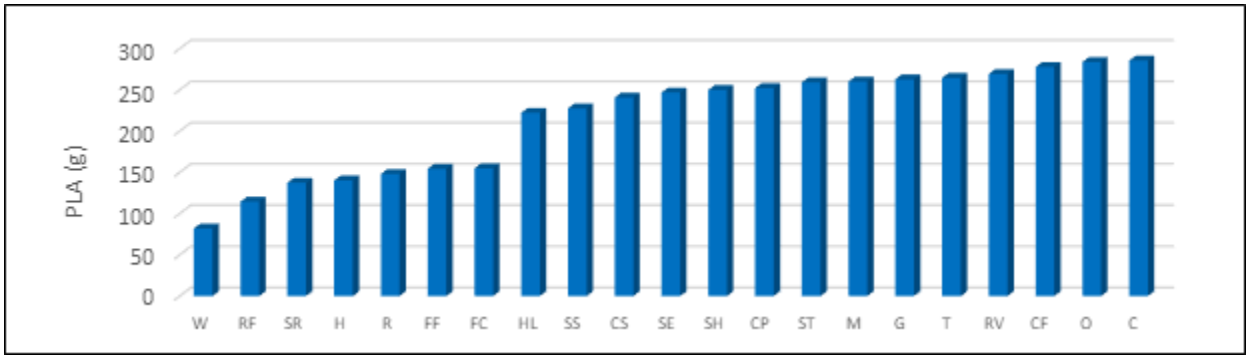


Figure 4: Peak resultant linear (PLA) head acceleration values (g) for the high speed of 4.9 m/s in the front impact direction. Sorted lowest to highest.

In the 3.1 m/s side impact condition the 21 helmeted tests resulted in a range of 35.7 – 129.7 g, and 2500 - 3678 rad/sec^2. In the 4.9 m/s side impact condition the 21 helmeted tests resulted in a range of 88.1 – 316.4 g, and 5609 - 24563 rad/sec^2.

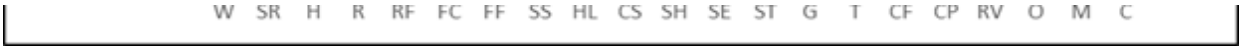


Figure 5: Peak resultant rotational (PRA) head acceleration values (rad/sec^2) for the 4.9 m/s front impact condition. Sorted lowest to highest.

In the 4.9 m/s rear impact condition the 21 helmeted tests resulted in a range of 82.9 – 332.0 g, and 3336 - 14381 rad/sec^2. The helmets' STAR values resulted in a range of 0.2518 - 4.8634 (Figure 6).

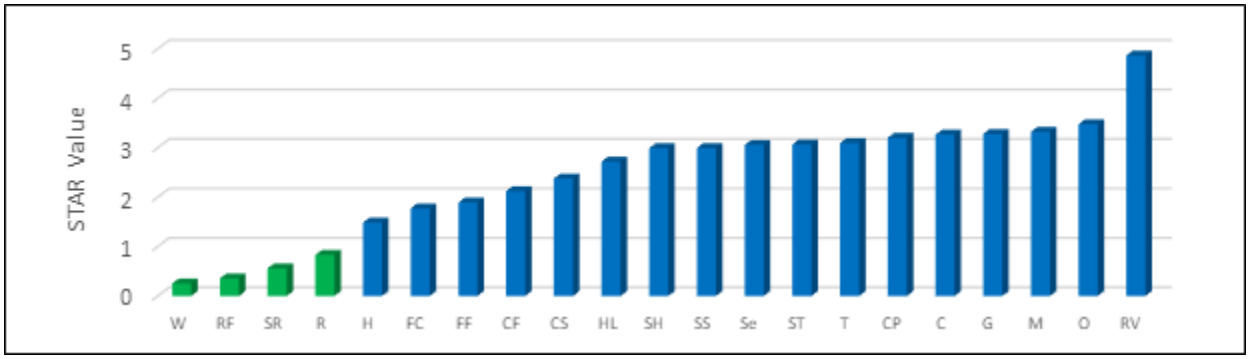


Figure 6: STAR values for each helmet with lower values indicating lower risk of concussion.

Discussion and Conclusions

The majority of the whitewater helmets performed poorly given that the STAR values observed for the helmets indicate an extremely high probability of concussion for each impact (Figure 6). The helmets should reduce head accelerations by a far greater margin for lower concussion risks (Figures 4 and 5). For example, the STAR values over three indicate that for the six impact conditions over three concussions would be predicted. In contrast, the best helmets can reduce this value below one. In order to provide a useful tool for consumers to make informed decisions, the STAR values for each helmet were used to create the star rating from five stars for the best helmet to one star for the lowest performing helmets (Table 2 and Figure 6). This is similar to how automobiles are rated up to five stars for consumers to easily understand the safety

performance (Hershman, 2001). For this study, STAR values below 1.0 were assigned the highest five star rating as they indicate less than one concussion for all six impact conditions. STAR values between 1.0 and 2.0 were assigned four stars, and STAR values of 2.0 to 3.0 were divided between the three and two and one star ratings. Below the one star rating is the "not recommended" category, which means that the helmets performed so poorly that they are not recommended for purchase. The "not recommended" helmets have STAR values above 3.0, indicating a very high risk of concussion in over half of the six impact conditions.

Manufacturer	Helmet Model	Price ($)	STAR Value	Rating
Sweet Protection	Wanderer Helmet	149.95	0.25	5
Sweet Protection	Rocker Fullface Helmet	329.95	0.36	5
Sweet Protection	Sweet Rocker - Dagger Edition	259.99	0.56	5
Shred Ready	Rocker Helmet	229.95	0.83	5
Shred Ready	Halfcut Whitewater Helmet	99.95	1.49	4
Shred Ready	Fullcut Whitewater Helmet	110.00	1.77	4
Shred Ready	Fullface Whitewater Helmet	149.95	1.89	4
NRS	Chaos Full Cut Helmet	69.95	2.12	3
NRS	Chaos Side Cut Helmet	79.95	2.38	3
NRS	Havoc Livery Helmet	49.95	2.72	2
Shred Ready	Shaggy Helmet	179.95	2.99	1
Shred Ready	Super Scrappy Helmet	89.95	2.99	1
Shred Ready	SESH Helmet	54.95	3.06	N.R.*
Sweet Protection	Strutter Helmet	199.95	3.06	N.R.*
WRSI	Trident Composite	199.95	3.10	N.R.*

WRSI	Current Pro	139.95	3.20	N.R.*
WRSI	Current	119.95	3.26	N.R.*
Gath	Gath Gedi	189.00	3.28	N.R.*
WRSI	Moment Fullface	179.95	3.32	N.R.*
Shred Ready	Outfitter Pro Helmet	49.00	3.48	N.R.*
Gath	Gath RV	209.00	4.86	N.R.*

Table 2: All 21 helmet models related to their respective price, STAR value, and star rating.

***N.R. stands for Not Recommended.**

Higher acceleration values for both linear and rotational acceleration were observed at higher impact speeds, with linear and rotational acceleration being strongly correlated (r^2 =0.72). Linear acceleration was observed to be higher in the front impact conditions, whereas rotational acceleration was observed to be higher in the side condition. A possible cause for this observation is the difference in centric and non-centric aspects for each impact location.

Helmet performance did not correlate well with other factors such as weight (r^2=0.03) and price (r^2=0.11). This highlights the necessity of a helmet rating system, because consumers cannot always use these factors as an indication of helmet performance. Moreover, all five of the manufacturers produced helmets that performed in the lowest "not recommended" category, while only one of the manufacturers, Sweet Protection, produced five star rated helmets.

These results are similar to what was observed with hockey helmets given that both whitewater helmets and hockey helmets performed very poorly on average (Rowson, et al., 2015). In contrast, other sports such as football have helmets that are all very high performing (Rowson & Duma, 2011). The whitewater helmets should reduce the head impact accelerations much more across all helmets. One method to accomplish this would be to mirror some of the technologies utilized to design the newer and more advanced football helmets (Bailey, et al., 2020).

A limitation of this study is that only one size of helmet was tested. This assumes that performance is consistent throughout each size of helmet. However, there still could be deviation in performance as size increases or decreases. An additional limitation of this study is the assumption that there is no difference in male and female injury response by using one metric for both sexes (Solomito, et al., 2019). Future research could include testing with different sized helmets as well as considerations for potential concussion risk differences between males and females.

Literature Cited

Peer Reviewed and Scholarly References:

Bailey, A. M., McMurry, T. L., Cormier, J.M., Funk, J.R., Crandall, J.R., Mack, C.D., Myers, B.S., & Arbogast, K.B. (2020). Comparison of laboratory AND On-field performance of American football helmets. *Annals of Biomedical Engineering, 48*(11), 2531-2541. doi:10.1007/s10439-020-02627-5

Bland, M. L., McNally, C., Zuby, D. S., Mueller, B. C., & Rowson, S. (2019). Development of the star evaluation system for assessing bicycle helmet protective performance. *Annals of Biomedical Engineering, 48*(1), 47-57. doi:10.1007/s10439-019-02330-0

Campolettano, E. T., Gellner, R. A., Sproule, D. W., Begonia, M. T., & Rowson, S. (2020). Quantifying youth football helmet performance: Assessing linear and rotational head acceleration. *Annals of Biomedical Engineering, 48*(6), 1640-1650. doi:10.1007/s10439-020-02505-0

Hershman, L.L., (2001). The U.S. new car assessment program (NCAP): past, present and future.

***International Technical Conference on Enhanced Safety of Vehicles,* Paper Number 2001-06-0245.**

Pellman, E. J., Viano, D. C., Withnall, C., Shewchenko, N., Bir, C. A., & Halstead, P. D. (2006). Concussion in professional football: Helmet testing to assess impact performance—part 11. *Neurosurgery, 58*(1), 78-95. doi:10.1227/01.neu.0000196265.35238.7c

Post, A., Oeur, A., Hoshizaki, B., & Gilchrist, M. D. (2013). Examination of the relationship between peak linear and angular accelerations to brain deformation metrics in hockey helmet impacts. *Computer Methods in Biomechanics and Biomedical Engineering, 16*(5), 511-519. doi:10.1080/10255842.2011.627559

Rowson, B., Rowson, S., & Duma, S. M. (2015). Hockey star: A methodology for assessing the biomechanical performance of hockey helmets. *Annals of Biomedical Engineering, 43*(10), 2429-2443. doi:10.1007/s10439-015-1278-7

Rowson, S., & Duma, S. M. (2011). Development of the star evaluation system for football helmets: Integrating player head impact exposure and risk of concussion. *Annals of Biomedical Engineering, 39*(8), 2130-2140. doi:10.1007/s10439-011-0322-5

Rowson, S., & Duma, S. M. (2013). Brain injury prediction: Assessing the combined probability of concussion using linear and rotational head acceleration. *Annals of Biomedical Engineering, 41*(5), 873-882. doi:10.1007/s10439-012-0731-0

Rowson, S., Duma, S. M., Greenwald, R. M., Beckwith, J. G., Chu, J. J., Guskiewicz, K. M., Mihalik, J.P., Crisco, J.J., Wilcox, B.J., McAllister, T.W., Maerlender, A.C., Broglio, S.P., Schnebel, B., Anderson, S., & Brolinson, P. G. (2014). Can helmet design reduce the risk of concussion in football? *Journal of Neurosurgery, 120*(4), 919-922. doi:10.3171/2014 1.jns13916

Schoen, R. G., & Stano, M. J. (2002). Year 2000 Whitewater Injury Survey. *Wilderness & Environmental Medicine, 13*(2), 119-124.

doi:10.1580/1080-6032(2002)013[0119:ywis]2 0.co;2

Solomito, M.J., Reuman, H., Wang, D.H. (2019). Sex differences in concussion: a

review of brain anatomy, function, and biomechanical response to impact. *Brain Injury,* 33(2), 105-110. doi.org/10.1080/02699052.2018.1542507

Spittler, J., Gillum, R., & DeSanto, K. (2020). Common injuries in whitewater rafting, kayaking, canoeing, and stand-up paddle boarding. *Current Sports Medicine Reports, 19*(10),

422-429. doi:10.1249/jsr.0000000000000763

Non Peer Reviewed References:

EN 1385: 2012 (2013) Helmets for canoeing and whitewater sports. *BSI Standards Publication*. Whitewater Photography. [Digital image]. Retrieved from https://adventuresonthegorge.com/

ERTLE THOMPSON MEMORIAL ENDOWMENT AWARD

The Ertle Thompson Memorial Endowment Award is established to honor Dr. Ertle Thompson, a long-term leader of VJAS and a former president of the VAS. When financial circumstances allow, these awards will be presented annually to the winners selected as the VJAS Delegates to the AJAS. The purpose of the funds is to help support attendance at the annual meeting of the American Association for the Advancement of Science and the American Junior Academy of Science.

Winner Meenakshi Ambati (11)

Identification of Fluoxetine as a direct NLRP3 inhibitor to treat atrophic macular degeneration: Molecular modeling, mechanism, morphometry, and meta- analysis(Year 2)
Albemarle High School

Cameron Sharma (11)

Winner

The Effect of Surface Dynamics on Atmospheric Water Harvesting
Mills E. Godwin High School

DR. R. DEAN DECKER HONORARIUM AWARD

The Dr. R. Dean Decker Honorarium award this year of $500 each is to go to the teacher/sponsor of the two top student winners of the AJAS trip. The monies can be used at the discretion of the recipients as long as it is related to the attendance at the AJAS meeting. Guidelines and procedures for the recipients will follow later.

Winner Dr. Bradley Gelfand

Winner Heather Martin

AWARDS FOR SPONSORS

The VJAS Committee recognizes and presents these awards for teachers &sponsors.

THE FRANKLIN D. KIZER DISTINGUISHED SERVICE AWARD

This award recognizes the exceptional contributions to VJAS of a STEM teacher.

Dr. Michael J. Wolyniak, Hampden-Sydney College

THE FRANKLIN D. KIZER SCIENCE TEACHER OF TOMORROW AWARD

This award recognizes an outstanding Virginia science teacher and provides an opportunity for professional development through attendance at the annual VAST meeting.

Elizabeth Wood, Washington-Liberty High School

VJAS DISTINGUISHED SERVICE AWARD

A special certificate is presented to a person for exceptionally outstanding service tothe VJAS and public recognition is given at the Research Symposium. This is themost prestigious award that the VJAS Committee gives.

Dr. Joshua Erlich, The College of William & Mary