2018 FINALISTS

2018 Broadcom MASTERS

OCTOBER 19–24, 2018

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 fair 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, D.C., 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 the mentors of more than 5,000 Broadcom MASTERS nominees in ~300 fairs

2018 TABLE OF CONTENTS

2018 Broadcom MASTERS Finalists

JACK ALBRIGHT
The Nueva School
Golden Gate STEM Fair
San Mateo County Office of Education STEM Fair

SRIRAM BHIMARAJU
The Harker School
Synopsys Silicon Valley Science and Technology Championship presented by the Santa Clara Valley Science and Engineering Fair Association

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

ANNA DU
Andover School of Montessori
Massachusetts Region IV Science Fair

JAMES FAGAN
Riverside Virtual School
Riverside County Science and Engineering Fair

ALICE FENG
The Harker School
Synopsys Silicon Valley Science and Technology Championship presented by the Santa Clara Valley Science and Engineering Fair Association

ROY C. GROSS
Terman Middle School
Synopsys Silicon Valley Science and Technology Championship presented by the Santa Clara Valley Science and Engineering Fair Association

GEORGIA HUTCHINSON
Woodside Elementary School
San Mateo County Office of Education STEM Fair

AHMAD ISMAIL
Granada Islamic School
Synopsys Silicon Valley Science and Technology Championship presented by the Santa Clara Valley Science and Engineering Fair Association

WILLIAM JENKINS
The Westminster Schools
Atlanta City Science & Engineering Fair
Georgia State Science and Engineering Fair

MIHIR NITIN JOSHI
Howard Street Charter School
Central Western Oregon Science Expo
Intel Northwest Science Expo

SHREYAS KAR
Meyzeek Middle School
Dupont Manual High School Regional Fair

ASMI KUMAR
Northwestern Middle School
Georgia State Science and Engineering Fair

JANANI KUMARAN
Abraham Lincoln Middle School
Alachua Region Science and Engineering Fair
State Science and Engineering Fair of Florida — Ying Scholars

GABRIELLA LUI
Quest Academy
Illinois Junior Academy of Science North Suburban Region 6 Science and Engineering Fair

VARUN MADAN
Lake Highland Preparatory School
Dr. Nelson Ying-Orange County Science Exposition
State Science and Engineering Fair of Florida — Ying Scholars

JOHN MADLAND
Leslie Middle School
Central Western Oregon Science Expo
Intel Northwest Science Expo

LILLIAN MEFFORD
Surfside Middle School
Florida Three Rivers Regional Science and Engineering Fair

GABRIELA HAMATY MURIEL
Saint Rose of Lima Catholic School
South Florida Science and Engineering Fair

AMARA ORTH
Lewis Central Middle School
State Science and Technology Fair of Iowa

JACQUELINE PRAWIRA
Altamont Elementary School
California State Science Fair

KATIE QUINN
Saint Francis of Assisi Catholic School
Kentucky Science and Engineering Fair

LAURA MARIA REILLY-SANCHEZ
Saint Matthew Catholic School
Alamo Regional Science and Engineering Fair
Texas Science and Engineering Fair

KENNEDY SOPHIA ROGERS
Chapel Hill Middle School
Georgia State Science and Engineering Fair

BENTLEY SIEMS
Delta Woods Middle School
Greater Kansas City Science & Engineering Fair

ESPEN SLETTNES
Homeschool
Synopsys Alameda County Science & Engineering Fair
California State Science Fair

PRATIK VANGAL
Stoller Middle School
Beaverton-Hillsboro Science Expo
Intel Northwest Science Expo

AKSHAYA VENKATESH
BASIS Scottsdale
Arizona Science and Engineering Fair

LEO WYLONIS
Tredyffrin-Easttown Middle School
Delaware Valley Science Fairs

GARY ZHAN
Bear River Charter School
Harold W. & Helen M. Ritchey Science and Engineering Fair of Utah

2018 JUDGING PANEL

SUSAN E. MULRONEY, PHD
Judging Panel Chair
Professor
Department of Pharmacology & Physiology
Georgetown University Medical Center

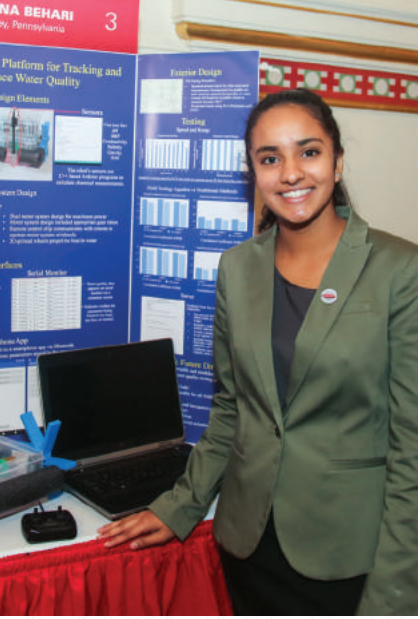
RHONDA DZAKPASU, PHD
Associate Professor
Department of Physics
Department of Pharmacology & Physiology, Georgetown University

SARAH JUDD, BS
Computer Science Teacher
Edward Brooke Charter School
East Boston

PATRICK L. MURPHY, BSEE/MBA
Director of Strategy, Integration and Planning
NASA's Space Technology Mission Directorate

CHRIS PARSONS, PHD
Affiliate Researcher
Institute of Biodiversity, Animal Health and Comparative Medicine,
Glasgow University

WILLIAM WHITE, BS
Associate Scientist
Department of Biological Sciences
Wichita State University



Why Middle School?

Broadcom MASTERS® is the premier science and engineering fair 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, D.C., the winner is awarded the $25,000 Samueli Foundation Prize.

The Process

To participate in Broadcom MASTERS, sixth, seventh and eighth grade students enter an independent science or engineering project in their Society-affiliated state or regional science fair. Judges select the top 10% of these competitors as nominees in the Broadcom MASTERS, of which over 5,000 were named in 2018.

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 each fall. 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 Broadocm MASTERS finalists. Finalists receive an all-expense-paid trip to Washington, D.C., 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.
- Robert Wood Johnson Foundation Award for Health Advancement of $20,000, which recognizes the student whose work and performance show the most promise in health-related fields.
- 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.
- The Lemelson Award for Invention of $7,500, awarded to a young inventor creating promising solutions to real-world problems.
- First and second place awards for students in each STEM discipline for a combined $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 sixth or seventh 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 Intel International Science and Engineering Fair in Phoenix, Arizona in May 2019.
- 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.

JACK ALBRIGHT

Hillsborough, California | Age: 14

Predicting the Future: Using Machine Learning to Forecast the Progression of Alzheimer's Disease

Project Background: Last year, Jack's grandmother learned she has Alzheimer's disease, or AD. Sadly, there is no cure at this time. The brain disease usually starts in middle or old age. Over time, it can cause problems with memory, language, behavior and problem-solving. These types of functions are called cognitive abilities. Patients often have confusion and mood swings too. Often, doctors don't identify Alzheimer's in its early stages, Jack notes. That's when treatments might help the most. "Given my background in computer science, I realized that the best way for me to help patients like my grandmother would be to use machine learning to forecast the progression of AD," he says.

Tactics and Results: Jack developed a machine-learning tool to predict the onset of mild and severe impacts from Alzheimer's on cognitive abilities. This type of machine-learning system figures out how to classify things based on many observations. In this case, Jack used data for 1,737 patients from a large database. Among other things, he focused on 15 markers for those patients. Research had linked those factors to the progression of Alzheimer's. Jack also paired data from each patient's doctors' visits with those markers. That gave him more data points. It also gave him data on how the disease progressed in each patient. Jack then used different machine-learning approaches to let his system figure out how to classify a patient's stage of the disease. He then tested the system with data for 110 different patients. Several of the machine-learning classifiers worked well. Jack plans to continue fine-tuning the system. Better prediction of the course of the disease could help identify patients who might be good candidates for clinical trials, he says.

Other Interests: Jack wants to be a computer scientist. "I strongly feel I can use my math and computer science abilities to do good in the world," he says. Meanwhile, his favorite extracurricular activity is Olympiad math tournaments. "I love the thrill of dissecting an unfamiliar problem and creating an elegant solution," he says. Jack enjoys fencing and flag football. He also swims and plays soccer, baseball, basketball and track. He's been learning Japanese and plays piano and guitar.

SRIRAM BHIMARAJU

San Jose, California | Age: 12

Low-Cost Archery Assistant with an Interface for the Visually Impaired

Project Background: "Named after the god of archery, I've always pursued archery as a passion," Sriram says. Over time, his skill level has advanced. Yet he's found it hard to practice accurately on his own. It costs too much to pay a coach for every session, and existing tools on the market can cost $1,000. Sriram decided to invent a low-cost tool to give archers real-time feedback. To do that, he drew on his knowledge of electronics and coding. Besides developing his own archery skills, Sriram also works with a group that helps people who are blind, so he made sure the system's guidance would be spoken aloud. That way, visually impaired archers could use it too.

Tactics and Results: Sriram's archery assistant uses physics, electronics and computer coding. Sensors let the system analyze just what an archer is doing as he or she aims. The system then gives real-time spoken guidance to help an athlete adjust their shot. For example, flex sensors measure resistance as the string is bent. The data goes to the system, which makes calculations. Then the user hears feedback. In a similar way, a phone's accelerometer measures tilt. Sriram's system uses this measurement to figure out the best angle for aiming the arrow, while the phone's gyroscope helps find the optimal direction for someone to aim. Sriram says his tool helps him practice, and coaches like the tool too. But he faced challenges: Problems with the wind. Inconsistent readings from flex sensors. Malfunctions for the gyroscope and accelerometer. Hassles with the phone app. And so on. "Doing my project taught me that nothing ever works!" Sriram says — at least rarely on the first try.

Other Interests: "I've always loved to make things fly," Sriram says. That appeal drew him to archery. It also inspired an interest in cricket, tennis, basketball and badminton. Sriram also follows his love of flying by building origami paper planes. Sriram sings in choir, and he plays several instruments, including the French horn, ukulele and Indians drums called tablas. He hopes to become a mechanical engineer, and is especially interested in developing vehicles to help reduce air pollution and mitigate climate change.

TYLER L. BISSOONDIAL

Bellmore, New York | Age: 13

MicroRNA-156 Regulates Gametophyte to Sporophyte Development and Sensitivity to Salinity in Ceratopteris richardii

Project Background: Flooding from hurricanes and high tides has increased the saltiness of soils near Tyler's home on coastal Long Island. Stress from salt can mess with the development of pollen in many plants, inhibiting their ability to reproduce. Salt can also affect various microRNAs in plant cells, Tyler notes. Those are short bits of single-strand ribonucleic acid, or RNA. Among other things, the hairpin-shaped bits regulate how cells express genes. In recent years, scientists have found ways to use microRNA to silence or knock out genes. Tyler used this process to learn more about how salinity can interfere with plant reproduction.

Tactics and Results: Tyler focused on a type of microRNA, called miR-156. Seed plants need it to make pollen that works well. Versions of it are in ferns too, and Tyler identified one of those for a specific fern. Tyler got spores to grow that species of fern. He also bought custom-made microRNA from a company to silence its miR-156. For his experiment, Tyler put soaked fern spores on agar plates. Another set of fern spores on agar plates also got some silencer microRNA. Tyler let the spores in both sets start growing into gametophytes, the form of a fern makes its male and female reproductive cells. After seven days, Tyler added salt to some plates in each set. Later he measured the size of the gametophytes, the amount of chlorophyll they made, and the number of their offspring plants. Spores treated with the silencer microRNA produced less-developed gametophytes with fewer offspring. Spores treated with both salt and the silencer microRNA had the least development.

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 going to concert halls with the Metropolitan Youth Orchestra and other groups he plays in. Tyler plays the bagpipe as well. For sports, he enjoys track and CrossFit. Tyler hopes to become a biologist. "Understanding how genes are regulated and dysregulated is important," he says. He also wants to understand how organisms respond to threats such as climate change and pollution.

ANNA DU

Andover, Massachusetts | Age: 12

Developing a Smart Infrared Based ROV to Identify Microplastics in Marine Environments

Project Background: Anna enjoys making jewelry with sea glass. One day when she was collecting it, she saw plastics scattered across the beach. She worried that a bird or other animal might mistake the brightly colored plastics for food. So, she started picking up the trash. "As I was collecting it, I couldn't help but notice just how much plastics there were," she says. Plastics aren't only on the beach, she adds. Huge amounts of plastic bits litter the ocean. The smallest bits are called microplastics. Anna wanted a low-cost way to spot accumulations of microplastics in the ocean, so that they could be cleaned up.

Tactics and Results: Anna invented a low-cost, automated system that can spot plastics underwater. Among other things, the system uses a camera that can detect infrared light. "There are many different types of plastics, each having their own characteristic absorption spectra," Anna explains. The system's camera takes photos. Those images are then compared to a reference library that Anna developed with help from an online database. That way, the system can tell plastics apart from other types of materials. Anna tested the system on land. Then she adapted it for a relatively dark underwater environment. Anna also built an ROV, or remotely operated vehicle, to carry her system through the water. It has a propeller she designed herself. Anna tested the whole system in a bathtub, and then she tried it out in her family's pool. She kept tweaking things to improve the durability and maneuverability of the ROV. "Finally I created one that was capable of being used in a real world, brackish water environment," she says.

Other Interests: "Nearly every day I do some form of maker activity," Anna says. "I enjoy coming up with my own plans and making my own electronic circuits and housings for my creations." Other favorite pastimes include writing, drawing, and studying the natural world. "I have my own backyard garden, which I experiment with," she says. Anna also enjoys ice skating, and she plays the violin and recorder. She hopes to become an environmental engineer. In that role, she hopes to help deal with the growing problem of plastics pollution.

JAMES FAGAN

Riverside, California | Age: 12

Design and Calibration of a Subsonic, Low Density Wind Tunnel for Martian Aerodynamic Research

Project Background: Inspiration for James's project came from a trip to Home Depot. "I was in the plumbing section and started playing with the drain pipes," he says, and he pieced together a tunnel on the floor. He's also had a longtime interest in Mars. One of his prior science projects tested what kind of wing would create the most lift with respect to drag on Mars. But any aircraft to be used on Mars would need to be tested for best results. And the atmosphere on Mars is only about 1/100th as dense as that on Earth. James set out to design a wind tunnel that could allow testing under conditions an aircraft would encounter on Mars.

Tactics and Results: James made a wind tunnel that can duplicate the low atmospheric pressure of Mars. He also built a fan for it with vanes made from old window blinds. And he found a way to swap out any air inside the tunnel with carbon dioxide, which makes up most of the atmosphere on Mars. The most efficient set-up uses two sets of tubes to return the gas blown through the tunnel back to the intake point, James reports. The system also worked better with eight 45-degree corners for the return tubes instead of four 90-degree corners. When James lowered the pressure inside the tunnel to that on Mars, he got a surprise. The fan motor's maximum rotations per minute jumped by 39 percent! And the total power to do that was only about a tenth of that required at Earth's atmospheric pressure. Reduced air pressure probably explains the results, James says. Nonetheless, "it could allow for a smaller battery, longer flight, or more powerful motor," he explains.

Other Interests: "My career goal is to become an aerospace engineer," James says. He likes the idea of being part of a team designing a new type of aircraft for a foreign environment. "And I like building things!" he adds. He has represented his school in writing and math competitions and in an international spelling bee. He studies Russian as well. "I like doing origami, playing the piano and chess," James adds.

ALICE FENG

San Jose, California | Age: 13

The Effect of Mushroom Species and Substrates on the Properties of a Novel Biodegradable Material: Mycelium

Project Background: Alice saw a fast-growing organic mushroom brick at a museum. That got her thinking. Each year, only about ten percent of the plastics produced worldwide get recycled, she reports. The rest ends up in landfills, waterways or other places. Mushrooms are a type of fungus. And mycelium is the vegetative part of a fungus that's made up of many branching threads. "If we could grow mycelium materials that possess similar physical properties to plastics, then mycelium would become the perfect environment-friendly alternative to plastics," Alice says.

Tactics and Results: Alice worked on her project with a partner, Arely Sun. They grew blocks made with different types of mushroom species. Then they compared the blocks' properties to three types of plastics. Alice and Arely used five kinds of mushroom species. They grew each kind on four different materials: sawdust, wood chips, hemp and corrugated paper. After about two months, they baked the blocks to stop the growth of the fungus. The team tested each block's strength, its ability to reduce the transfer of heat, and its ability to reduce noise. Alice and Arely compared those data with results for fiberglass, low-density Styrofoam, and high-density Styrofoam. They tested other qualities of their blocks as well. For example, they looked at how broken block pieces would biodegrade, and they looked at how well the blocks would resist corrosion. Some mushroom blocks reduced sound as well as the plastics, and one type of block turned out to be stronger than even high-density Styrofoam. With more work, mycelium could replace some plastics, she says.

Other Interests: "Figure skating immerses me in a winter wonderland where gracefulness combines with power," Alice says. "Competitive figure skating also teaches me to get up after I fall and to keep on going after a setback," she says. She won a medal at the 2018 Central Pacific Regional Figure Skating Championships. Alice also plays the piano. She won third place in a national competition this year. Other activities include dance, swimming and school clubs. "I have always wanted to be a forensic scientist," Alice says. As she sees it, forensic scientists analyze many types of evidence "and piece them together like a puzzle."

ROY C. GROSS

Palo Alto, California | Age: 13

An Emergency Communication Mesh Network for Civilians: Lessons from Puerto Rico

Project Background: Roy got his amateur radio license in 2017. Soon afterward, Hurricane Maria hit Puerto Rico. The storm knocked out the power grid on the island. Phones and the internet stopped working. Soon food, medicines and other emergency supplies arrived on the island. But the lack of communication hampered response workers' efforts. "Inspired by my passion for radio technology, I decided to build a new emergency communication system," Roy says. He wants it to work when other systems fail. "I was taught that the most basic human needs are water, food, shelter and hope," Roy says. "These are in short supply after a natural disaster, but they are all within reach if you can communicate."

Tactics and Results: "I have invented a device which connects to your smartphone and lets you send and receive text messages, without the use of cell towers or internet," Roy says. He started out with a used radio and an Arduino programmable board. After some other trials, he tapped into an existing network called APRS, which stands for Automatic Position Reporting System. It's a radio-based system for digital communication. APRS can send out and monitor local areas for packets of information, such as location data, traffic reports and more. Radio units can repeat and send the packets of information on again through the network. Roy got his device to work with Bluetooth and a smartphone. Then he built two devices with his final design. Next he did five types of tests. "I showed that message and location data could reliably be sent up to five miles," he reports. Radio units could re-transmit messages for longer distances, or the units can transmit messages to satellites. The batteries charge with solar power or a car battery.

Other Interests: "I want to be an electrical engineer, like Nikola Tesla," Roy says. "I am inspired by his passion and perseverance. He never gave up, even when his laboratory burned to the ground." Roy loves working with ham radio. Additionally, he sings in choir and plays piano, trumpet and guitar. For sports he plays soccer and basketball. He also enjoys outdoor activities, such as hiking, mountain biking and camping.

GEORGIA HUTCHINSON

Woodside, California | Age: 13

Designing a Data-Driven Dual Axis Solar Tracker

Project Background: Georgia's uncle recently installed solar panels on his home. The more sunlight that directly hits a solar panel, the more electricity it can produce. And the more electricity it can make, the more it can save on utility bills, and the sooner it will pay back its purchase costs. Dual-axis trackers do the most efficient job of following the sun, because they move along two axes. However, they cost a lot. Georgia had an idea based on her trip to see the solar eclipse in 2017. "I realized if man knew where and when the eclipse will be, we must know where the sun will be at other times," she says. "This inspired a data-driven dual-axis solar tracker."

Tactics and Results: Many trackers for solar panels use pricey sensors. Instead, Georgia relied on an equation from the National Oceanic and Atmospheric Administration, or NOAA. The equation uses a place's location data to say where the sun will be in the sky at any date and time. Georgia used that plus more math to build a computer model. It shows how electricity from solar panels pointed at those spots would compare to electricity produced by fixed-position panels. Georgia then wrote a computer program to control her tracker's motor and the position of the solar panels. Finally, she put everything together. She tested the device and compared it to the output from fixed panels on two days in early 2018. The results were within eight percent of her model's predictions. Over a full year, the movable panels would produce a lot more electricity. "In the [San Francisco] Bay Area, data-driven dual-axis solar trackers could reduce the payback period of solar by up to 40 percent," Georgia says.

Other Interests: "I love the ocean and have been surfing my entire life," Georgia says. She would love to invent an automated device to help her judge which waves to catch. She also loves playing volleyball and water polo. "In both sports, the most important trait is to put the team goals ahead of individual goals, while giving 100 percent," she says. Georgia sings in a choir, and plays both the French horn and clarinet. She plans to become a mechanical engineer.

AHMAD ISMAIL

Santa Clara, California | Age: 14

Effect of Combination Antifungal Therapy on the Treatment of Candidiasis

Project Background: Ahmad's project takes aim at a fungal disease called invasive candidiasis. A type of yeast causes the disease. According to the Centers for Disease Control and Prevention (CDC) in Atlanta, GA about 46,000 people in the United States contract it each year. And about three out of ten wind up dying from it. Many patients have recently been in the hospital or otherwise ill with cancer or another disease. Invasive candidiasis often starts out with a fever and chills. It can spread to the heart, brain, bones, eyes and joints. Ahmad wanted to explore ways to treat the infection.

Tactics and Results: In an earlier science project, Ahmad looked at how single antifungal medicines affect this yeast. But single medicines sometimes fail, he notes. This year he tested how a combination of antifungal medicines would affect the treatment of invasive candidiasis. "I was trying to find an effective treatment by studying mechanisms of action and target sites in the yeast cell," he says. Ahmad grew yeast cells in solutions of water and broth and on agar plates. One sample grown in each of the three media served as a control. Ahmad then treated multiple samples from each medium with one combination made from two of six types of antifungal agents. After that, he measured and compared the growth of the yeast in each sample. The most effective combo was a mix of two medicines known as synthetic azoles and synthetic allylamines. These medicines react with a yeast cell's ability to make different enzymes.

Other Interests: "I am interested in pursuing a career as a medical doctor due to my passion for biology and medicine," Ahmad says. "I know this will be a rewarding career due to the satisfaction of helping others live a healthy life," he explains. His favorite hobbies are squash and exercise. He also likes to run track and hopes to play either tennis or badminton in high school. Ahmad studies Assamese, Hindi and Arabic. He's also active in a variety of clubs and projects at school and with his local religious community.

WILLIAM JENKINS

Atlanta, Georgia | Age: 14

Robotic Tennis Ball Sorter

Project Background: "One frustrating problem for competitive tennis players like me is when dead tennis balls are mixed with the thousands of good balls," Will says. Dead balls bounce lower and mess up a player's shots. Training centers know about the problem. From time to time, some centers have coaches sort all the balls by hand, which takes up lots of time and costs centers money. Other centers skip sorting and just replace all their balls periodically. That saves time but trashes many good balls as well. Either way, millions of tennis balls go to landfills every year —"enough to stretch from [Washington] D.C. to Anchorage" in Alaska, Will says.

Tactics and Results: Will designed and built an automatic tennis ball sorter. "My machine uses the same drop method professional tennis coaches use to sort balls," he explains. One at a time, the device drops each ball onto a brick surface. Sensors are lined up to correspond with light beams at different heights. A computer connected to the sensors notes which light beams a ball blocks when it bounces. The computer then signals a motor that controls a tilt table. A net catches the ball and drops it onto the table. The ball then rolls into a basket for good or bad balls. After lots of tweaking, Will tested the machine. He did ten trials each for three good balls and three bad balls. The data showed that the machine sorted the balls consistently and correctly. For his next prototype, Will plans to shorten the cycle time and have four parallel sorting lines. That way, the machine could sort 4,800 balls in an hour! Will hopes to develop the project into a money-making business.

Other Interests: Will's favorite sport is tennis, but he also enjoys water and snow skiing, ping pong, lacrosse, and baseball. He's active in scouting, computer club and robotics. He's an amateur juggler as well! If his tennis ball sorter leads to a profitable business, Will plans to lead the company. Otherwise, he hopes to pursue a career in computer science. "I believe that artificial intelligence is a game-changing technology," he says.

MIHIR NITIN JOSHI

Salem, Oregon | Age: 12

Terrella Aurora Model: A Demonstration of Charged Particle Shielding for Space Exploration

Project Background: "The thing that inspired me for this project was the idea of living on a different planet and expanding into unknown territory," Mihir says. In 2010, President Barack Obama announced a bold plan: send humans to Mars sometime during the 2030s. SpaceX has now brought multiple rocket boosters back to earth so they can be used again. Space travel may not be far away, Mihir realized, but living on Mars would present challenges. One problem is harmful solar radiation, which comes in the form of charged particles. To find a solution, Mihir teamed up with John Madland. Together, they looked for a way to deflect those charged particles.

Tactics and Results: Mihir and John showed that a magnetic shield set above the surface of Mars might protect people on the planet's surface. "Then the charged particles will be deflected away from the planet, thus creating a 'safe zone,'" Mihir explains. Together the boys built a scale model to test their idea. In the model, a vacuum chamber simulates space. The model also has an electron gun, which represents the sun sending out charged particles. To make it, the boys repurposed a small transformer. They also used an old neon sign transformer for the power system. To represent Mars and its magnetic field, Mihir and John made a sphere. It has two stainless steel hemispheres with magnets in each end. The magnetic shield for the model uses an Alnico magnet. Alnico refers to alloys of iron that contain aluminum, nickel and cobalt. Tests showed that the magnet in fact deflected radiation in a teardrop-shaped region. A more powerful magnet could provide even more deflection in space, they suggest.

Other Interests: "I love flying drones," Mihir says. So, "if I were to pick a profession, I would choose aeronautical engineering." Sending his own drone into the sky lets him "participate in the life of a bird and the joy of flying," he says. For music, he loves playing the cello and piano. Mihir sings in a choir as well. He stays active with badminton, table tennis, fencing, softball and track.

SHREYAS KAR

Louisville, Kentucky | Age: 13

Right Charity–A Software-Based Web Application to Bring Donors, Charities and Receivers on the Same Platform and Facilitate to Donate and Distribute Most Needed Items to Right People at Right Time

Project Background: In 2017 Hurricane Harvey hit Texas and Hurricane Maria caused widespread damage in Puerto Rico. Shreyas saw in the news that people were suffering, but he also saw that people wanted to help. That happens when other disasters strike too. But, Shreyas adds, "many times, the donations don't match the need." Shreyas talked with lots of people who work with charitable groups. "They helped me to understand how donations and distribution work," he says. After additional research, he set out to build a software platform to record people's needs and help get those needs filled.

Tactics and Results: Shreyas figured out what the flow of screens would look like in his application. Then he wrote up brief stories for different charity groups that would use the system. Each story had a few short sentences about the group's needs. Several of those user stories made up what he calls a backlog. Then Shreyas got down to coding, and designed the application's web pages. He connected his application to a database he made with an open source product, while working on debugging the programs along the way. Once he had coded the entire application, Shreyas tested it for different scenarios. "For example, if a donor logs in, he should be able to view the most needed items and then add those items in the donation cart," he explains. At checkout, the donor would schedule a drop off for the donations. Likewise, a charity could see what donations were coming in. And the application would update the inventory of needs. Shreyas has shared the application with some local charities for their use.

Other Interests: Shreyas wants to become a mathematician. "I can do more research in mathematics and find new ways to solve problems," he says. Also, he notes, math plays a big role in most fields of science. Shreyas enjoys the MATHCOUNTS club, computer club, robotics, and Science Olympiads.

ASMI KUMAR

Milton, Georgia | Age: 14

Developing a Device to Predict Autistic Meltdowns Using Arduino & MS Azure

Project Background: Asmi knows a boy whose sister has autism. Autism includes a range of conditions. People with autism often have problems with social skills. Many of them also have repetitive behaviors or problems with communication. Although some people with autism can hold jobs and function at a high level, other people have more serious problems. The sister of the boy Asmi knows has serious disabilities. Sometimes the girl and other people with autism have meltdowns. They lose control when they become overwhelmed. Asmi wanted to help. Her device aims to warn people when one of those meltdowns might occur. With a bit of warning, family members and caregivers could perhaps take action to help protect someone.

Tactics and Results: Asmi built and programmed a device that tracks users' heart rates. As someone wears it on their wrist, the device sends data to a web-based and mobile program. The program calculates the beats per minute. It also calculates additional statistics dealing with the intervals and peaks as the heartbeat rate changes. The program then compares those data to the "normal" heart rate range for each individual user. If the heartbeats begin to increase too rapidly in a short time, or if they soar or dip abnormally, the program sends out a notification through the mobile app. That warns a parent or caregiver of a potential meltdown. Testing with peers, publicly available data and simulated data showed that the device could accurately detect and predict abnormal heartbeat rates. Asmi hopes to work with university researchers to get more data on autistic children. That way she can keep working to improve her device.

Other Interests: "The music a piano can create is beautiful and so relaxing," says Asmi. She has been playing for more than eight years. She also enjoys singing in the choir and playing basketball with friends. "It's a perfect activity for anyone to have fun!" she says. Beyond that, Asmi considers math her "greatest passion." She often hosts summer math circles at a neighborhood clubhouse. And she tutors other students in her local area. Asmi plans to become a computer scientist.

JANANI KUMARAN

Gainesville, Florida | Age: 14

Integrated Control of the Invasive Aquatic Plant Hydrilla Using Snails and a Plant Growth Regulator (Continuation Project: Year 2)

Project Background: "Living in Florida means being close to freshwater springs, lakes and rivers," Janani says. But waters in the area are often full of Hydrilla, an invasive plant. It crowds out native plants in the water, and interferes with boat travel on waterways. Last year Janani tested whether a type of snail could help control the water-weed. This year, she wondered if combining that control with chemical treatments could help even more. "If I could find a viable solution, I would be helping many of my friends' families that live around these infested lakes and springs," she says.

Tactics and Results: Janani collected 500 Hydrilla tips for each of three trials in the project. First, each trial's plants grew for two weeks in water treated with an insecticide. Then, plants went into different dishpans. Each trial had control groups where plants got no treatment to control the weeds. Other pans added only snails to the plants, while some pans had just the weeds plus one of two chemical weed killers. The first two trials used a weed killer called Clearcast. The third trial added pans to test a weed killer called Fluridone as well. In addition, each trial also had pans treated with both snails and one of the weed killers. "Significantly stronger control" of the weed resulted when a weed killer and the snail could act together, Janani reports. "If I was to continue this topic, I would see how the integrated control would work in a natural environment," she says.

Other Interests: "Playing tennis is my 'go-to' extracurricular activity," Janani says. "Through tennis I have met and interacted with many amazing people that I otherwise wouldn't have known." She also swims and runs track. Janani plays the piano as well. Activities at and outside of school include 4-H, art club and Girls Who Code summer camp. Janani also helps out at Gainesville Rabbit Rescue. She hopes to become a physician specializing in psychiatry. "I want to help people reach a state of mind to be able to live their lives to the fullest," she says.

GABRIELLA LUI

Palatine, Illinois | Age: 14

Design a Fully Automated Real Time Presence Detection Safety System in a School Environment Using Radio Frequency Identification (RFID) Technology

Project Background: Dozens of school shootings have killed or hurt students across the United States. Thousands more students are traumatized by the violence. Sadly, Gabriella says, "school shootings cannot be prevented without our American politicians' willingness to tighten gun control." Yet she still wanted to help. RFID stands for Radio Frequency Identification. The technology codes digital information into "smart" tags or labels. A separate reader can receive and decode the data. And the devices don't have to be within each other's line of sight. Gabriella thought RFID could help locate students in an emergency, which would allow help to arrive more quickly.

Tactics and Results: Gabriella designed an RFID system for school settings and tested it in a classroom and on a bus. "My system design is capable of providing real-time events," Gabriella says. RFID tags use electromagnetic energy at the frequency of radio waves. Antennas pick up the signals and send them on to a reader. Of course, students move around a lot, and school settings vary. Gyms tend to have high ceilings. Classrooms have lower ceilings. School buses have a lot of metal; sometimes that can shield electromagnetic fields. Gabriella calculated how many antennas each setting needed. She also set up a system to analyze all the data from the tags. She tested how different factors affected the accuracy of readings. Then she tested what happened when students with tags moved around in the classroom and on the bus. The readings produced millions of data points. Gabriella wrote an app to automate analysis of the data. The system worked well to track each student's arrival and departure times and their location on an ongoing basis.

Other Interests: Gabriella enjoys many styles of music, from hip hop to classical. "Playing piano and guitar never fails to bring me joy," she says. She also enjoys photography and video editing. "It's an incredible way to keep tangible reminders of precious moments," she says. Her other pastimes include cooking, painting and golf. Gabriella also volunteers at a food bank and retirement home. She is interested in biomedical research and hopes to become a medical doctor.

VARUN MADAN

Orlando, Florida | Age: 14

Field Testing of Feeding Bacterium Bifidobacterium infantis *(Found in a Human Gut Probiotic) in Order to Improve Honey Bee Health*

Project Background: Honey bees play a huge role as pollinators. They fertilize many of the plants farmers grow, which helps provide us with fruits and vegetables. Seventy years ago the United States had about six million managed beehives. Today fewer than three million remain. The rapid decline needs to stop, Varun says. "Otherwise, our most prized pollinators could go extinct." A university professor's talk taught him about immune system problems faced by many bees. Varun wondered whether supplemental feeding of a helpful gut bacterium could help honey bees. He decided to find out — even if it meant a bit of discomfort. "I was stung 42 times, once even in my bellybutton!" he says.

Tactics and Results: Varun used a type of bacteria called *Bifidobacterium infantis (B. infantis)*. It helps keep people's digestive tracts healthy. Some research suggests it may also help with the immune system. Varun fed sugar solutions with high and low doses of the bacteria to bees in two hives each at a local apiary. He fed plain sugar solution to a fifth hive that was his control group. Varun replenished the solutions every two weeks for 6 weeks. Afterward, he collected data from each hive. He counted the eggs and young in five frames from each hive. He weighed each hive's honey. At set intervals, he tallied bees exiting each hive to forage, and he calculated totals for the number of bees and brood in each hive. "We clearly had a winner," Varun reports. "The low dose-fed hives outperformed high dose and sugar solution-fed hives in three of the four study parameters." In his view, the bacteria have the potential to be an effective tool for enhancing honey bee health.

Other Interests: Varun loves doing theatre. "It has taught me creativity, patience, hard work and dedication throughout many rigorous rehearsals and performances," he says. He's also in choir and enjoys Bollywood dance. He plays several instruments too, including the piano, violin, guitar and drums. As an athlete, he's active in tennis and track. Varun plans to become an environmental engineer. "This job can change the world in such great ways," he says.

JOHN MADLAND

Salem, Oregon | Age: 14

Terrella Aurora Model: A Demonstration of Charged Particle Shielding for Space Exploration

Project Background: Last year, John visited NASA's Jet Propulsion Laboratory in California. "I got to see the latest Mars Mission spacecraft," he says. That got him thinking. Earth is surrounded by a large region where its magnetic field is dominant. That's called a magnetosphere, and it protects Earth from a lot of harmful charged particles that come from the sun. Mars, in contrast, "has a very weak magnetosphere, and it does get more radiation than what is considered a safe limit," John says. Any colony of people on Mars would definitely need protection. He and Mihir Joshi teamed up. Together, they aimed to tackle the problem before people try landing on Mars.

Tactics and Results: John and Mihir showed that a magnetic shield set above the surface of Mars might protect people on the planet's surface. "It will deflect the harmful charged particles away from the planet's surface, thus creating a 'safe' zone," John explains. Together, the boys built a scale model to test their idea. In the model, a vacuum chamber simulates space. The model also has an electron gun, which represents the sun sending out charged particles. To make it, the boys repurposed a small transformer. They also used an old neon sign transformer for the power system. To represent Mars and its magnetic field, John and Mihir made a sphere. It has two stainless steel hemispheres with magnets in each end. The magnetic shield for the model uses an Alnico magnet. Alnico refers to alloys of iron that contain aluminum, nickel and cobalt. Tests showed that the magnet in fact deflected radiation in a teardrop-shaped region. A more powerful magnet could provide even more deflection in space, they suggest.

Other Interests: John wants to become an electrical engineer. "When I was little, my favorite presents were broken appliances to take apart," he says. Since then, he's put a lot of things together, such as a computer, a soldering station, and even an ion engine. "However, I am not just an electronics nerd," John adds. "I also play the saxophone and also run cross country and track, swim, cook, and make movies." He's also his family's go-to electrician, plumber and drywall expert.

LILLIAN MEFFORD

Panama City Beach, Florida | Age: 14

Operation Turtle Grass: Exploring the Relationship Between Turbidity & Thalassia testudinum in St. Andrew Bay & Grand Lagoon

Project Background: "We live on a lagoon near the Gulf of Mexico, and fish is in our diet," Lillian says. "I chose my seagrass project partly because healthy fish require healthy seagrass." Studies have shown that the blade width of turtle grass is an indicator of its health. Lillian wondered how the water's turbidity might affect the turtle grass's health. Turbidity deals with how cloudy or hazy water is, and soil runoff or other pollution can increase turbidity. Lillian focused on a specific type of turtle grass growing in a bay near her hometown. The bay is an estuary – a transition zone between a river and a marine environment.

Tactics and Results: Lillian collected water samples from four places in St. Andrew Bay in Florida. To measure turbidity, she compared the water's observed turbidity in vials to calibrated samples. She also described the appearance of the water at each spot. Water from the location with the highest turbidity was "dark and murky," Lillian notes. "In fact, mud residue formed on my skin when collecting samples there." That spot was near a bridge and concentrated human development, she adds. Lillian also carefully cut more than 1,900 turtle grass blades from her sampling spots. Back at home, she counted and logged the number of healthy blade samples from each location versus ones that were damaged or dead. She also used a ruler to measure the width of each blade at its base. She recorded all the turtle grass data on a spreadsheet. Then, she compared the average blade widths with the turbidity levels at each location. The more turbid the water was, the lower the average blade width was, Lillian found.

Other Interests: "I love baton twirling because I get very excited and filled with joy when I finally master a trick like the vertical one-turn," Lillian says. She also enjoys dance, especially lyrical and contemporary styles. She shines on stage too. She recently played Gertrude McFuzz in "Seussical the Musical, Jr." Her other activities include choir, yearbook and student council. Lillian hopes to become an architect. "Architecture will bring together my love of design, art and color," she says.

GABRIELA HAMATY MURIEL

Miami Shores, Florida | Age: 15

Paraplegics Achieving Stability in the Vertical Wind Tunnel

Project Background: People who are paraplegics can't control their legs and lower bodies. Yet many of them still enjoy adventures. Gabriela learned that when she met Jessika and Rey. Both have paraplegia, yet they love assisted skydiving outdoors. "They say they feel free!" Gabriela says. Gabriela enjoys indoor skydiving in a vertical wind tunnel and wanted to help paraplegics to learn that sport as well. However, there was a problem. To "catch the wind," indoor skydivers need to keep their hips down, arms out in front, and legs bent up behind them. How could paraplegics do that, if they couldn't control their legs? Gabriela decided to find a way.

Tactics and Results: Gabriela built models for two devices to keep a paraplegic person's legs in the proper position for indoor skydiving. One model holds the ankles in place. The other is a right-angle pad for the knees. For the ankle holder's materials, she used Oodles Monster Jumbo noodle foam and industrial strength Velcro. Those materials would not hurt a person's skin. Yet they would be strong enough to hold the ankles 30.48 centimeters (12 inches) apart and prevent any flapping. To make the knee pad, Gabriela used computer design software and a 3D printer with plastic "ink." Next came field testing at an indoor skydiving center. A professional skydiver and Gabriela both tested the models three times inside the wind tunnel. "Finally, two paraplegic individuals tested the models," she reports. "It was a success!" Gabriela has since been working another issue for on a way to accommodate a paraplegic's urine catheter better. That wasn't a problem in the trials. Nonetheless, she says, "I learned from doing my project that ideas are never final."

Other Interests: In addition to indoor sky diving, Gabriela's school and community activities include Girl Scouts, art club, and yearbook. Biking, reading and traveling are other favorite pastimes, as well as playing with her dog Amber. "I am interested in nanosystems engineering for a career, Gabriela says. She likes that it has applications in a wide range of fields. For now, she works with computer design software and makes things at a nearby maker lab.

AMARA ORTH

Council Bluffs, Iowa | Age: 14

Chemical Analysis of Honey Bee Propolis: Habitat Diversity Affects the Quality of Propolis, an Essential Component of Honey Bee Colonies

Project Background: Amara's grandparents are commercial beekeepers. "I love watching and working with honey bees on their farm and realize their importance in the ecosystem," she says. Yet she worries about the bees. Parasites and disease have killed many honeybee colonies, and there are fewer bee hives now than there were decades ago. This concern led to her chemistry project. Specifically, Amara wanted to know more about propolis, a compound produced by bees. Honey bees make that glue-like substance with saliva and plant materials they collect in their area. "They use propolis to line their hive and reduce fungal, bacterial, and viral infections," she explains. If the chemical quality of propolis decreases, so would bees' ability to fight off infections, she notes.

Tactics and Results: Amara collected propolis from honey bee yards at five places in northeast Iowa. Satellite images and other online tools let her figure out how diverse the habitat was at each spot. Amara took her samples to a university lab and analyzed the samples with gas chromatography mass spectrometry. That process identifies the individual chemicals in a sample. It also tells how much of each chemical is present. Amara identified more than 200 chemical compounds in her samples. She then compared the results with the relative diversity of habitat at each sampling spot. The propolis from the bee yard with the least diverse habitat had the lowest number of total compounds. The propolis from that spot also did not have an antimicrobial chemical which the samples from the other bee yards had. Amara hopes her work can help beekeepers select good locations for their bee yards.

Other Interests: "I like being able to illustrate my creativity through art," Amara says. She is a member of the art club at school, and several of Amara's other interests include sewing, cooking, and playing the guitar and banjo. Amara is active in sports, including soccer, basketball, softball, track and wrestling. Besides all that, she helps out on her family's flower and honey bee farm, and helps sell flowers and honey at the local farmers' market. She hopes to one day become a zoologist.

JACQUELINE PRAWIRA

Mountain House, California | Age: 14

Bio.fiber.plastic: The Effect of Lignocellulosic Fiber in Enhancing the Formation and Tensile Strength of Rice Bioplastic

Project Background: "My chore of taking out the garbage taught me how much waste we produce every day," Jacqueline says. Indeed, the United States produces lots of garbage — more than 200 million tons each year. Last year, Jacqueline worked on a broken rice bioplastic. It's made with broken rice starch, water, acetic acid and other materials. This year, she explored how fibers from common plant-based materials found in garbage would affect the formation and strength of the plastic. Specifically, she wanted to test the effects of different types of lignocellulose, the main building block for a plant's cell wall. It includes compounds known as cellulose, hemicellulose, and lignin.

Tactics and Results: Jacqueline made bio.fiber.plastic with fibers from three sources: paper, cotton and corn husks. For each source, she mixed batches with six different ratios of the fiber to broken rice starch. She then tested multiple samples of each type for strength and flexibility. To test tensile strength, Jacqueline applied force to each sample until it broke. She then divided the maximum force for each trial by that sample's cross-sectional area. Jacqueline tested flexibility by repeatedly bending each sample until it creased, tore and broke. Plastic made with paper fiber scored highest overall for tensile strength. However, higher paper content made the sample more rigid. Plastic with cotton fibers was the most flexible overall, but strength went down as the percentage of cotton in a sample went up. Plastic with corn husk fibers had more strength as the percentage of fibers in the samples increased, but it was noticeably rigid for all ratios. Overall, Jacqueline thinks there's promise in upcycling cellulose fibers that would otherwise be thrown away.

Other Interests: "Learning martial arts has changed my life," Jacqueline says. She's currently working towards her second-degree black belt. "Yes, getting hit hurts," she says, but she knows she must keep going. "And this isn't limited to Martial Arts," she adds. "No matter what life dishes out, you have to keep going, to reach your goals and be successful in life." She enjoys competing in other areas as well, including Science Olympiad. Jacqueline hopes to become an environmental engineer.

KATIE QUINN

Louisville, Kentucky | Age: 12

Exploring Atrazine's Neurotoxicity as a Possible Cause of Parkinson's Disease

Project Background: The boxer Muhammad Ali was a hero in Katie's hometown of Louisville, Kentucky. He died of Parkinson's disease, or PD, which is a disease of the brain and nervous system. It affects movement, memory and mood. Katie also talked with a man who learned five years ago that he has the disease. He shared what it was like living with tremors and other symptoms. "He showed me how this disease affects real people and why it is important to discover what causes PD so we can prevent people from developing the disease," she says. She wondered if exposure to Atrazine might play a role. People use that chemical in weed killers on crops and lawns.

Tactics and Results: Katie worked with small flatworms called planaria. They "have a nervous system similar to the human nervous system," she explains. Katie gave high and low doses of the weed killer chemical to two experimental groups of worms, and a control group got none. After one, three and seven days, she measured the flarworms' responses to bright light. She also measured how far they moved in one minute. After a week, she put a bit of food in each petri dish. She timed how long it took each worm to smell and eat the food. The weed killer slowed the test groups' behaviors. "They were dose and time dependent," Katie notes. She then gave a medicine called Rytary to all three groups. The medicine boosts levels of a messenger chemical in the brain called dopamine. The medicine excited all the worms. When it wore off, the test groups' symptoms returned. "This is similar to Parkinson's disease," Katie says.

Other Interests: "I am interested in becoming a neurologist because this project has shown how important the nervous system is and how easily it can be damaged," Katie says. For fun, she plays the recorder and xylophone. She also enjoys sports, including basketball and volleyball. "I enjoy playing volleyball because I like the sport, and it is fun to play with my teammates," Katie says. She's active in Girl Scouts, and she volunteers for a group that helps refugees in her area.

LAURA MARIA REILLY-SANCHEZ

San Antonio, Texas | Age: 15

The Role of Tilapia Skin and UV Light on Tissue Regeneration and Wound Healing

Project Background: As a Girl Scout, Laura volunteers at a local hospital, where she visits veterans. Many of those people are in pain and have wounds that won't heal. Those wounds are at a high risk for infections. "This inspired me to look for ways to help with faster wound healing and tissue regeneration," Laura says. Some studies have shown that wound healing may be improved with ultraviolet light, which is also called UV light. Similarly, some studies suggest that the use of tilapia skin might help wounds heal faster. Laura decided to test these possibilities.

Tactics and Results: Laura did her experiments with a type of flatworm called *Planaria dugesia*. It can regrow parts of its body after an injury, and has been used in various studies on tissue regeneration and healing. Laura's hypothesis was that injured flatworms exposed to both UV light and tilapia skin would heal faster compared to other groups. Laura assigned some of the flatworms to control groups. She also set up test groups with flatworms who had been cut and flatworms who had been burned. Within those groups, she exposed some flatworms to a tilapia skin treatment and other subgroups to UV light. Some flatworms got both treatments. Over the next 24 days, Laura measured the flatworms' length, movements, and survival. She also tested the level of alkalinity or acidity in the flatworms' water. Her data showed that activity and regrowth were similar for the tilapia skin and UV light treatments. When she combined the two treatments, the flatworms' activity was "much improved," she says. Those flatworms grew longer as well.

Other Interests: "This is my tenth year dancing," Laura says. She especially likes ballet and jazz styles. She also stays active with cheerleading, swimming, and track. As a Girl Scout, Laura volunteers at a local Veterans Administration Hospital. She also does community service work at a shelter for homeless women and children. Laura plans to become a medical doctor. In her view, physicians "have the perfect combination." They plan treatment and care for patients. They're part of a team with other professionals. They can do research to advance science. And they can be leaders in their communities.

KENNEDY SOPHIA ROGERS

Douglasville, Georgia | Age: 13

Play It Safe: Detecting Concussion Prone Impacts in Youth Sports

Project Background: "I have a love for the arts, and I like figuring out how to make things work," Kennedy says. She used those skills to address a growing concern in youth sports. From 2010 to 2014, the number of concussions diagnosed for Americans under age 22 rose fivefold. Concussions result from hard blows to the head, which can cause the brain to slam against the skull. Serious injury or even death can result. Kennedy wanted a way to let athletes know if a hit had been hard enough to cause a concussion. "Knowing this information at the time of impact would allow an athlete to get immediate care and possibly reduce damage from repeated impact," she says.

Tactics and Results: "I designed a prototype for a device that can be worn when playing sports to assist with detecting impacts," Kennedy says. Sensors detect and register impacts. If a hit is hard enough, a buzzer will sound and lights will go on. To make the device, Kennedy used Arduino programming software with a LilyPad textile circuit board. It's a sew-on circuit board with electrically conductive thread and fabric. Her first design for a headband didn't work, so she switched to a cap design. That gave her more room for sensors and other parts. Kennedy programmed the board while it was still pieced together. However, getting the sensors, lights and buzzers to all work took patience. "Moving from one stage of testing to the next often resulted in one programming piece no longer working," she explains. After lots of debugging, Kennedy sewed the parts onto a cap. Then she tested the final prototype on a plastic foam head. The design worked – both lights and sound came on when there was a high impact.

Other Interests: "I love to take pictures," Kennedy says. Many of her shots are close-ups with cropped angles. "I enjoy this style of taking pictures because it allows you to see one thing from several different perspectives," she says. Kennedy's other artistic pursuits include playing the violin and saxophone. She also enjoys ballet, jazz and tap dancing, as well as running. She plans to become a computer scientist. "I like to code, and I like to explore," she says.

BENTLEY SIEMS

Lee's Summit, Missouri | Age: 13

Radiation's Effects on Bacteria Surface Area

Project Background: Trillions of bacteria cells make their homes in and on the human body. Some types are harmful and can cause diseases. But many other bacteria help the body stay in good health. Meanwhile, people get multiple medical tests and processes that use radiation. Some of those processes diagnose and track medical conditions. Some medical treatments also use radiation. So far, lots of research has studied the safety of those processes for people. But little research has looked at the possible effects on bacteria within the human body. Bentley decided to find out more. "Will radiation exposure disrupt the human bacteria ecosystem by eliminating harmful or helpful bacteria?" he asked.

Tactics and Results: Bentley worked with a harmless strain of a bacterium called *Escherichia coli*, or *E. coli*. He swabbed bits of the bacteria in petri dishes with agar. He put different types of radioactive diodes on the lids for his experimental groups. One group of dishes got polonium, which gives off alpha radiation. Another group got strontium, which gives off beta radiation. The third test group got a type of cobalt. It emits gamma radiation. Bentley also had a control group. He put his sealed dishes in an incubator for two weeks at a warm temperature. After two weeks he figured out the surface area of each colony in its dish. He'd thought the gamma radiation group would have the least surface area. However, those colonies had the largest surface area. Bentley also did an analysis of variance. It showed no statistically significant difference between the results for his three test groups and the control group. Therefore, he rejected his hypothesis. He thinks it would be interesting to try similar tests with radiation from an X-ray machine.

Other Interests: Bentley is a certified scuba diver. "Beneath the water's surface exists a fascinating and beautiful world with unusually diverse plants and animals," he says. "It's exciting, adventurous, and allows a greater depth of appreciation for marine life." He has also traveled across the country with his family to collect minerals and fossils. Beyond that, he enjoys flying drones, is learning to keep bees and plays the trumpet too. Bentley plans to become a zoologist.

ESPEN SLETTNES

Castro Valley, California | Age: 13

Minimal Embedding Dimensions of Rectangle K-Visibility Graphs

Project Background: Like many little kids, Espen loved playing with switches to turn things on and off. But that wasn't all. "At age five, I was playing with three consecutive light switches on the wall and tried to loop through all 23 = 8 combinations of switches with as few flips as possible," he says. "I ended up discovering a systematic way to do this flipping only one switch at a time, and then generalized it to more switches." In a similar way, his current project explores a math phenomenon at one level and takes it to higher dimensions. "My research project is in pure math and exploration-driven," he says.

Tactics and Results: Espen's project deals with rectangle (k-) visibility graphs. Two parallel rectangles within a set are visible to each other if their vertical or horizontal edges have lines of sight with each other when another parallel rectangle of some width is between them. (Imagine the lines of sight between the edges of two 13 x 19 cm cards with a 10 x 15 cm rectangle of some width centered between them.) Rectangle visibility graphs show that relationship for two or more rectangles in a set. Those and other types of visibility graphs can be helpful models for circuit boards, computer chip designs, and more. Espen explored the concept. Then he expanded it into higher dimensions. In particular, he looked at the bounds for d-dimensional rectangle k-visibility graphs. Those kinds of graphs show rectangles (or hyper-rectangles) in some d number of dimensions. The axis-parallel edge lines of the figures can intersect no more than some k number of rectangles (or hyper-rectangles). Espen plans to publish some of his work in a research journal.

Other Interests: Espen stays active with badminton, soccer, track and cross country. He loves music and plays the cello and piano. He also enjoys both hip hop and ballroom dancing. Espen plans to become a mathematician. "I enjoy abstract thinking and the process of finding and proving mathematical truths," he says. As he sees it, mathematicians contribute to human knowledge in ways that can make the world a better place.

PRATIK VANGAL

Portland, Oregon | Age: 15

Ameliorating Acute Respiratory Infections from Solid Biomass Fuel Combustion and Empowering Rural Kitchens with a Sustainable, Cost-Effective Ventilation Solution

Project Background: "The World Health Organization (WHO) estimates around 3 billion people are exposed to toxic smoke from burning solid biomass fuels in rural kitchens worldwide," Pratik reports. That smoke poses serious health risks. Indeed, the smoke causes millions of premature deaths each year, he adds. He saw some of those smoky kitchens when he visited a small village in India last year. "The women complained of breathing discomfort, chest pain, cough and eye irritation from chronic smoke exposure," Pratik says. A switch to a cleaner energy would help. Better ventilation would improve indoor air quality as well, he says.

Tactics and Results: Pratik designed a low-cost ventilation system with recycled solar cells and cooling fans from retired computers. Many rural homes don't otherwise have electricity, he says, and new solar cells are pricey. Yet millions of wafers for those cells are recycled, tossed or sold cheaply each year because of minor defects, he notes. So, he learned how to reuse scrap photovoltaic (PV) wafers. He built the exhaust fan of the system with parts from old desktop computers. He connected several fans in parallel and put them onto an air-exhaust panel. Once he got everything hooked up, he tested the system. First, he made sure his PV system would make enough power. Then he tried it out with a rural kitchen model he built with cardboard. "To mimic biomass fuel smoke, I used smoke-making fireworks to fill the kitchen with soot," he notes. The system cleared the kitchen of smoke in less than a minute. Pratik also designed a software app to help people learn about the comparative risks from biomass fuels.

Other Interests: Pratik hopes to become a neurologist. "The human brain has always intrigued me," he says. He loves playing classical piano music. "It helps unclutter my mind and allows me to focus better," he says. Pratik has been in Boy Scouts for several years and enjoys outdoor activities with the troop. He also volunteers regularly at a local food bank. He relishes a good game of chess, and enjoys swimming, basketball, fencing and tennis.

AKSHAYA VENKATESH

Scottsdale, Arizona | Age: 14

A Novel Mobile App to Minimize Food Waste and Maximize Harvest

Project Background: Akshaya's family shares some of their backyard garden harvest with neighbors. Some of the extra fruits and vegetables also go to her local temple. But she saw how many other people wasted their food. "According to a 2016 EPA study, America throws away more than 38 million tons of food produce every year," she reports. That figure includes lots of spoiled produce. With that in mind, she set out to design a phone app that can help local food banks gain access to the excess food. Akshaya hopes that the app will help keep surplus produce from going to waste.

Tactics and Results: Akshaya's app lets users list the type of produce they have, their address, and other information. When someone at a local food organization signs in, that person can see where donations are available. Then the organization can send its staff or volunteers to each pickup spot to collect the produce. To develop the app, Akshaya worked in a programming environment known as Xcode. She created her app with a programming language called Objective C. She also used a variety of other tools, including the Cocoa Touch Framework, AWS cloud web services, and MySQL for data storage. She then made arrangements with a non-profit food produce rescue group in her area to collect food donations listed on the app. Family, friends and neighbors agreed to list donations for the initial test. The field test worked well. "By using my app, the organization can send people to harvest and pick up the fruits and veggies to distribute to the needy," she says. She hopes to scale up the app for more widespread use.

Other Interests: Akshaya volunteers her time collecting fruit from agreeable neighbors' yards for local refugee camps and other people in need. She also teaches coding skills to refugees in her area. "I most enjoy dance and singing," she says, especially Indian classical dance, Indian classical songs, and American songs. She plays violin and participates in tennis, swimming and gymnastics. She would like to become a biochemist. "Learning about the things that make up your body and life has always been fascinating to me," says Akshaya.

LEO WYLONIS

Berwyn, Pennsylvania | Age: 14

"Make Airplanes Great Again:" Optimizing and Controlling Aircraft Wing Shape and Efficiency In-Flight through Novel Polymer Artificial Muscle Actuators

Project Background: When Leo was little, he often experimented with the wing flaps and elevators on paper airplanes. Different adjustments could make the plane fly better. Last year, he read about polymer artificial muscles (PAM). Polymers are chains of smaller, repeating chemical units. Many plastics are polymers. "Polymer artificial muscles contract when heated, and have a very high strength to weight ratio," Leo says. He wondered if he could use the shape-shifting material to control an airplane wing. A PAM actuator inside it would make the back edge of the wing flex down or up. If it worked well, the device could lead to lighter, more fuel-efficient airplanes.

Tactics and Results: Leo used polymer artificial muscles to build an airplane wing actuator, which is the part that controls the wing's movements. The polymer muscles have a heating wire wrapped around them. The device also has carbon fiber rods and a housing that Leo made with 3D-printing. In addition, he designed and built a remote-controlled model airplane. Leo's device lets the artificial muscles move a rod that connects to the outer ribs of the model aircraft wing. He also put sensors in the wings to collect data during test flights. The data let him analyze the effects on lift and drag. In addition, Leo made videos of his test flights. "I was able to see real-life effects of the wing-twisting design," he says. He knows that much more research and engineering must take place before the concept can be used in a commercial aircraft, yet he feels his project is a good start. "Using the new design, airplane efficiency may be controlled during different phases of flight," Leo says.

Other Interests: "I am most interested in being a mechanical engineer because I have always enjoyed working with my hands," Leo says. He plays both the piano and French horn. He also does volunteer work on trails at parks in Pennsylvania. "I really enjoy mountain bike racing on my local NICA team," Leo says. He's proud of how he improves his racing times over the season, and he's glad to use his mechanical skills to help teammates fix and adjust their bikes.

GARY ZHAN

Logan, Utah | Age: 14

The Colder, the Bluer–Significant Enhancement of Indigoidine Production Using a Cold-Shock Inducible Promoter

Project Background: "My best friend is allergic to everything containing synthetic dyes," Gary says. Those dyes are in toys, clothes, food, drinks, paper and other products most of us use every day. A dye called Blue 1 is especially problematic for Gary's friend and other people. One natural alternative is called indigoidine. Bacteria can make it, and it has a bright blue color. "However, indigoidine is still too expensive for industrial applications," Gary says. His project aims to make the process more efficient to lower the cost. The strategy: Get the bacteria to do more work with the same resources.

Tactics and Results: Gary tinkered with how to trigger when bacteria start making the blue dye indigoidine. Plasmids are rings of double-stranded DNA, or deoxyribonucleic acid. As in longer DNA chromosomes, amino acids on plasmid DNA spell out a genetic code. In this case, part of the code tells the cell to make the dye. But something has to trigger the process. That's done with a sequence of DNA code called a promoter. Unfortunately, the promoter currently used often starts working too soon. It tells the cells to make the dye while they're still growing at a warm temperature. But the dye molecule can only fold properly when it's cooler, so an early start wastes some of the cells' energy and resources. Instead, Gary introduced a different promoter into a plasmid. He then inserted it into bacteria and tested his new process. Gary's new system worked best at 18° Celsius (64° F). And it boosted production of the dye by about 28 percent over the current method.

Other Interests: Gary has played the piano since he was five years old. "A piano allows me to express my feelings through music and allows me to tell a different story every time," he says. He also plays the guitar and sings in the choir. For sports, Gary enjoys soccer, tennis and swimming. He also volunteers at an assisted living community in his area. "I would like to become a synthetic biologist in the future," he says.

2018 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 seventh 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 seventh 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.

About Broadcom Foundation

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.

The foundation inspires young people to pursue careers in STEM and to develop 21st Century skills of critical thinking, collaboration, communication and creativity. It is a founding member of the National STEM Funders Network and plays a leadership role in the STEM Education Ecosystem Initiative in the U.S. and Israel.

The foundation's signature programs, the Broadcom MASTERS® and the Broadcom MASTERS® International, are the premier science and engineering competitions for middle school students around the United States and the world.

Learn more at **www.broadcomfoundation.org** and follow us on Twitter **(@BroadcomSTEM).**

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The Society for Science & the Public is a champion for science, dedicated to expanding scientific literacy, effective STEM education and scientific research. Founded in 1921, we are a nonprofit 501(c)(3) membership organization focused on promoting the understanding and appreciation of science and the vital role it plays in human advancement. Through its acclaimed science research competitions, including the Regeneron Science Talent Search, the Intel International Science and Engineering Fair, and the Broadcom MASTERS, and its award-winning magazine, *Science News* and digital media properties, *Science News for Students*, the Society is committed to inform, educate and inspire.

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