2019 FINALISTS

2019 Broadcom MASTERS

OCTOBER 25–30, 2019

Broadcom MASTERS® (Math, Applied Science, Technology and Engineering for Rising Stars), a program of Society for Science & the Public, is the premier middle school science and engineering research competition in the United States.

In the only middle school STEM competition leveraged through Society-affiliated fairs, the top ten percent of 6th, 7th and 8th grade projects around the nation are nominated to compete in the Broadcom MASTERS. The Top 300 Broadcom MASTERS are selected by scientists and engineers through blind scoring of their comprehensive online applications.

From the Top 300, 30 finalists are selected to present their research projects in Washington, DC, and compete in hands-on team STEM challenges that test their abilities in 21st Century skills — critical thinking, collaboration, communication and creativity — through project-based learning. Top awards include cash prizes, including the Samueli Foundation Prize of $25,000, STEM summer camps and more.

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- Parents, teachers and mentors of all the Broadcom MASTERS nominees in ~300 fairs

2019 Broadcom MASTERS Finalists

2019 TABLE OF CONTENTS

2019 Broadcom MASTERS Finalists

DAVID ANAND
Home School
Northeastern Ohio Science and Engineering Fair

MARY SHEA BALLANTINE
Saint Francis of Assisi Catholic School
Louisville Regional Science and Engineering Fair

RACHEL BERGEY
Home School
Delaware Valley Science Fairs

TYLER L. BISSOONDIAL
Grand Avenue Middle School
Long Island Science and Engineering Fair

BRIAN CHEN
The Harker School
California Science & Engineering Fair

SIDOR CLARE
Beehive Science & Technology Academy
University of Utah Science and Engineering Fair

WILLIAM WADE DANIEL
First Baptist Church School
Louisiana Region VII — Science and Engineering Fair

AUTRI A. DAS
Stoller Middle School
Beaverton-Hillsboro Science Expo

JOHAN DEMESSIE
Mason Middle School
State Science Day

RYAN EDWARD DRAKE
Rancho Christian School
Riverside County Science and Engineering Fair

ANNA DU
Andover School of Montessori
Massachusetts Region IV Science Fair

LAUREN U.C. EJIAGA
Lake Forest Charter
Greater New Orleans Science and Engineering Fair and Louisiana Science and Engineering Fair

PAULINE VICTORIA ALLASAS ESTRADA
Fugman Elementary School
Fresno County Science Fair

RYLAN LEE GARDNER
Franklin Junior High School
Arizona Science and Engineering Fair

ALAINA GASSLER
Avon Grove Charter School
Delaware Valley Science Fairs

HANNAH GUAN
BASIS San Antonio Shavano Campus
Alamo Regional Science and Engineering Fair

KASSIE HOLT
Beehive Science & Technology Academy
University of Utah Science and Engineering Fair

RISHAB KUMAR JAIN
Stoller Middle School
Beaverton-Hillsboro Science Expo and Intel Northwest Science Expo

ISABELLE SOPHIA KATZ
Joaquin Moraga Intermediate School
Contra Costa County Science and Engineering Fair

ALEXIS TEA MACAVOY
Crocker Middle School
San Mateo County Office of Education STEM Fair

GIANNA G. NILVO
School of Dreams Academy
Central New Mexico Regional Science and Engineering Challenge and New Mexico Science and Engineering Fair

RINOA JACQUELINE OLIVER
Georgiana Bruce Kirby Preparatory
Santa Cruz County Science and Engineering Fair

MADISON NICOLE PERKINS
Gilmer Intermediate School
East Texas Regional Science Fair

ASHWIN PRABHAKAR
Discovery Middle School
North Alabama Regional Science and Engineering Fair

MERCEDES RANDHAHN
Saint Joseph Catholic Middle School
University of Utah Science and Engineering Fair

HANNAH T. SHU
International School of Monterey
Monterey County Science and Engineering Fair

KYLE P. TIANSHI
The Cambridge School
Greater San Diego Science and Engineering Fair

SEANN RICHARD TORRES
Saint Adelaide Academy
San Bernadino, Inyo, Mono, (SIM) Science and Engineering Fair

GANESH VENU
Friendswood Junior High
Science Engineering Fair of Houston and Texas Science and Engineering Fair

RUHI YUSUF
Challenger School — Ardenwood
Golden Gate STEM Fair

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2019 Broadcom MASTERS Finalists

Why Middle School?

Broadcom MASTERS® is the premier science and engineering research competition for middle schoolers, where students demonstrate their mastery of **M**ath, **A**pplied **S**cience, **T**echnology and **E**ngineering as **R**ising **S**tars in STEM.

Participants in Broadcom MASTERS are inspired, mentored and encouraged to stay with math and science through high school and beyond so that they are prepared to pursue exciting STEM careers.

Students who participate in Broadcom MASTERS are better prepared through project-based learning to meet the challenges of the future as tomorrow's innovators. They will lead the way with scientific breakthroughs, engineering innovations and technological know-how.

Middle school students are invited to compete for awards and accolades in Broadcom MASTERS when competing at their local Society-affiliated science and engineering fair.

At the competition finals for Broadcom MASTERS in Washington, DC, students can win cash prizes and experiential awards. The top winner is awarded the $25,000 Samueli Foundation Prize.

The Process

To participate in Broadcom MASTERS, 6th, 7th and 8th grade students enter an independent science or engineering project in their Society-affiliated state or regional science fair. Judges select the top 10 percent of these competitors to enter the Broadcom MASTERS, of which thousands are named each year.

Nominees go online to complete the comprehensive Broadcom MASTERS application and the entries are scored by scientists, engineers and evaluators during the summer.

The Society announces the Top 300 Broadcom MASTERS late summer each year. The Top 300 and their teachers receive an educational prize in recognition of their achievements.

Thirty competitors are selected from the Top 300 to compete as Broadcom MASTERS finalists. Finalists receive an all-expense-paid trip to Washington, DC, to showcase their projects and compete in teams to demonstrate their STEM acumen and 21st Century skills. They also visit historical sites in the nation's capital that celebrate innovation.

Awards

Finalists receive a cash award of $500 from Broadcom Foundation in recognition of their advancement to the Broadcom MASTERS finals. Based on their performance over three days of competition, finalists may receive top awards. The following awards are presented:

- Samueli Foundation Prize of $25,000, which recognizes the top middle school student among the 30 finalists who demonstrates mastery of science, technology, engineering and math. He or she exemplifies how research, innovation and team work come together to achieve STEM goals.
- STEM Talent Award of $10,000, sponsored by DoD STEM, awarded to a finalist who demonstrates excellence in science, technology, engineering or math, along with the leadership and technical skills necessary to excel in the 21st Century STEM workforce and build a better community for tomorrow.
- Marconi/Samueli Award for Innovation of $10,000. This finalist demonstrates both vision and promise as an innovator, and ideally, in the spirit of radio inventor Guglielmo Marconi, has applied concepts from electrical engineering.
- Robert Wood Johnson Foundation Award for Health Advancement of $10,000, which recognizes the student whose work and performance show the most promise in health-related fields, and demonstrates an understanding of the many social factors that affect the health of communities.
- Lemelson Award for Invention of $10,000, awarded to a young inventor who exemplifies the ideals of inventive thinking by addressing a critical societal problem in order to improve the lives of others. He/she demonstrates the application of empathy, STEM knowledge, design thinking and an entrepreneurial mindset in the research and development of a tangible product.
- First and second place awards for students in each STEM discipline for nearly $30,000 in experiential or product awards for their ability and promise in each of these disciplines, including top awards in math from Robert John Floe, President, Floe Financial Partners.
- Rising Star Awards are presented by Broadcom Foundation to two 6th or 7th grade finalists who exemplify great promise and will represent the United States as delegates to the Broadcom MASTERS International, which brings together middle school delegates from around the world as student observers to the International Science and Engineering Fair in Anaheim, California in May 2020.
- The Top 300 Broadcom MASTERS receive special recognition through a gift from Jeff Glassman, CEO, Covington Capital Management.

Awards Honoring Finalists' Schools and Teachers

Broadcom Foundation and the Society recognize the important contributions of the teachers who educate, mentor and support Broadcom MASTERS competitors by awarding a gift of $1,000 to each of the 30 finalists' schools to be used for STEM programs and a classroom subscription to *Science News* magazine.

DAVID ANAND

Akron, Ohio | Age: 14

Monitoring Water Quality of the Yellow Creek Watershed Using Macro-Invertebrate Sampling and Automated Continuous Testing with a DIY Microcontroller for Physical and Chemical Measurements

Project Background: Yellow Creek is a stream near David's home in Ohio. Several months ago, he collected samples of macroinvertebrates from the creek. At that time, the news was good. The stream had a diverse and abundant mix of species. However, David worries about people's land use in the surrounding area. Runoff from roadways can increase the levels of salt and other pollutants. Rain and other precipitation can also wash fertilizer or other pollutants into the stream. Fertilizer run-off can feed harmful algae blooms. "Recent data indicates water quality is declining," David reports. Unfortunately, "there is no easy way to track water quality, except by volunteers taking manual periodic measurements," he says. He set out to find a better solution.

Tactics and Results: David designed a water quality monitoring kit called STREAM. That stands for Smart Technology for Reliable, Efficient Monitoring. "The goal was to automate collecting data," he explains. That way, there could be day-to-day information about stream conditions, and someone wouldn't have to go out into the field every day to get it. David built STREAM with micro-controllers and other parts. The system collects information about the water's pH, temperature and levels of dissolved oxygen. It also measures how well the water can conduct an electric current. That matters, because various pollutants can increase the levels of chemical ions. Road salt is one example. David tested his system at a spot along Yellow Creek. The results compared well with ones from a commercial sampling kit. David also checked how different conditions affect water quality. After precipitation, for example, the stream flow increased, and dissolved oxygen levels went up. However, conductivity levels rose the day after crews spread salt on nearby roads.

Other Interests: "I want to be an astronaut," David reports. His dream is to explore Mars and elsewhere in space. "It is the last frontier," he says. David is getting a jump on some skills by taking part in a local Civil Air Patrol program. Aside from that, he plays the viola with the Akron Youth Philharmonic Orchestra. David also enjoys a variety of sports, including soccer, basketball, running and swimming.

MARY SHEA BALLANTINE

Louisville, Kentucky | Age: 13

Automotive Exhaust: Creating a Selective Environment for Bacteria

Project Background: One day Mary Shea and her mom were out driving. Another car pulled in front of them and she noticed that people on the side of the road were breathing in that car's exhaust. "That made me wonder what that was doing to their lungs," she says. More specifically, she wondered how car exhaust might affect someone's respiratory microbiome. A microbiome is the whole group of microorganisms — bacteria, viruses, fungi and more — that make their homes in and on a person or other animal's body. In this case, Mary Shea wondered about the car exhaust's effects on the group of microbes in people's lungs and the rest of their respiratory system.

Tactics and Results: Mary Shea tested what automobile exhaust would do to three types of bacteria. She collected car exhaust through a flexible tube that fed into a flask with water. She then put some of the exhaust media into tubes with the different types of bacteria. Those bacteria all grew more slowly than control groups that had not been exposed to car exhaust. Additional tests showed that the effect on the bacteria's growth depended on the dose. In this case the dosage was the concentration of car exhaust. Yet another experiment showed that the exhaust made it harder for two of the three types of bacteria to move. Mary Shea also tested how bacteria exposed to car exhaust would respond to antibiotics. Two types of bacteria were better able to resist one type of antibiotic. And all three types were slightly better able to resist another antibiotic. Car exhaust negatively affects the respiratory microbiome, Mary Shea concluded. And it creates a selective environment for harmful, drug-resistant bacteria as well, she says.

Other Interests: "I really enjoy tap dancing because I have to focus very hard on combining lots of movements, and I have met a lot of new dancers," Mary Shea says. She's also active in basketball, swimming and art club. "I would really love to study forensic pathology," she says. As she sees it, a job in that field would let her help solve mysteries about what caused people's deaths.

RACHEL BERGEY

Harleysville, Pennsylvania | Age: 14

Spotted Lanternflies: Stick'em or Trick'em?

Project Background: "Spotted Lanternflies are most likely the largest economic threat facing Pennsylvania today, and thousands of them have invaded my family's maple trees," says Rachel. The invasive species originally came from China, Bangladesh and Vietnam. The insects can cause oozing sap, leaf curling, wilting and dieback on trees. One way to try to trap the pests is with yellow sticky bands around trees. However, that strategy has weaknesses. Tape has a limited surface area and needs frequent replacement. Some Spotted Lanternflies can jump off the tape, and the tape can catch and kill helpful insects and even birds. "I thought there must be a better way to combat this invasive species," Rachel says.

Tactics and Results: Rachel designed her own Spotted Lanternfly traps with tinfoil and netting. As the insects climb up the tree, they come to a tinfoil dome that wraps around the tree. A small tunnel at the top leads into a bag made from netting. Once inside, the insects are trapped. Rachel set up some of her traps on maple trees. As a variation, she painted parts of some tree trunks white. She also tested a BugBarrier tree band for cankerworms and gypsy moths. And she compared all the traps' performance to the yellow sticky tape that's commonly used to trap the pests. For two weeks, Rachel counted more than 3,000 Spotted Lanternflies that built up in or on each trap. "The tinfoil and netting trap without paint caught 103 percent more Spotted Lanternflies and 94 percent less other insects" than the yellow sticky tape control, she reports. And the trap is environmentally friendly. "It does not use chemicals, it saves other insects and it is reusable," she says.

Other Interests: "One of the things I love most is fishing!" Rachel says. "I love spending time in the great outdoors and appreciating natural bodies of water." She enjoys skating, skiing, hiking, basketball and gymnastics. She also sings in choir and plays the piano, violin, guitar and recorder. "I want to be a pharmacist because it would give me a great opportunity to help people get better," she says.

TYLER L. BISSOONDIAL

Bellmore, New York | Age: 14

Identification and Characterization of Salt-Tolerant (stl) Mutants in Raphanus sativus

Project Background: Hurricanes and high tides bring frequent flooding to areas near Tyler's home on Long Island. The waters leave salt on soils. Too much salt can kill crops and other plants. Stress from salt can also affect little bits of genetic matter in plant cells. Those hairpin-shaped bits are made of single-strand ribonucleic acid, or RNA, which help govern how cells express genes. Last year, Tyler did a research project on the role of those RNA bits in a certain type of fern when it was stressed by salt. This year he continued his research on plants and salt stress. "This project led to discovery of strains of radishes that can grow in high salt," he says.

Tactics and Results: Tyler knew that exposure to radiation can lead to mutations in cells. He wondered if exposure of seeds to a radioactive form of cobalt could trigger genetic changes. And he wondered if at least one of those changes might produce a salt-tolerant radish. First, he grew some regular radish seeds with distilled water and some with different salt solutions. He found a salt concentration that restricts normal seed germination and growth. He then tried to sprout radish seeds in that solution. The control group had wild-type radish seeds. He also tried sprouting some radish seeds that had been exposed to radiation from cobalt-60. "Of the 1,000 seeds, only three seedlings developed," Tyler says. He grew those seedlings indoors and then planted them outside. Only one of the plants produced seed pods. Tyler harvested the seeds. Then he tested if they would grow with salt solution. Compared to wild-type radishes grown under salt stress, his mutant plants had more proteins and more chlorophyll.

Other Interests: "I enjoy playing the viola because it helps me think, and it develops my hand-eye coordination and expression," Tyler says. He loves playing at concert halls with the Metropolitan Youth Orchestra and other groups. Tyler plays the bagpipe as well. His sports and other activities include track, art club, computer club, robotics, student council and yearbook. Tyler hopes to become a biologist. "Humans and other organisms face many threats like climate change and pollution," he says. "It is important to understand how organisms respond to these changes at all levels."

BRIAN CHEN

San Jose, California | Age: 14

Validating Novel Algorithm-Generated Crop Rotations to Combat Nutrient Depletion: A Second Year Study

Project Background: Nutrient levels in soil go down if farmers plant the same crops year after year in the same field. For that reason, most farmers rotate the crops they grow over a span of several years. Brian knew about the practice because his grandmother has done farming. He wondered how to make the process better. Last year, he used the programming platform C++ to design an algorithm that could suggest crop rotations based on which nutrients a plant consumes and which ones it might produce. "By checking if Plant A produced any nutrients Plant B needed, the algorithm linked different plants together to form a crop rotation." This year, he tested how well his algorithm's suggestions would work in practice.

Tactics and Results: Brian's first test sequence planted corn, then alfalfa, then wheat and then corn again. The second sequence was the same, except it added banana peel to the first planting of corn. The third rotation went from cabbage to peas, garlic, and then cabbage again. Control groups for each sequence had the same crop grown four times in a row. Brian grew each crop for 30 days. Then he compared the fourth round of each planting to the first round. He also compared the last round of rotated crops to the last round of the control groups. His rotation for corn, alfalfa and wheat without the banana peels did significantly better than the control. More seeds germinated in the last round, and those corn plants grew about 30 percent higher than the last round of the control group. The rotation with banana peels did poorly because of a mold problem. There wasn't a significant difference in cabbage growth from the rotation. The results show the algorithm can help in some cases, Brian concludes.

Other Interests: "Playing tennis for eight years has taught me that having a positive mindset will always benefit me, especially when facing a challenge," Brian says. His other athletic activities include basketball, swimming, running and hip hop dance. He plays the piano and violin and is on his school's robotics team, yearbook, computer club and student council. He hopes to become an astrophysicist.

SIDOR CLARE

Sandy, Utah | Age: 14

Bound and Bricked

Project Background: Humans might one day build a base to live in on Mars. But transporting building materials there would take months and cost huge amounts of money. The whole process could go quicker and might cost less if bricks could be made there with the soil, or regolith, on Mars. Sidor and her partner, Kassie Holt, set out to make bricks with material like that found on Mars. They also explored how to make binders that could keep the bricks together. They wanted to make sure their bricks would be durable and reliable. After all, Mars has a harsh environment, so buildings would need to be sturdy!

Tactics and Results: The girls used a soil mix known as Mars Global Simulant MGS-1. It has chemical and mechanical properties like the soil on Mars. The girls tried different binders to hold their bricks together: polyester resin, polystyrene, and recycled high density polyethylene, or HDPE. They made their resin brick by adding resin to the soil mix. For the HDPE bricks, they used melted bits of plastic from a bucket. For polystyrene bricks, the girls used two methods to mix the plastic with acetone and the soil mix. Some other tries at brickmaking failed. But the girls had enough to head to the lab at a community college. The compression tester there had a computer and multiple cameras hooked up to it. The equipment let the girls track how much pressure the bricks could withstand. The polyester resin brick was the strongest. "Our Mars resin brick can withstand more pressure than concrete," Sidor says.

Other Interests: "Rock climbing is unquestionably one of the highlights of my week," Sidor says. "It feels really good when I finish a hard route knowing I persevered and figured out how to get past the hard part of the climb." Sidor is an active Cadette in Girl Scouts and participates in Girls Who Code. She plays both the guitar and ukulele. She hopes to become a nutritionist. "Learning how nutrients and macromolecules are used in our body, as well as how a person's diet affects their health, is something that really fascinates me," says Sidor.

WILLIAM WADE DANIEL

Shreveport, Louisiana | Age: 13

The Aphid Wolf, A Cold-Blooded Killer

Project Background: "I've always found the natural world to be full of fascinating things," Wade says. At first, he wanted to do a project on antlions, also known as doodle bugs. Then he did background research and learned about a related insect known as the aphid wolf. It's the larval form of the lacewing, and it's a sneaky predator. The insects use their prey's dead corpses as camouflage when they go hunting, Wade explains. In that way, "they infiltrate aphid colonies that are protected by ants." The aphid wolf tends to prefer aphids for food. However, it's also been known to eat other kinds of insects — more than 100 per day. Wade wondered how far the aphid wolf might venture if aphids weren't handy to eat.

Tactics and Results: Wade distributed lacewing eggs in two rose bush areas. One had previously been treated with pesticide pellets to get rid of any aphids. The other area was a neighbor's untreated roses, which were infested with aphids. Wade let the eggs hatch in each area. Then a few days after the aphid wolves' second molt, he collected specimens. He used tweezers, dissecting tools and a microscope to remove and examine the aphid wolves' debris casings. Wade had thought the larvae in the treated area would have gone outside their initial area to find food. To his surprise, there was little evidence of that. Instead, most of their debris casings were hollow carcasses of other aphid wolves. Faced with a lack of food, the insects had become cannibals. Wade thinks the unexpected outcome of his study could help farmers who use lacewing larvae to help control pests. The results suggest farmers should take time to distribute eggs evenly over their entire fields of crops, he says.

Other Interests: Wade hopes to become an aeronautical engineer. "I love to study engine design and wing design and their effects on lift and performance," he says. And he ranks flying lessons as his favorite activity. "I like the feeling of being free and in the air," he says. Wade also likes to ride horses. "I have enjoyed mastering trotting, cantering and jumping," he says. He also does track and cross-country and plays the trombone.

AUTRI A. DAS

Portland, Oregon | Age: 12

Electrochemical Reduction of Carbon Dioxide with Microwave Treated Electrocatalyst

Project Background: "My inspiration for this project was first triggered last time when I visited Bangladesh," Autri says. "A severe flood affected all areas across the country, especially the coastal regions near the Bay of Bengal." Climate change is causing more flooding in the area, she learned. Autri says weather patterns are also changing in the area around her home in Oregon. "Carbon dioxide is one of the biggest contributors to global warming," she notes. One way to treat carbon dioxide is to convert it into other hydrocarbons, which can then be used for fuel. However, current processes tend to use expensive metal catalysts. Autri set out to find other choices that would be less expensive and more environmentally friendly.

Tactics and Results: Autri made three test catalysts from different sources of carbon. One had ground-up tea leaves, another used charcoal powder and the third used coconut shell in an ash form. To make them work better, she added tiny amounts of, or doped, each material with nitrogen. The nitrogen came from melamine, a chemical in many plastics. Autri mixed her carbon and nitrogen materials and exposed them to microwave energy. To test each catalyst, she set up a basic electrolysis cell with a battery and water. She saturated the water with carbon dioxide. Then she let the process run. As carbon dioxide levels went down, a color indicator in the solution would change from yellow to green and then to blue. As a control, Autri also ran her test with a copper sulfate catalyst. Autri's most efficient catalyst was the one made from coconut shells. It reduced carbon dioxide by 98 percent and performed about as well as metal catalysts.

Other Interests: "I enjoy dancing in the style Bharatanatyam," Autri says. That's a type of Indian classical dance, she explains, and each dance tells a story. "Moreover, it is a symbol of my heritage to connect to," she says. Autri plays the flute and violin. She also volunteers with the Portland Food Project. She hopes to become an imagineer. She especially likes how the career can combine different aspects of science, engineering, technology and math.

JOHAN DEMESSIE

Mason, Ohio | Age: 14

Salt-Stain Effect for a Rapid, Low-Cost Analysis of Drinking Water

Project Background: When Johan visited his grandparents in Ethiopia, he noticed that many of the local people have yellowed teeth. "The stain was the result of excessively high concentrations of fluoride in the drinking water," he explains. Johan also learned that the town's water supply was "hard," meaning the water had a variety of dissolved salts in it. "Although many of these salts are vital at low concentrations, elevated levels of salts and hardness are toxic," Johan notes. He wondered if there was a way to determine the salt levels in drinking water without having to send samples out to a laboratory. That method could be helpful for people in low-income countries, he mused.

Tactics and Results: Johan focused on the way salts in water form crystals as droplets dry. The crystals would leave a stain pattern on a surface, he reasoned, and those patterns might let him characterize and identify the salts. Johan mixed four different concentrations of eight common salts with tap water. Lab-quality distilled water served as his control. He put one and two drops of each solution on clean glass slides and left them to dry for 12 hours. He took digital photos of the crystal images, including some images with different focus depths. Johan then analyzed the photos with software called Image-J. The software also let him make some 3-D images. Stain patterns for each salt differed. "Thus, a fingerprint of the salt can be observed in the stain," Johan says. He also saw complex patterns where tap water came from groundwater, which contained some other mineral salts. "This method allows anyone with a digital camera to analyze their drinking water for salt content," he says.

Other Interests: "Playing tennis is good exercise, while also being a fun sport," Johan says. "I also like playing the violin with my school and local youth orchestra." He enjoys cooking and helps prepare a meal each year at a homeless shelter in his community. Travel with family is also a favorite activity. "Travelling exposes me to other people, cultures [and] lifestyles, and made me realize our interconnections," he says. Johan hopes to become a medical doctor.

RYAN EDWARD DRAKE

Temecula, California | Age: 14

A New Desalination Method: Comparing the Effectiveness of Non-Toxic Carboxylic Acid Directional Solvents to Reduce Salinity Levels

Project Background: The Earth has lots of water, but 97 percent of it is in the oceans. And that water is too salty for drinking and for most crops. Desalination can reduce the saltiness of sea water, but most methods are costly and use lots of energy. "I became inspired to find an improved desalination method," Ryan says. He lives in Southern California. That area has frequent droughts, and other factors stress its water supply as well. Billions of people worldwide also face the prospect of living in water-stressed areas within the coming decade. Ideally, a better desalination method could help boost people's water supplies in an economical manner.

Tactics and Results: Ryan's strategy focused on coconut oil and soybean oil. The two non-toxic oils are types of carboxylic acids. They have chemical properties that can let them either dissolve in water or separate from a solution. Ryan put different concentrations of saline solution and one of the oils into collection tubes. Then he mixed the emulsions vigorously at different levels of heat. Heat helped the solvent be hydrophilic—somewhat water-loving— so it could pull water out of the saline solution. A hotter temperature worked better. Ryan let the mixtures settle for two minutes and then spun them in a hand-made centrifuge. "The salt and saline concentrations settled to the bottom," he explains. He drained off the desalinated water and tested its saltiness. Coconut oil worked better than soybean oil. Ryan's best trials cut the salinity levels by between 70 and 95 percent. He got similar results with reused coconut oil. The processed water was still too salty for drinking water standards. Nonetheless, Ryan says, "this process shows promise."

Other Interests: "I've always been fascinated about how things work and how to improve them," Ryan says. He hopes to become an electrical engineer. He's already built Tesla coils, Van de Graff generators and small-scale ion propulsion devices. And he got his Extra Class HAM radio license in 2018. Ryan plays on competitive travel baseball teams. "It helps keep me physically fit and well-rounded beyond academics," he says. His other sports include basketball, golf and martial arts.

ANNA DU

Andover, Massachusetts | Age: 14

Investigating a Machine Learning Based ROV to Identify Aggregation of Marine Microplastics

Project Background: "I have always loved the ocean, and in particular, the marine animals that inhabit it," Anna says. Pollution from microplastics is a worldwide problem, she notes. Microplastics are teeny, tiny bits of plastic that can contain chemicals that are harmful to marine animals and other species that eat them. Some microplastics float or are spread throughout the water, but large amounts also build up on the ocean floor. It's critical to identify where those build-ups are and what's in them in order to develop any cleanup plan, Anna says. She developed a remotely operated vehicle, or ROV, to spot plastics underwater.

Tactics and Results: Anna built her first plastic-spotting ROV last year. Among other things, it uses a camera to detect infrared light. The system compares camera images of particles to a reference library that Anna developed. This year, she added a way for the system to identify colors found in synthetic dyes. She also worked on a method that looks at the morphology, or structure, of plastic bits. Anna tested the methods with samples from the lab and field, as well as in virtual, computer-based environments. "The morphology classifier identified microplastics correctly 55 percent of the time," she says. Her infrared color mapping system was accurate nearly two-thirds of the time, and her method to spot unnatural colors was accurate 79 percent of the time. When she combined all three methods and used machine learning to train the system, testing showed the results were correct 91 percent of the time.

Other Interests: "My favorite hobby is reading, followed closely by writing," Anna says. One of her projects is a book about science fairs. She also enjoys after-school maker activities and likes to work on small electronics projects. Anna plays the violin and recorder. She also likes to ice skate. Anna recently started a nonprofit organization called the Deep Plastics Initiative. It aims to teach other young people about plastic pollution. The program also encourages young people to start their own projects to recycle or reduce the use of plastics. Anna hopes to become an environmental engineer.

LAUREN U.C. EJIAGA

New Orleans, Louisiana | Age: 14

Ozone Depletion: How It Affects Us

Project Background: "I was always fascinated by nature," Lauren says. She has become concerned about the problem of ozone depletion. A layer of ozone high in Earth's atmosphere screens out some of the sun's harmful radiation. Humans' use of certain chemicals has led to a gradual, uneven thinning of that layer. A thinner ozone layer lets more harmful ultraviolet radiation through. That includes UVB radiation, which can damage DNA, proteins, lipids and membranes, Lauren notes. She wondered how current levels of ultraviolet light from the sun affect plants' growth and performance. After all, green plants need sunlight to make their food. So, they really can't avoid exposure to increased levels of radiation.

Tactics and Results: Lauren put pansy plants inside three hollow growing cases made from plastic pipes and connectors. Then she attached plastic films to each one. The films either filtered out or let in specific wavelengths of radiation. Pansies in one structure were exposed to UVA radiation but not UVB. Plants in another structure were subjected to UVB radiation but not UVA. And a control group of plants got a regular balance of both UVA and UVB radiation. Every other day, Lauren measured each plant's chlorophyll content with a handheld meter. She also observed changes in the plants' foliage and flowers. After 15 days, the plants in the control group had fairly normal growth. In contrast, plants that got UVA but not UVB radiation lost about 14 percent of their chlorophyll. And plants exposed to UVB but not UVA radiation lost about 61 percent of their chlorophyll. Lauren says this suggests that UVB radiation" is too strong to be protected against if not balanced out."

Other Interests: "I enjoy any hobbies that involve my creativity, and any sport that I can play for fun," Lauren says. Her favorite sport is volleyball, "because it involves playing side by side with a team." She also enjoys tennis, soccer and taekwondo. She also plays the piano, flute and ukulele. "I'm pushing to pursue a career in anesthesiology," Lauren says. She hopes one day to work with Doctors Without Borders to help provide critical care in countries around the world.

PAULINE VICTORIA ALLASAS ESTRADA

Fresno, California | Age: 12

Early Detection of Drought Stress in Bell Pepper (C. annuum) *Using a Remotely Operated Vehicle with an Infrared Camera*

Project Background: A long drought has led to huge crop losses in California. "Farmers who suffered the most were from the central valley where most of the fruits, nuts and vegetable crops are grown," Pauline says. She knows, because that's where she lives. "Witnessing this tragedy happen before my eyes gave me the resolve to find a possible way to help farmers manage their water use efficiently," she says. She learned about the Crop Water Stress Index, or CWSI. It's a way of telling when crops need water, based on the temperature of the crop's leaf canopy, weather conditions and vapor pressures. Pauline set out to design a remotely operated vehicle to give farmers that information.

Tactics and Results: Pauline's rover has an Arduino-based controller mounted on a six-wheel chassis, or frame. The controller can give the rover's precise location, thanks to GPS, which stands for Global Positioning System. Pauline added an infrared camera to the set-up. Analysis of its readings could provide data on the temperature of the plant canopy. Then she took the rover out to experimental fields of pepper plants at a local university. "The soil moisture level for each plant was also measured on the same day," she adds. She collected data on water vapor pressures from the National Weather Service's website. Pauline used Microsoft Excel to calculate the CWSI from her data and created graphs. She also used statistical methods to figure out the degree of correlation between the calculated CWSI and actual soil moisture levels. The two were generally consistent, which means her system worked well. "The results of this study can have a big impact on the way irrigation is managed in the field," Pauline says.

Other Interests: I enjoy doing ballet most because it teaches many skills that are important in life," Pauline says. "It teaches you to never give up and to always try your hardest. It teaches you that hard work and determination bring you to your goals. It also lets me express myself through my body." She hopes to become a medical doctor. She's especially interested in treating patients who have cancer.

RYLAN LEE GARDNER

Mesa, Arizona | Age: 14

Stall/Spin Recovery Via Increased Lift and Upwards Pitching Moment Using the Magnus Effect

Project Background: "Throughout our lives, my twin brother Ian and I have been absolutely fascinated by flight," Rylan says. Unfortunately, different aerodynamic conditions can lead to spins and stalls. Together, they're a leading cause of accidents, he reports. "Deep stalls, icing tailplane stalls, low altitude stalls, and violent spins are nearly impossible to recover from utilizing current systems," he says. He and his brother teamed up to see if they could design a way to help pilots regain control of an aircraft if those problems arose.

Tactics and Results: Rylan and Ian's safety design uses a backward spinning cylinder. It's on the leading edge of an aircraft's wing. "This design harnesses the characteristics of the Magnus effect," Rylan says. The Magnus effect explains why curveballs curve when baseball pitchers throw them. A spinning ball or cylinder will deflect air as it moves ahead. That deflected air pushes against air on the other side. As a result, air on the other side pushes back against the spinning ball or cylinder, changing the direction of the ball or cylinder's path. For the boys' design, the spinning cylinder "was intended to make the plane rotate downwards, increase its lift and reduce its drag," Rylan says. The boys made a radio-controlled prototype from a Sky Raider glider. Then they went to a local high school's wind tunnel and ran tests. The design provided more lift force, less drag force, and a greater increase in the plane's angle of attack. "Potentially, the system could reduce crashes and improve the safety of modern air travel," Rylan says.

Other Interests: Rylan hopes to become an aeronautical engineer. "I am particularly passionate about aerospace science, flight, and learning," he says. "Engaging my mind and acquiring new knowledge brings me joy, and flight gives me freedom," he adds. He plays the trumpet, French horn and recorder. His favorite athletic activities include hiking, martial arts and lacrosse. He's also active in Boy Scouts and volunteers for a variety of community service activities.

ALIANA GASSLER

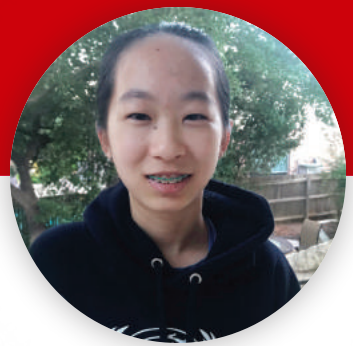
West Grove, Pennsylvania | Age: 14

Improving Automobile Safety by Removing Blind Spots

Project Background: Alaina's family owns a Jeep Grand Cherokee, but her mom doesn't like driving the vehicle because of its large A-pillar design. Those pillars are the vertical supports on each side of the windshield, and their large size provides more protection in case of a rollover crash. However, their size and angle also result in blind spots. Blind spots are areas that drivers can't see from their usual sitting position at the wheel, either directly with their eyes or with help from the car's mirrors. "I started to think about how blind spots are a huge problem in all cars," Alaina says. She decided to design a device to deal with the problem.

Tactics and Results: "My prototype had to reduce blind spots in a safe, efficient way," Alaina says. The materials had to be affordable and easily accessible and the device had to be practical and work in different lighting conditions. She also noted that the design should not lead to other kinds of car accidents. The solution she came up with uses a webcam mounted outside the passenger side A-pillar. The camera images are then displayed on the inside of the pillar so the driver can see them. Alaina's first prototype used a projector inside the car to show the images. She used 3-D printing to make a special part so the projector's image would focus properly at close range. The system worked in test drives with her dad. However, bright light sometimes made it hard to see the projector's images. Alaina plans to use LCD screens (liquid crystal display screens) for her next prototype. "LCD screens are easier to see in daylight than projected images," she explains.

Other Interests: "I have always loved dancing," Alaina says. She has studied lyrical, hip hop, ballet and jazz styles. She's performed in the school musical and plays the string bass as well. Alaina is a senior Girl Scout and also enjoys field hockey. "I really want to go into the field of physical therapy because I love to work with and help people," Alaina says. "I would also love to design new machines/prosthetics that will help people develop skills to get better," she adds.



HANNAH GUAN

San Antonio, Texas | Age: 13

Genetic Prediction of Biological Age: Exploring the Relationship Between Epigenetic Markers and All-Cause Mortality

Project Background: In Hannah's county, the number of 65- to 69-year-olds went up more than 42 percent between 2010 and 2016. She is concerned about the aging population's health. "Aging is the most important risk factor associated with many diseases," she says. Examples include cancer, high blood pressure, type 2 diabetes, heart disease and a brain disease called Alzheimer's. Our genes have molecular codes that tell cells how and when to make a wide range of proteins. Genes are inherited. However, changes to genes can sometimes turn them on or off. Those changes can occur at any point during an organism's life. Epigenetics is the study of those changes. Hannah wondered if there was a link between epigenetics and aging.

Tactics and Results: Hannah did a big data dive into a public database of health information, called PubMed. She focused on two markers that can signal epigenetic changes. One of them deals with telomeres. Those are repetitive sequences of chemical groups at the ends of chromosomes. Chromosomes are long strands of DNA, or deoxyribonucleic acid, which contain our genes. The telomeres protect the chromosomes. However, they can shorten when cells divide or face certain kinds of stress. Hannah's statistical analysis of telomere length drew from 27 data sets with information from more than 131,000 people. The other marker she looked at is DNA methylation. That process adds extra chemical groups, called methyl groups, to DNA molecules. Her work on DNA methylation used data for almost 17,000 individuals. Hannah found that both telomere length and DNA methylations were associated with overall mortality. The results suggest that epigenetics plays a role in the body's aging process, she says.

Other Interests: Many people have helped Hannah's family, she says. As a way to give back, she founded a group called San Antonio Math Include. It provides free math help to students from a wide range of cultures, backgrounds and experiences. The group's 30 volunteers have taught students from about seven dozen schools, she reports. "I am passionate about math and want to be a math professor in the future," she adds. Hannah plays both the piano and flute.

KASSIE HOLT

Sandy, Utah | Age: 13

Bound and Bricked

Project Background: Humans might one day build a base to live in on Mars. But transporting building materials there would take months and cost huge amounts of money. The whole process could go more quickly and might cost less if bricks could be made with the soil, or regolith, on Mars. Kassie and her partner, Sidor Clare, set out to make bricks with material like that found on Mars. They also explored how to make binders that could keep the bricks together. They wanted to make sure their bricks would be durable and reliable. After all, Mars has a harsh environment, so buildings would need to be sturdy!

Tactics and Results: "Making bricks is a lot harder than it seems to be," Kassie says. The girls used a soil mix known as Mars Global Simulant MGS-1. It has chemical and mechanical properties like the soil on Mars. The girls tried different binders to hold their bricks together: polyester resin, polystyrene, and recycled high density polyethylene, or HDPE. They made their resin brick by adding resin to the soil mix. For the HDPE bricks, they used melted bits of plastic from a bucket. For polystyrene bricks, the girls used two methods to mix the plastic with acetone and the soil mix. Some other tries at brickmaking failed. But the girls had enough to head to the lab at a community college. The compression tester there had a computer and multiple cameras hooked up to it. The equipment let the girls track how much pressure the bricks could withstand. The polyester resin brick was the strongest. "In fact, our polyester resin brick was so strong that it was stronger than concrete and came second only to limestone!" Kassie says.

Other Interests: "I really like helping people," says Kassie. She likes working with people to protect their computers from hackers. She mentors at robotics camps and helps put food bags together for families who are in need. She dances ballet, sings in choir and plays both the piano and ukulele. Kassie hopes to be a computer scientist. She and some team members have already created a smartphone app called Water Bank. It connects to her city's database so local residents can watch their water usage and conserve water.

RISHAB KUMAR JAIN

Portland, Oregon | Age: 14

The Pancreas Detective: A Novel Artificial Intelligence-Based Post-Biopsy Tool to Screen Genetic Mutations Towards Personalizing Pancreatic Cancer Treatment

Project Background: "I have been deeply moved by family friends passing away from cancer," Rishab says. Pancreatic cancer starts in an organ that makes enzymes and hormones that help with digestion and the control of blood sugar. Rishab met several patients and survivors when he volunteered at a race to raise money to help fight the disease. Then he visited a lab in Boston and learned about DNA sequencing. That process spells out the order of nucleic acids in the molecules that contain cells' genetic information. He wondered if he could design an artificial intelligence tool to work with the results of that sequencing. Perhaps the results could help suggest treatments for patients.

Tactics and Results: Rishab calls his tool The Pancreas Detective. It works with images of tissue samples from pancreatic cancer patients and uses data from the images to figure out which of five types of genetic mutations a patient probably has. To do that, Rishab used a set of math rules called the k-Nearest Neighbors Algorithm. It basically finds the known data points in a large group of data that come closest to something that it's trying to classify. But first Rishab needed that large group of data. He downloaded biopsy images of tissues for 453 cancer patients. Then he wrote an algorithm to pick out hundreds of features from those images. Among other things, "the technique helped quantify tumor intensity, shape and texture," he explains. Rishab used 70 percent of the data to train his artificial intelligence tool. Then he tested it with the remaining 30 percent of the data. The tool worked well, he reports. He hopes doctors might someday use it to choose mixes of treatments that will help more patients survive.

Other Interests: "I enjoy cross-country and 5K runs," Rishab says. "I am an active Boy Scout as well." He's editor-in-chief of his school newspaper. He also founded the Samyak Science Society, a nonprofit organization that works to promote science, technology, engineering, arts and math for all children. Rishab was named one of *Time's* 25 Most Influential Teens in 2018. He hopes to become a biomedical engineer.

ISABELLE SOPHIA KATZ

Moraga, California | Age: 15

Analyzing Musical Instruments/Voice Using Signal Analysis and a Novel Color-Fingerprinting Technique for Vocal Training

Project Background: Isabelle is a dedicated musician and singer. She became fascinated by the differences in tones among different brands of pianos. She had heard experts use different adjectives to talk about those tones: "Diffuse." "Metallic." Even "fat." Those words had meaning, but they weren't very specific. Isabelle decided to see if she could use digital sound processing to get an objective characterization of both a note's frequency and its tone, or timbre. She also wanted the technique to work with other instruments besides the piano. She wondered if the method could work with sung notes as well.

Tactics and Results: Isabelle started with ten recordings of the middle C note from three brands of pianos. She used software and an algorithm to break down a musical sound into its different frequencies. Isabelle also got data for the notes' harmonics. Those are overtones that some instruments make when a basic, or fundamental, note is played. Isabelle then went further. She used music from the "mellow" and "bright" settings on her electric piano to design a way to measure a musical sound's tone. She put her results together and got a "color fingerprint" for musical sounds. Colored circles in the fingerprint stand for a fundamental note and its harmonics. The thickness of each circle is based on the peaks of the different frequencies. Isabelle's method could characterize notes and tones for a piano, guitar and violin. She also found a way to show if a sung note is off on its pitch. "The next step for this project is to build a working prototype smartphone app" to train singers, she says.

Other Interests: "I write and cover songs with my acoustic guitar," Isabelle says. She also performs her songs and poems during open mic programs at coffee houses. As a triathlete, she swims, runs and bikes. She also enjoys hiking and rock climbing. And she has fun cooking together with her family. Isabelle hopes to become a science teacher. "I love public speaking, and as a professor, one has to do this every day as part of their job," she says.

ALEXIS TEA MACAVOY

Hillsborough, California | Age: 14

Designing Efficient, Low-Cost, Eco-Friendly Activated Carbon for Removal of Heavy Metals From Water

Project Background: People have spent millions of dollars to clean up San Francisco Bay, which is near Alexis's home. "Yet heavy metal contamination is still a problem there and elsewhere," she notes, and suggests that much of the problem could have been avoided if people had filtered their wastewater. Other areas would do well to filter their wastewater, too. Many commercial water filters use activated carbon. The material's tiny carbon bits have been processed with high heat to give them lots of tiny pores. Their surface area helps the bits adsorb, or grab onto, contaminants. Alexis decided to make her own activated carbon with different plant-based materials. Using bio-wastes would be eco-friendly and lower the costs of wastewater treatment, she reasoned.

Tactics and Results: Alexis tested four types of activated carbon that she made with different plant-based materials: coconut shells, walnut shells, sawdust and ash. She ground the materials to a specific mesh size, then treated samples of each kind of material with two acids at different levels of heat. Next, she rinsed the materials with sodium bicarbonate, also known as baking soda. Finally, she treated the samples with salt or fluoride before a final rinse and drying. Alexis packed equal volumes of filter materials and water into burettes. For controls, she also made filters with untreated, ground plant materials. She had a commercial water filter, too. Alexis poured a solution with water and copper into each filter. Then she drained the liquid and measured how much copper remained in the water. The best results came from the sawdust and walnut fluoride filters in Alexis's Phase 2 tests. They absorbed up to 30 times more copper than the commercial filter did!

Other Interests: "The hobby I most enjoy is playing my violin," Alexis says. "Music stimulates so much emotion inside me, and I love the sense of achievement." She also sings in choir and does jazz dance. She enjoys rowing and is part of her school's Mock Trial team and its Green Team Trash Patrol. She hopes to become a biochemist. "I love solving problems that relate to our current society, and working as a biochemist can give me a chance to solve these problems for a living," Alexis says.

GIANNA G. NILVO

Los Lunas, New Mexico | Age: 13

The Digestion of Cat Food — Digestive Enzymes or Not?

Project Background: "My experiment's inspirations were my cats, Pepe, Charlie and Casper," Gianna says. Two of them had suffered from digestive issues and pancreatic disease. The digestive system handles how our body takes in food, breaks it down into useful parts and expels what's left. Digestibility deals with how much of a food the body can absorb for use. In an earlier experiment, Gianna had tested the digestibility of different brands of cat foods. Some companies also sell enzyme supplements to help promote digestion. "I wanted to see if adding a digestive enzyme to my cats' diet would increase digestibility as the manufacturers claimed," Gianna says. "Or, would it be money wasted?"

Tactics and Results: Digestive enzymes are proteins that help break a food down into chemical bits that the body can use. Gianna ran her tests with different brands of cat foods and enzyme supplements. She added some of each cat food to a beaker, along with some of an enzyme supplement. She also added a solution of muriatic acid, to mimic the acidity in a typical cat's stomach. Gianna let each beaker sit for 12 hours, then drained the liquid with a strainer. Next, she added some pineapple juice. The juice has enzymes which are similar to those in a cat's small intestine. After 12 hours, she drained the liquid and let material remaining in the beaker dry. Then she weighed the beakers with their residue. The digestibility for a couple of dry cat food brands went up more than 7 percent when she used one brand of enzyme. Across all brands, however, the supplements increased the food digested by less than 2 percent. Gianna's overall conclusion: "It's not worth spending the money."

Other Interests: "You'll find me on the fairway most weekends playing golf!" Gianna says. She also enjoys a wide range of other outdoor activities, including hiking, biking, fishing, soccer, baseball and more. Gianna enjoys using a metal detector to search for "cool finds" and also likes shooting at gun ranges. She volunteers at an animal clinic and hopes to become a veterinarian. In addition to her cats, she has a dog named Thor.

RINOA JACQUELINE OLIVER

Santa Cruz, California | Age: 13

Factors Affecting the California Science & Engineering Fair Results

Project Background: Last year Rinoa attended the awards ceremony for California's state science fair. She noticed that several students came from Orange County. That county's median income places it in the top third for the state. "Are students from privileged areas or highly rated schools more likely to win in the California State Science & Engineering Fair?" she wondered. On the flip side, might students from less well-to-do areas be missing out? Rinoa decided to dig into decades of science fair data to find out. She also looked into other factors that could affect a student's chances for winning.

Tactics and Results: Rinoa obtained 29 years of California state science fair results. She also did research to find out the median household incomes for cities where the students went to school. Then she got to work analyzing the data. The top winning projects tended to come from more well-to-do areas, she found. Moreover, she found a growing gap between income levels for cities with the top three projects and the income levels for cities for all other projects. Also, the average of the median city incomes for all participating projects was more than the statewide median income. Schools with fewer than five projects were much more likely to be in areas in the bottom quartile of income levels than in the top quartile. The opposite was true for schools with more than 100 projects. And winning seems to make winning more likely, Rinoa found. Some schools' history of winning in certain categories was a good indicator that another project in the same category would place in the top four.

Other Interests: "I really like doing the science fair," Rinoa says. One of her earlier projects was on the mathematics of honeycombs. Another science project dealt with acoustics in rooms. Yet another project looked at lead levels in the water for local schools. Rinoa plays the piano and violin. She also volunteers with a group to remove invasive plants along a river near her home. "I am interested in engineering science" as a possible career, she says.

MADISON NICOLE PERKINS

Gilmer, Texas | Age: 14

Stayin' Alive

Project Background: "The human problem that I wanted to solve was the balance between economic development for improved pasture land and the biodiversity of an East Texas woodland," Madison says. She got the inspiration for the project when her parents cleared five acres of land to build another pond on their farm. "One day I saw small fish, or fry, come through the spillway into the new pond," she says. A spillway is a channel that controls the flow of water from a pond. In this case, the new pond was still being built and there was little vegetation. She wondered how the small fish would survive. She also wondered how a lack of vegetation could affect a pond's biodiversity.

Tactics and Results: Madison did her research at a pond on her family's farm. She mowed down the land plants and removed underwater vegetation from one 10-meter (33-foot) stretch near the shore. She left the vegetation in place along another 10-meter stretch. She built homemade Hester-Dendy habitats and placed them at three spots along each stretch. These devices have spaced-out stacks of plates to collect various types of macroinvertebrate animals. She collected the devices after four weeks. In addition, she collected specimens with a seine and a homemade plankton net every two weeks during December and January. Madison counted and identified the species she collected. Different sampling methods collected more species in each of the two areas. She also found differences in water temperature, dissolved oxygen and carbon dioxide levels. But at least for the first four weeks, she didn't see a statistically significant difference in each area's biodiversity for fish and macroinvertebrates. "The biodiversity study should be continued for an entire year," she says.

Other Interests: Madison is a competitive baton twirler. She does tap, jazz and ballet dancing as well. She's also a member of Future Farmers of America. She raises show broiler chickens for her county's show. She also enjoys creating braided bracelets with thread. Madison hopes to become a pediatric oncologist. "I want to be the smiling face to the children and their parents as I problem-solve to determine the best way to cure their cancer."

ASHWIN PRABHAKAR

Madison, Alabama | Age: 14

Multifunctional Biodegradable Polymers for Environmental Applications

Project Background: "Human activities have led to significant air and water pollution," Ashwin says. Many of those activities release carbon dioxide, that is one of several greenhouse gases which drive climate change. Not all carbon dioxide treatments use biodegradable materials, Ashwin notes. He knew that green plants convert carbon dioxide and water into sugar and oxygen when they make their own food. That process is called photosynthesis. Ashwin wondered if he could use that process to treat waste carbon dioxide gas in a lab experiment. He also wanted to combine his treatment process with electronic and other sensors. The sensors would make it easier to monitor the process.

Tactics and Results: Ashwin's treatment method uses chloroplasts from spinach leaves. Chloroplasts are the food factories in green plants' leaves. Ashwin's system also uses a hydrogel that comes from algae. Hydrogels are "smart" materials, meaning they change their structure in response to things such as changes in temperature or the water concentration. Salinity, acidity or alkalinity can also affect hydrogels. Ashwin put bits of the hydrogel and chloroplasts into a calcium chloride solution. He also added iron oxide particles, which can be moved around with a magnet. The hydrogel encased the chloroplasts and iron oxide, forming capsules. Next came testing. Ashwin pumped carbon dioxide into a solution with the capsules. He added a light source and set up a gas monitor. He also set up a tool to measure electrical resistance and used material from red cabbage juice to test the pH. All the readings showed that the system worked to convert the carbon dioxide gas into oxygen gas. The used hydrogel particles were biodegradable when the process was done.

Other Interests: Ashwin hopes to become an aeronautical engineer. NASA's Huntsville facility and the Army's Redstone Arsenal are not far from his home. So, he says, he has grown up around airplanes, missiles and rockets. Ashwin enjoys academic challenge activities, such as math team, Scholar's Bowl and a GreenPower race team. "Playing the violin allows me to take a break from everything else going on at that time," he adds. He also plays soccer and tennis.

MERCEDES RANDHAHN

Ogden, Utah | Age: 14

Opioid-Like Deactivation

Project Background: Opioid medicines can help patients cope with pain after surgery or when they're ill. People don't always need all of their pills, but they don't always get rid of the leftover medicine properly, either. "Many people keep their unused medications on the premise they may need them later," Mercedes says. "However, this increases the risk for accidental usage by children, opioid overdosing, and suicide." "My hope is to develop a method that could deactivate opioids at home safely and efficiently," Mercedes says. She wants to find a way to stop the drugs' ability to cause harmful chemical reactions.

Tactics and Results: By law, Mercedes couldn't work with actual opioids. However, she learned that the opioid morphine belongs to a group of chemicals known as alkaloid salts. Caffeine is also an alkaloid salt, and is readily available to teens. So, Mercedes worked with it as a "makeshift opioid." Alkaloid salts react with acids to form salts. With that in mind, Mercedes looked for a readily available acid that could react with the caffeine. "I used vinegar, a common household item that contains acetic acid," she says. She also added activated carbon. Activated carbon has many tiny pores to hold onto or react with other molecules. After all, if vinegar could deactivate the caffeine, "I didn't want it to be reactivated," Mercedes explains. She used a lab analysis method and statistics to compare her treated mixture to untreated caffeine. She also compared the treated mixture to a mix of vinegar and carbon without the caffeine. The results and additional calculations showed that her treatment had changed the chemical nature of the molecules.

Other Interests: "One of the activities that I most enjoy is hiking," Mercedes says. She also enjoys climbing at gyms or in trees. "There's a certain freedom in ascending above civilization," she says. Her other athletic activities include soccer, basketball and skiing. She also plays the piano and recorder. She currently hopes to pursue a career in chemical engineering. That career would let her do work involving her two favorite subjects, chemistry and math.

HANNAH T. SHU

Seaside, California | Age: 14

Using Physics and Fourier Analysis to Determine the Audio Frequencies to Evaluate Acoustics of the Violins

Project Background: As a musician, Hannah knows that the acoustic quality of a violin makes a difference. "Most buyers note that violins that have a higher price range tend to have a higher...quality of sound," she notes. However, that's not always the case. Prices for good violins start at several hundred dollars and go up from there, so a poor choice could be costly! Advanced software and other equipment can measure some features of a violin's acoustic quality. However, Hannah notes that most musicians buying a violin can't afford such high-tech equipment. Yet most prospective violin buyers do carry a smartphone. "Are modern smartphones powerful enough to analyze the acoustic quality of different violins and help buyers pick their dream violin?" Hannah wondered.

Tactics and Results: Hannah used a smartphone with a VisualAudio app to record notes from two dozen violins in different price ranges. The app and other software let Hannah make spectrograms. These show different qualities of sound over time. Those qualities include a sound's frequency, loudness and signal power. On Hannah's spectrograms, an intense yellow color showed when a sound was more powerful and had greater depth. In contrast, a subdued purple meant those sound qualities were more limited. Hannah also used the results to make different graphs. One graph, for example, showed how different violins' overtones compared to each other. "More harmonics create a more musical sound," that people describe as lyrical, singing or bright, Hannah explains. Her tests showed that the top three-ranked lower-priced violins came close to some sound qualities of the more expensive ones. Overall, though, her analysis showed that sound qualities for the higher-priced violins were indeed different from those of the lower-priced violins.

Other Interests: Hannah began playing the violin at age 8. She's now at the advanced intermediate level. "I learn new skills every day as I practice," she says. She also plays the piano. Hannah enjoys basketball, volleyball, Tae Kwan Do and flag football. She volunteers at the Monterey Food Bank. "I would like to be a hematologist, which is a doctor that primarily studies blood," Hannah says.

KYLE P. TIANSHI

San Diego, California | Age: 13

A Microscopic Particle Detector Using Laser Microscopy and Image Processing

Project Background: When Kyle went camping, he was fascinated by how his flashlight beam lit up tiny particles of dust in the air. He found out that scattered light made it possible to spot those normally invisible particles. Later on, he learned about the growing problem of plastics in oceans, lakes and other waters. "The ever-growing microplastic contamination in water sources poses a massive health problem to society," he notes. Yet current tests for total suspended solids tend to be costly and time-consuming. Remembering the flashlight beam from his camp-out, Kyle set out to design a detector that would use light to find and measure suspended microscopic particles.

Tactics and Results: Kyle wanted his system to identify teeny, tiny particles in water, even if they were in small concentrations. And the system had to work quickly, accurately and consistently. Kyle's prototype aimed a laser pointer at a right angle to water solutions placed under a microscope. He took digital images of the lit-up samples then used image processing software to analyze and graph the data. He also checked his system by measuring a known quantity of micron-sized spheres in different concentrations of water. The results let him know that the system was spotting particles, and not air bubbles. "This detector is very efficient," Kyle reports. It took only ten seconds to record the video, and just another second to process the data. The laser, microscope and water container only cost about $35 when he bought individual parts online. He thinks mass production might one day bring the costs down to as low as $15.

Other Interests: Kyle hopes to become an imagineer. He loves writing science fiction books and already has several available on Amazon. "Imagineering enables me to think of mythical beasts and characters from my stories and visualize them in action," he says. "My goal is to turn my books and dream worlds into movies." He also enjoys composing music on the piano. He plays the cello and sings in choir as well. Kyle's favorite sports include badminton, golf, volleyball and running.

SEANN RICHARD TORRES

Highland, California | Age: 15

An Ecosystemic Analysis on Vertebrate Coprolitic Inclusions from the White River Formation

Project Background: "My favorite hobby is fossil collecting," Seann says. "It allows me to get a 'hands-on' experience into the prehistoric world." His research project involved hands-on work with coprolites. Those are fossilized feces, or poop fossils. Those fossils can contain bits of undigested food that animals ate. For the samples in Seann's project, those animals were vertebrates that lived millions of years ago in an area that's now part of Nebraska. Some of their poop has been preserved in rock known as the White River Formation. Seann wondered if the fossils could give him clues about the food chain there long, long ago.

Tactics and Results: Seann worked with 25 coprolite specimens from a fossil site in Nebraska. He examined each one for fragments of bones, teeth, plants or other material. He also inspected each specimen under a microscope. He looked for tiny bits of fossilized bone or teeth, or imprints of hair, grass or other material. Based on that work, he determined whether a specimen came from either a plant-eating or meat-eating animal. "Carnivore coprolites are more abundant within the White River Formation" than ones from plant-eating vertebrates, Seann's samples suggest. Thirteen specimens came from meat-eating animals. Six were from plant eaters. And six couldn't be characterized. Based on the results, Seann thinks that animals known as hyaenodonts and archaeotherium were at the top of the prehistoric food chain. Animals known as nimravids and canids were also carnivores there. Those animals would all have preyed on plant-eating animals known as oreodonts. Those extinct hog-like animals were related to modern-day camels. Seann thinks his approach can help for studies of other areas and eras.

Other Interests: "Drawing is another favorite hobby of mine," Seann says. "It allows me to express myself and create fantasies not present in this reality." His activities at school include computer club, robotics, student council, science club and Academic Decathlon. He plans eventually to volunteer at the San Bernardino County Museum near his home. "To be able to volunteer at a museum and tour guests around the exhibits would be amazing," he says. He'd like to pursue a career in archaeology, which is a branch of anthropology.

GANESH VENU

Friendswood, Texas | Age: 14

Can Potassium Help Save Water in Rice Production?

Project Background: Many people around the world suffer from water shortages and a lack of food security. "I know how difficult it truly is to find water in India," Ganesh says. He wanted to help. He focused his research on rice, a main food source for people in India. The crop also needs different nutrients to thrive, including potassium. Studies have suggested that an increase in potassium could cause a decrease in transpiration. That's the process by which water moves through plants from their roots and evaporates through small pores on the leaves. Ganesh wondered if he could use the idea to help save water.

Tactics and Results: Ganesh conducted two studies with rice plants grown either in soil or with hydroponics. Hydroponics is a method of growing plants that uses water-based solutions without soil. He fed plants in the control groups with a standard nutrient solution. Ganesh treated plants in his test groups with nutrient solutions plus different amounts of potassium. Plants in the test groups for his hydroponics study lost less water compared to the control group. The water savings increased as the potassium concentrations went up. However, the no-soil plants thrived best in the control group and in the groups that got fed with just 100 or 200 parts per million (ppm) of added potassium. In the soil study, the control group lost the least water overall. However, its plants had the most water loss per gram of leaf tissue. The plants with 100 ppm of added potassium had the highest water loss. However, plants in that group had the lowest water loss per gram of leaf tissue. Based on that, Ganesh figures that adding some potassium can actually save water and increase crop yields.

Other Interests: "My favorite hobby is to play the violin because it helps me to let go of my emotions and to feel tranquil," Ganesh says. His second favorite hobby is playing chess. "It is a lot of fun and helps me to improve my focus and concentration too," he says. For sports, Ganesh enjoys tennis as well as soccer and running. He also likes robotics and is a Life Scout in Boy Scouts. He hopes to become a research scientist.

RUHI YUSUF

Newark, California | Age: 13

Effectiveness of Different Plants as Coagulants to Purify Contaminated Drinking Water

Project Background: "I wanted to find effective, safer alternatives to chemicals for villagers to purify water," Ruhi says. Her uncle in India manages a water district. It provides drinking water to people in more than 300 villages. Unfortunately, the underground pipelines for drinking water and wastewater often run parallel to each other. And those pipes are not always watertight. Leaks happen, and the drinking water can become contaminated. The water district has given chemical purification packets to many people in villages. However, the chemicals can give the water an unpleasant taste and smell, which many people don't like. Yet when people drink the water without using the packets, they can get sick. Ruhi wondered if plant-based materials might be used for purification instead.

Tactics and Results: Many water treatment plants use a chemical process called coagulation that pulls certain contaminants out of water. Alum, or aluminum sulfate, is often used for that purpose. It causes tiny particles of material in water to clump together. Then after a while, the clumped particles settle out. Ruhi tested four types of plant materials as possible alternatives to alum. She ground up moringa seeds, okra seeds, and nirmali seeds. She also prepared aloe vera gel from that plant's leaves. She added an equal amount of each material to water mixed with koalin clay. She mixed each turbid water sample vigorously for one minute. Three minutes of slower mixing followed. Then the samples sat for three hours. The timing let some solid settle out. Then Ruhi tested the treated water. All the plant materials substantially cut down on the turbidity of the water. They also reduced the total dissolved solids to levels close to the World Health Organization's standards. The pH values were within safe drinking water ranges.

Other Interests: "My favorite hobby is practicing an Indian flute called bansuri," Ruhi says. Playing it gives her a sense of stillness and helps relieve stress from school. She has also been playing the piano since she was four years old. She hopes to become a computer scientist. "Computer science is all about learning the tools to solve real-world problems," she says.

2019 Broadcom MASTERS
FINALISTS INDEX

Broadcom MASTERS

THE INSPIRATION

In recognition of the importance of STEM education and the importance of sparking insight and developing 21st Century skills through project-based learning, the Broadcom Foundation is proud to sponsor the Broadcom MASTERS and congratulates all finalists for their hard work and dedication to following their passions in science, technology, engineering or math.

The inspiration to sponsor the Broadcom MASTERS is found in the personal history of Broadcom's co-founder, Dr. Henry Samueli.

Just like the thousands of young people competing in science fair competitions throughout the United States and the world, Henry Samueli's storied career in electrical engineering was ignited during the formative years of middle school with a 'hands-on' electronics project in his West Hollywood 7th grade electric shopclass.

Henry Samueli convinced his teacher to let him construct a vacuum-tube short-wave radio from a Heathkit catalog that he worked on every night for an entire semester. When he brought the assembled radio into school, the teacher plugged it in and it worked.

From that moment on, Henry Samueli was hooked on electrical engineering. "That became my mission in life, from 7th grade onward, to find out how radios work." He went on to earn his Bachelor's, Master's and Ph.D. degrees in electrical engineering at UCLA and his amazing career trajectory as an engineer/innovator led to the founding of Broadcom, today an international Fortune 500 company known as Broadcom, Inc.

Broadcom Foundation and Society for Science & the Public thank Dr. Henry Samueli and his wife Dr. Susan Samueli for their generosity in presenting the Samueli Foundation Prize, the top award of $25,000, at the Broadcom MASTERS.

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Founded in April 2009, the Broadcom Foundation is a 501(c)(3) nonprofit with the mission of advancing science, technology, engineering and math (STEM) education by funding research, recognizing scholarship and increasing opportunity.

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