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

The foundation inspires young people to pursue careers in science, technology, engineering and math (STEM) through its signature programs, the Broadcom MASTERS® and the Broadcom MASTERS® International, premier science and engineering competitions for middle school students around the United States and the world.

Learn more at www.broadcomfoundation.org

About Society for Science & the Public
Society for Science & the Public is a 501(c)(3) nonprofit membership organization, dedicated to the achievement of young researchers in independent research and to the public engagement in science. Established in 1921, its vision is to promote the understanding and appreciation of science and the vital role it plays in human advancement. Through its acclaimed education competitions, including the Regeneron Science Talent Search, the Intel International Science and Engineering Fair and the Broadcom MASTERS, and the Science News media group, including the award-winning Science News and Science News for Students, the Society is committed to inform, educate and inspire.

Learn more at www.societyforscience.org
2016 FINALISTS
Society for Science & the Public thanks the following for their support:

**Title Sponsor**
- Broadcom Foundation

**Supporters**
- The Lemelson Foundation
- Robert Wood Johnson Foundation
- Samueli Foundation
- Allergan
- Deloitte.
- KPMG
- Science News for Students
- Wolfram Research

**Educational Partners**
- Computer History Museum
- Georgetown University School of Medicine
- Smithsonian Environmental Research Center
- 300 Affiliated Regional and State Science & Engineering Fairs and the 6,000 students nominated across the United States
- Parents, teachers and mentors of the 2,343 Broadcom MASTERS entrants

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About Broadcom MASTERS

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.

Society-affiliated science fairs around the country nominate the top 10% of sixth, seventh and eighth grade projects to enter this prestigious competition. After submitting the online application, the top 300 semifinalists are selected.

From the semifinalist group, 30 finalists are named and will present their research projects and compete in hands-on team STEM challenges to demonstrate their skills in critical thinking, collaboration, communication and creativity at the Broadcom MASTERS finals. Top awards include a grand prize of $25,000, trips to STEM summer camps and more.
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2016 Broadcom MASTERS FINALISTS

DAVIA ALLEN
Early County Middle School
Georgia State Science and Engineering Fair

AKHILESH V. BALASINGAM
Challenger School, Strawberry Park
Synopsys Silicon Valley Science and Technology Championship presented by the Santa Clara Valley Science and Engineering Fair Association

MAYA S. CHANDAR
Canterbury School, Fort Myers
Thomas Alva Edison Kiwanis Science and Engineering Fair

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

NATHAN K. DENG
Henry E. Huntington Middle School
Los Angeles County Science and Engineering Fair

ARIA EPPINGER
Winchester Thurston School
Covestro Pittsburgh Regional Science & Engineering Fair

JAMES FAGAN
Alcott Elementary
Riverside, Inyo, Mono, San Bernardino (RIMS) Science and Engineering Fair

SIENNA FINK
St. Joseph School Fullerton
Baltimore Science Fair

ANANYA GANESH
The Westminster Schools
Georgia State Science and Engineering Fair

ADISHREE GHATARE
Challenger School, Shawnee
Synopsys Silicon Valley Science and Technology Championship presented by the Santa Clara Valley Science and Engineering Fair Association

JOAQUIN HACES-GARCIA
Santa Gertrudis School
Coastal Bend Regional Science Fair

NADINE HAN
Boston Latin School
Massachusetts Region VI Science Fair

SAMUEL KAHN
High Tech Middle
Greater San Diego Science and Engineering Fair

OLIVIA LAZORIK
Saint Edward’s School
Indian River Regional Science and Engineering Fair

ETHAN LEVY
Aventura Waterways K-8
South Florida Science and Engineering Fair

OMAR MAJZOUB
Franklin Fine Arts Center
Chicago Public Schools Student Science Fair

SONJA MICHALUK
Timberlane Middle School
Mercer Science and Engineering Fair

ASHINI MODI
Caddo Middle Magnet
Louisiana Science and Engineering Fair

ANUSHKA NAIKNAWARE
Stoller Middle School
Beaverton-Hillsboro Science Expo

NIKOLAI ORTIZ
Seashore Middle Academy
Coastal Bend Regional Science Fair

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2016 Broadcom MASTERS Finalists
AALOK NITAL PATWA
Stratford Middle School
Synopsys Silicon Valley
Science and Technology
Championship presented
by the Santa Clara Valley
Science and Engineering Fair
Association

RACHEL PIZZOLATO
John Curtis Christian School
Greater New Orleans Science
and Engineering Fair

SHREYA RAMACHANDRAN
Stratford Middle School
Synopsys Alameda County
Science & Engineering Fair
cosponsored by Lawrence
Livermore National Laboratory

LUCAS RITZDORF
Kalispell Middle School
Montana Science Fair

ELEANOR WREN SIGREST
Louise A. Benton Middle
School
Prince William-Manassas
Regional Science Fair

SANTIAGO STONE
St. John the Evangelist
Anne Arundel County Regional
Science and Engineering Fair

EMHYR SUBRAMANIAN
Challenge School
Denver Metropolitan Regional
Science and Engineering Fair

DAVEN YADAV
The Westminster Schools
Georgia State Science and
Engineering Fair

KAIEN YANG
Nysmith School for the Gifted
and Talented
Fairfax County Elementary and
Middle School Science and
Engineering Fair

2016 Broadcom MASTERS Finalists

2016
JUDGING PANEL

WILLIAM WALLACE, PHD
Judging Panel Chair
Georgetown Day School

RHONDA DZAKPASU, PHD
Department of Physics
Georgetown University

SARAH JUDD, BS
Curriculum Developer
Girls Who Code

SUSAN E. MULRONEY, PHD
Physiologist
Georgetown University
Medical Center

PATRICK L. MURPHY, BSEE/MBA
NASA Aerospace Technology
Engineer
NASA Headquarters

MELANIE HARRISON OKORO
Environmental Scientist
National Oceanic and
Atmospheric Administration

LYNDA SMITH, MS
Lead Teacher, Science Teacher
Lakeshore High School Math &
Science Center
Why Middle School?

Broadcom MASTERS® is the premier competition for middle school students, where students demonstrate their mastery of math, applied science, technology and engineering through science fair competition.

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 careers in science, technology, engineering and mathematics.

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 schoolers are invited to compete for awards and accolades in Broadcom MASTERS when they compete at their local Society-affiliated science and engineering fair.

At the competition finals for Broadcom MASTERS in Washington, DC, the winner is awarded the $25,000 Samueli Foundation Prize.

The Process

To participate in Broadcom MASTERS, sixth, seventh and eighth grade students complete an independent science or engineering project, then enter their regional or state Society-affiliated science fair. Judges select the top 10% of these competitors as nominees in the Broadcom MASTERS, of which over 6,000 were named in 2016.

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Thirty competitors are selected from the top 300. Finalists receive an all-expense-paid trip to Washington, D.C. to showcase their projects, compete in teams and visit historical sites that celebrate innovation.

Awards

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

- **Samueli Foundation Prize of $25,000**, which recognizes the top middle school student from this premier group of 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.
- Two students in each STEM discipline are awarded first and second place awards for a combined $30,000 in experiential or product awards for their ability and promise in each of the disciplines, presented by Allergan.
- **Rising Star Awards** are presented to two sixth or seventh grade students to represent the United States as Broadcom MASTERS International delegates. They will travel as student observers to the Intel International Science and Engineering Fair in Los Angeles, California in May 2017. These Rising Stars will be among a select group of Broadcom MASTERS International delegates from around the world.

Awards Honoring Finalists’ Schools and Teachers

In recognition of the important contributions by teachers to STEM education and their support of the Broadcom MASTERS competitors, each of the 30 finalists’ schools will receive $1,000 from the Broadcom Foundation. Additionally, their teachers will be awarded with a classroom subscription to Science News magazine. The teacher of the Samueli Foundation Prize recipient receives $1,000, courtesy of Deloitte.
DAVIA ALLEN
Blakely, Georgia | Age: 14

Comparing Three Different Vegetable Protein Flours as Additives to Increase the Efficiency of Food Waste as a Feed for Black Soldier Fly Larvae

Project Background: “Industrialized countries waste food while people in underdeveloped, drought stricken, or war-torn areas starve,” reports Davia. “If only there were a way to get wasted food to those in need without spoilage.” Her project explores one indirect way that could make that happen. Young black soldier flies eat food waste — and lots of it. As a result, their bodies grow to have a protein content of 40 percent or more. The insect larvae can be frozen or dried for later use as a feed for poultry or fish. Davia wondered whether giving the hungry larvae vegetable protein additives could make the process more efficient.

Tactics and Results: Davia decided to compare soy, quinoa and peanut flours as supplements to black soldier fly diets. She divided 3,000 black soldier fly larvae into 12 groups of 250 larvae each. She weighed each group to determine their starting weights. Then she set up identical conditions for each group and fed them daily. Three groups served as a control, and they ate vegetable and fruit waste only. Three of each of the remaining nine groups ate vegetable and fruit waste plus one of the supplemental flours. Every three to seven days, Davia separated the larvae from the food, put them in clean containers and weighed the insects. Just before the insects were ready to form pupae, she weighed them for the last time. “Soy flour seems to hold the most promise for increasing larvae size and growth rate while maintaining larvae health,” Davia reported. Although the peanut flour group gained weight faster, that group also had the greatest number of deaths or escapes.

Other Interests: “I have yet to try a sport I do not like, even when I am not the most proficient on the team,” Davia notes. She’s active in cheerleading, cross country, track, tennis and basketball. In addition to her athletic and academic pursuits, she plays the piano and enjoys church activities. As a future career, Davia says, “I want to study medical science combined with human nutrition so that I can help medically impoverished areas.”

Akghilesh V. Balasingam
San Jose, California | Age: 13

Galloping Prisms: On the Optimal Design of a Novel Aeroelastic Energy Harvester for Remote Environmental Sensing

Project Background: Networks of electronic sensors help scientists collect data to study many types of environmental issues. Those data can let researchers monitor conditions even in remote places or over widespread areas. Sensors don’t require a lot of electricity, but it can be a challenge to power them with batteries that need changing. “So, I invented a low-maintenance, small-scale, on-site generator,” Akghilesh says.

Tactics and Results: Akghilesh’s portable generator starts with a cantilevered beam made of flexible brass. One can think of it as a springy diving board made of metal. A lightweight prism is on the free end of the beam. When air flows around the prism, aerodynamic forces interact with the elastic qualities of the beam, which causes the beam to move. A device on the beam, called a piezoelectric transducer, converts that energy into electricity. Akghilesh built several prototypes of his device to test. That way, he says, “I could change beam lengths and prism sizes systematically while keeping other variables fixed.” Akghilesh incorporated a wind tunnel he built in his tests, and used slow-motion video analysis and smoke tests to see how each prototype performed. He collected data on each trial and found that the best design produced enough electricity for up to five LED lights.

Other Interests: Starting with the primary colors of red, yellow and blue, Akghilesh enjoys mixing precise earth tones and other hues for his oil paintings. He is athletic and enjoys both soccer and squash. “I love playing squash because it is fast paced,” he notes. “The ball bouncing off the walls brings excitement and unpredictability.” Akghilesh plays the violin and enjoys singing, and partakes in various school activities. He also volunteers at an assisted living and nursing facility for the aged. “I learn life lessons from the elderly” through that service, he notes. Akghilesh hopes to become an environmental engineer. He says, “I am now excited about dedicating my career to developing technologies for monitoring and protecting our environment.”
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The Effects of Ultrasound Waves vs. Laser Beams on the Regrowth of Lumbriculys variegatus (A Novel Study)

Project Background: Energy is all around us in different forms, and different frequencies can affect living organisms in positive or negative ways. On the positive side, for example, ultrasound and laser energy frequencies have been used in certain kinds of therapies. Maya decided to see if those forms of energy could help speed up mitosis, or cell division, to repair tissue. She worked with a model organism, the California blackworm.

Tactics and Results: California blackworms often reproduce by regeneration. When a worm breaks apart, it can usually grow a new head or tail. Working under supervision, Maya cut 30 worms at a point 50 percent along their length. The incision would start the regeneration process. Over the next three weeks, she exposed one Petri dish with ten regenerating worms to seven-minute treatments of ultrasound waves. During that same time period, she exposed ten worms in another Petri dish to five-minute treatments with helium-neon laser light. Ten worms in a third Petri dish were not treated at all, and served as a control group. Maya made repeated measurements of the worms to track their growth. “The ultrasound group healed the fastest,” Maya reports. One possible explanation is that the energy caused pressure changes that may have helped repair the cell membrane. The laser treatments also helped speed up the cell division needed for regrowth. “But it was much slower compared to the ultrasound,” Maya notes. She is now curious about how ultrasound energy might speed cell differentiation in stem cells.

Other Interests: “I love reading and playing the flute because they transport you to different worlds,” says Maya, “whether you are reading the Harry Potter series or playing ‘Farewell to Dobby.’” She also enjoys sports, especially track and basketball. “If you are part of a team, the key to winning is effective and clear communication,” she says. Maya hopes to become a medical doctor. “I want to be one of those people who can take control of the situation and give the gift of health to others,” she says.
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MAYA S. CHANDAR
Cupertino, California | Age: 13

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A Novel Method for Reducing Water Consumption in Germinating Seeds

CYNTHIA CHEN
Cupertino, California | Age: 14

Project Background: Cynthia’s home state of California is experiencing a drought, and about 80 percent of water usage is for farming, she reports. “If I could even slightly reduce the amount of water consumed by crops, it would have a significant impact,” Cynthia says. Toward that end, she developed a small capsule in which a seed could germinate and grow while using less water.

Tactics and Results: Cynthia put seeds into biodegradable pods filled with soil. Each pod went into a flexible, biodegradable filter. Between the pod and the filter was a layer of hydrated water crystals, a material that absorbs and retains water. “Because of the proximity of water crystals, more water would be able to enter the soil and centralize at the seed, and thus hydrate the seed more efficiently,” Cynthia explains. She made capsules for three types of seeds: kidney beans, field corn and squash. She planted groups of each type of seed capsule, as well as control groups of plain seeds. The groups received 5, 10 or 15 milliliters of water every two days. In each group, Cynthia tracked how many seeds germinated and the number of days it took for them to germinate. Each species of seed capsules in the group that received only 5 milliliters per watering grew at the same rate as the plain seeds that got 15 milliliters. Seeds in capsules also had a higher success rate for germination and germinated faster. “I concluded that the capsule can save two-thirds of the water while achieving the same results,” Cynthia reports.

Other Interests: Cynthia says her volleyball team is like a second family. “Our joy, laughter and tears bond us into an inseparable group,” she says. Previously, Cynthia played violin with the California Youth Symphony. She hopes to one day start a company on the forefront of a subject in science, technology, engineering and math (STEM). Her company would encourage more women to take part in STEM careers, an issue of great importance to her.
BRENDAN CROTTY
Muskogee, Oklahoma | Age:14

Comparative Study of Insulating Materials for a Gas Forge

Project Background: Brendan’s passion for the centuries-old craft of blacksmithing inspired his modern materials engineering project. When blacksmiths heat metal to very high temperatures in forges, the metal becomes malleable, or softer. This allows the blacksmith to hammer, press or bend metal into different shapes. Commercially available forges are expensive, Brendan notes. Forges must be insulated because they become extremely hot. Brendan tested different possibilities for insulating a homemade forge with a “mix that would be safe, economical and effective.”

Tactics and Results: Starting with 16-ounce cans, Brendan made seven test forges. He fitted each with a tube for a propane torch. He then lined each can with a different insulating material to a thickness of 3/4-inch (about 2 cm). After that, Brendan tested each forge. To start, he heated each forge for 12 minutes. At each minute mark, he measured the external temperature of the can with an infrared thermometer. “The lowest temperature rise indicated the material with the best insulating properties,” Brendan explains. Three of the lining materials failed because the material bubbled during heating. For the remaining four forges, Brendan inserted a small piece of steel at the 12-minute mark. He timed how quickly each piece became “yellow hot,” indicating a temperature of 1,800 degrees. The sooner that happened, the better the lining’s heat retention and reflectivity, Brendan reasoned. He also reviewed Material Safety Data Sheets to gauge the relative safety of different linings. Results showed that a commercially available ceramic fiber had the best heating qualities. However, Brendan preferred a particular mix of perlite, sodium silicate, aluminum oxide, plaster and talc. He found that that material was a better insulator and also less expensive and safer.

Other Interests: Brendan hopes to run his own metal fabrication business someday. “This career would allow me the ability to create anything that I can imagine,” he says. “It is also important to me to preserve the lost art of metal working in any way possible.” Brendan is an accomplished Irish dancer who has participated in a variety of competitions. He also plays piano and guitar.

NATHAN K. DENG
San Marino, California | Age:14

Cleaning has always fascinated Nathan. This is true whether he is washing dishes at home or reading about oil spill clean-ups. Both of these jobs typically use chemicals called surfactants — chemicals that break up the surface tension of a liquid, breaking up big drops. Surfactants also grab onto grease to help water wash it away. Unfortunately, some surfactants can be toxic to ecosystems when mixed with oily compounds. Nathan set out to find an efficient cleaning method that is sustainable and environmentally safe.

Tactics and Results: “Lowering surface tension is the key to effective cleaning, because it allows water to permeate through the crevices of dirty objects,” Nathan notes. To see how well different approaches could do that, he needed to measure surface tension. The smaller the weight of the drops formed by a liquid, the less surface tension that liquid would have. Existing measuring options were too crude or costly, so Nathan designed his own equipment that uses a syringe, flexible tubing, a thermometer and a precise scale. He then tested how different temperatures affect the surface tension of distilled water. Nathan found that as temperature increased, surface tension decreased at a steady rate. He also tested the effects of varying concentrations of a surfactant and salt, each on their own and also in combination with each other. Using a surfactant alone lowered the water’s surface tension. A combination of surfactant with a bit of salt worked even better. Nathan reasons that that could save money and possibly reduce environmental impacts. Since his device worked well, he’s now planning to improve it and hopes to package it as an affordable kit that others can use.

Other Interests: Nathan loves hiking and tennis. He is passionate about music and has played the piano since kindergarten. He also takes part in scouting and other activities. “I want to be part of a new generation of green chemical engineers who will create and develop chemicals that improve people’s lives, the economy, and industry, while keeping the environment safe and sustainable,” Nathan says.
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Drop by Drop: Manipulating the Surface Tension of Water to Find the Best Way of Cleaning

Project Background:
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ARIA EPPINGER
Pittsburgh, Pennsylvania | Age: 15

Roundup®’s Effect on Human Gut Bacteria

Project Background: Roundup® is a weed killer that works on a wide range of plants. “Roundup Ready” crops are genetically engineered so that the weed killer won’t hurt them. Farmers can spray Roundup® over fields of those crop varieties to control weeds, and the crops will still grow. Although farmers have used Roundup® since the 1970s, some recent studies question its safety. Findings suggest it could lead to an imbalance in beneficial and harmful gut bacteria in farm animals. Aria then wondered how the weed killer might affect the balance of gut bacteria in humans.

Tactics and Results: Aria grew two types of bacteria found in the human gut. She chose *C. sporogenes* as her model beneficial species and *E. coli* as the model harmful species. Water and an antibiotic served as positive and negative controls. Aria let the bacteria colonies grow for 24 hours at the same temperature. She subjected her experimental groups to five different dilutions of Roundup®. Every ten minutes, she took readings from a colorimeter, a device which measures the intensity of color. The more the bacteria in each sample grew, the more it would absorb certain wavelengths of light and emit color. Aria collected data over the course of 12 hours for each of three trials. She made adjustments to control for each species’ growth rate. Then she calculated the concentration of weed killer that would inhibit growth for half of each bacteria colony. The dose that inhibited the beneficial bacteria was more than an order of magnitude smaller than that for the harmful bacteria. “My work suggests that Roundup® could throw off the good-bad gut bacteria balance in people and potentially lead to serious diseases like cancer, diabetes, obesity, anxiety and depression.”

Other Interests: “I’m a musical foodie born with gills,” jokes Aria. She enjoys swimming, playing the violin and viola, and cooking. “Nothing beats homemade fresh mint chocolate ice cream in the summer!” she says. Math is Aria’s favorite subject at school, and she hopes to become a biostatistician. “Biostatisticians have the best of both experimental science and math occupations,” says Aria.

Project Background: “Mars has always fascinated me,” James says. News of NASA’s Mars 2020 Rover mission got him thinking. “Why doesn’t NASA send a reusable drone to Mars?” This would allow the drone to fly on multiple observation missions. “I believe this drone would increase Martian exploration capabilities significantly, as well as complement current rover missions,” James notes. James tested different aircraft wing designs to see what might work best on Mars.

Tactics and Results: The atmosphere on Mars is only about 1/100th as dense as that on Earth, James reports. So, an aircraft on Mars would need as much lift as possible in order to take off. To collect data, James built two wind tunnels. A horizontal tunnel measured the aerodynamic lift force generated on an airfoil. A second wind tunnel in a vertical orientation measured drag. For testing, James built 18 different airfoils. He varied the surfaces, geometric shapes and cambers, or curves, on the different designs. Each had a chord length of three inches and also had magnets glued to it. James used those magnets to attach the airfoils to corresponding magnets glued to six dowel rods. Each rod was cut so James could test his airfoils at different angles of attack relative to the air flowing through the wind tunnel. Based on his research and experiments, James concludes that his idea for a Martian drone aircraft would work. The best airfoil design he tested had a “frontal biased” camber, meaning more of its volume was toward the front. That airfoil’s trailing edge also directed air flow downward.

Other Interests: “Some of my favorite extracurricular activities include drawing, reading, and math,” James says. He enjoys soccer and softball. James is also an avid chess player. He hopes to become an aeronautical engineer. “I get excited about my wind tunnel experimentation, and the scientific principles that I’m learning, but I dream about the possibility of designing an entirely new aircraft that might actually fly in the Martian sky someday!” says James.
JAMES FAGAN
Riverside, California | Age: 10

A Wind Tunnel to Test for the Best Aerodynamic Characteristics for Flight on Mars

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Other Interests: “Some of my favorite extracurricular activities include drawing, reading and math,” James says. He enjoys sports and is active in both soccer and softball. James is also an avid chess player. He hopes to become an aeronautical engineer. “I get excited about my wind tunnel experimentation, and the scientific principles that I’m learning, but I dream about the possibility of designing an entirely new aircraft that might actually fly in the Martian sky someday!” says James.
When Your Christmas Tree Gets Drier, It Increases the Chance of Fire

**Project Background:** After a Christmas tree fire killed a family in her area, Sienna was prompted to investigate how to prevent such a tragedy. Holiday trees lead to about 210 home fires each year in the U.S., according to the National Fire Protection Association. On average one in every 31 of these reported fires results in death, Sienna adds. She studied how a lack of water affects the risk of Christmas trees catching fire. “With this evidence, I thought I could help inform people of the dangers surrounding dry Christmas trees and help them be safer,” she says.

**Tactics and Results:** Sienna cut 18 even lengths of pine tree branches and divided them into six sets. One set received no water after cutting. The other sets were placed in water and were removed one at a time over the course of five weeks. Afterward, Sienna measured the moisture content of one branch from each set. To do that, she weighed each selected branch and baked each of them for three hours to remove any moisture. Then she weighed the branches again. “The sample that remained hydrated contained over 50 percent water by mass, while samples without hydration for as little as a week contained less than half of that amount,” Sienna says.

Next, Sienna put each branch over a lit can of Sterno® and timed how long the branch took to start burning. Additionally, she timed how long each branch kept burning. After all samples were cool, she weighed each branch again. “Drier branches ignite faster,” Sienna reports. “The drier a tree, the more mass the resulting fire will burn per second,” she adds.

**Other Interests:** “The hobbies I enjoy most would be drawing and animating,” Sienna says. “Doing these activities relieves stress.” In addition to scouting, student council and other activities, Sienna plays the flute and is in choir. She hopes to become an emergency medical technician. “I think that I could be an effective paramedic because I am often able to maintain my composure in extremely stressful situations when critical action is required,” Sienna says.

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**Project Background:** “I am a habitual jaw clencher,” says Ananya. This condition is called bruxism, an overuse of a jaw muscle that has led to jaw pain, migraines and sore teeth for Ananya. Her partner, Daven Yadav, has a sister with bruxism. Together, Ananya and Daven set out to design a non-invasive way to measure overexertion of the jaw muscle. A device with the system could alert someone to the issue, which could lead the person to modify their behavior, the team believes.

**Tactics and Results:** Ananya and Daven reasoned that as the jaw muscle tires from overexertion, the electric signal it generates would decrease. Before designing a device based on that hypothesis, they had to test the concept. To do that, the pair designed a circuit board to record electric signals detected by sensors. After recruiting six volunteers at school, they attached electrodes to skin near a forearm muscle. Each person flexed that arm hard for a standard time period. Then Ananya and Daven attached the electrodes to the volunteers’ faces near the jaw muscle. They told the subjects to clench their jaws, and light displays and sounds signaled when to relax. As Ananya and Daven expected, amplitude of the electric signals from the muscle contractions decreased over time. That showed that fatigue had set in. Much more work would be necessary to make a practical biofeedback device, including more testing and extensive design details. Most importantly, the team achieved the first big step: they showed a correlation between measurable electric signals from the jaw muscle and muscle fatigue. Ananya feels the device could help jaw clenchers “break the habit and cure the pain.”

**Other Interests:** “The hobbies I enjoy most would be drawing and animating,” Ananya says. “Fishing lets Ananya relax and spend time with her father. Yet ‘the outcome can be completely unpredictable,’” she says. In addition, “I like woodworking because it allows me to create what I can imagine.” She is interested in many sports, including archery, and she makes pens from broken arrows for sick children. Ananya also plays the clarinet and tenor saxophone. She plans to become a biomedical engineer.
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ADISHREE GHATARE
San Jose, California | Age: 14

A Software Application as a Learning Platform for Increasing Memory Retention of Definitions of Words

**Project Background:** When Adishree was preparing for a national vocabulary bee, she had to learn the meanings of 1,000s of words. Even after having tried different learning tools and techniques, she says, “I had trouble remembering words in the long term.” The experience led her to research how people remember information such as vocabulary words. This led Adishree to develop her own application to help people learn and remember vocabulary words.

**Tactics and Results:** For each word, users of Adishree’s app can make different types of “cards.” She uses a story method to have users create conversation bubbles to tell a story involving the word. Some methods explain a word’s etymology, its origin and background, while other methods let users create images they would associate with the word or connect the word with a phrase. Adishree tested her app with volunteers who learned six new words to study with her app. She tested each subject’s knowledge of the word after they used the app, and ran follow-up tests three days later. As a control, Adishree also gave each person an additional six words to study through their own preferred method. Adishree recorded all of the data and then analyzed it. “All of my test subjects achieved better recall scores using my app over their preferred method,” she reports. Three days after learning words with Adishree’s app, almost all of the volunteers remembered most of those words, with an average score of 5.59 out of 6. In contrast, they remembered an average of only 2.47 words three days after learning them with their own preferred method.

**Other Interests:** Adishree has been programming since fourth grade, and she hopes to become a computer scientist. She serves on student council and volunteers in the community. Additionally, she plays the piano and violin, runs half marathons, swims competitively and studies Indian classical dance. “I can build a story through dance and music,” Adishree says.

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**Project Background:** A news story prompted Joaquin’s idea. When a father mistakenly left his four month-old baby inside the family car, tragedy followed. “The temperature inside the vehicle can increase rapidly, reaching high temperatures that cause heat stroke to infants,” explains Joaquin. “There should be a way to make drivers remember when they have a baby in the car to avoid future tragedies,” he thought. Towards that end, Joaquin set out to design an alarm that would warn people if they forgot to take their baby out of the car seat.

**Tactics and Results:** In order for his alarm system to work, Joaquin needed a way for it to detect when a baby was in a car seat. He tried working with a weight sensor, but it produced too many false positives. For example, the alarm might go off if a baby moved in the seat, or if a driver rested objects on the car seat. After more research, Joaquin decided to use a magnetic sensor, which could be activated when the seat belt was closed. He also decided that the system should hook up with a car alarm system, instead of a phone or other device that might be turned off or could malfunction. If a driver tried to lock the car while the baby was still strapped in, “the car alarm system would start sounding, and the car would not lock,” he explains. Now that his prototype works, Joaquin’s next engineering project will be hooking it up to the alarm system of an actual car. “I want to help parents avoid the risk of forgetting by accident,” which could change the family’s lives forever, he says.

**Other Interests:** “I enjoy playing team sports, such as baseball and basketball, because I like doing exercise and competing alongside with my teammates to get the best results,” says Joaquin. He plays in the school band and also volunteers for a soup kitchen in his hometown. Joaquin hopes to become a mechanical engineer. “I love to work by selecting materials and finding ways to use them as never imagined,” Joaquin says.
A Software Application as a Learning Platform for Increasing Memory Retention of Definitions of Words

San Jose, California | Age: 14

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Project Background:
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Other Interests:
Adishree has been programming since fourth grade, and she hopes to become a computer scientist. She serves on student council and volunteers in the community. Additionally, she plays the piano and violin, runs half marathons, swims competitively and studies Indian classical dance. “I can build a story through dance and music,” Adishree says.

Saving Babies: Preventing Heat Stroke Implementing a Novel Car Seat Alarm System

Kingsville, Texas | Age: 14

JOAQUIN HACES-GARCIA

Project Background:
A news story prompted Joaquin’s idea. When a father mistakenly left his four month-old baby inside the family car, tragedy followed. “The temperature inside the vehicle can increase rapidly, reaching high temperatures that cause heat stroke to infants,” explains Joaquin. “There should be a way to make drivers remember when they have a baby in the car to avoid future tragedies,” he thought. Towards that end, Joaquin set out to design an alarm that would warn people if they forgot to take their baby out of the car seat.

Tactics and Results:
In order for his alarm system to work, Joaquin needed a way for it to detect when a baby was in a car seat. He tried working with a weight sensor, but it produced too many false positives. For example, the alarm might go off if a baby moved in the seat, or if a driver rested objects on the car seat. After more research, Joaquin decided to use a magnetic sensor, which could be activated when the seat belt was closed. He also decided that the system should hook up with a car alarm system, instead of a phone or other device that might be turned off or could malfunction. If a driver tried to lock the car while the baby was still strapped in, “the car alarm system would start sounding, and the car would not lock,” he explains. Now that his prototype works, Joaquin’s next engineering project will be hooking it up to the alarm system of an actual car. “I want to help parents avoid the risk of forgetting by accident,” which could change the family’s lives forever, he says.

Other Interests: “I enjoy playing team sports, such as baseball and basketball, because I like doing exercise and competing alongside with my teammates to get the best results,” says Joaquin. He plays in the school band and also volunteers for a soup kitchen in his home town. Joaquin hopes to become a mechanical engineer. “I love to work by selecting materials and finding ways to use them as never imagined,” Joaquin says.
Project Background: Nadeine loved seeing the vast landscape, green forest and wildlife of Yellowstone National Park when her family visited a few years ago. “However, we saw a large area charred by previous wildfires and some other areas cordoned off due to ongoing wildfires,” she recalls. “That was when I decided to look for ways to improve wildfire management.” One factor that affects the risk of a wildfire is the fuel moisture. That refers to the ratio between water and dry materials in trees and other material that could burn. Nadeine wondered if it would be feasible to use satellite data to estimate fuel moisture on the ground.

Tactics and Results: Satellites can detect infrared emissions from vegetation, tracking data which scientists can then use to estimate the total water content in the plants. This is different from fuel moisture, which also depends on the dry materials present. Nonetheless, Nadeine hoped to show a correlation between the two types of data. She downloaded a year’s worth of data on vegetation water content for various locations from a NASA satellite mission. For the same time frame, she also downloaded fuel moisture data for 140 types of fuel at 661 active sampling sites from the National Fuel Moisture Database (NFMD). The second set of data served as the “ground truth,” for what conditions actually were for fuel moisture at different locations. Nadeine used a variety of statistical methods for her analysis. Eighty seven percent of the site fuel types showed a positive correlation between vegetation water content as measured by satellites and fuel moisture as determined on the ground. “Thus, this study suggests that it is feasible to use satellite data to estimate wildfire fuel moisture,” Nadine reports.

Other Interests: Nadine hopes to become an environmental engineer. “The need to find more efficient renewable resources will grow, along with the need to find better ways to lessen natural disasters,” she notes. Nadine’s favorite extracurricular activity is her school’s dance club. “Dance is a great way to exercise and to keep me fit and healthy,” she says.
**SAMUEL KAHN**
San Diego, California | Age: 14

*Post-Fire Regeneration in Coastal Sage Scrub —
Second Year of Study*

**Project Background:** In 2014, a wildfire burned part of an endangered Coastal Sage Scrub habitat at a regional park near Sam’s home. He then wondered how things might change as plants grew back in the area. “Would there be the same native plants growing back, would different species appear, or would a lot of invasive non-native plants take over?” he asks. “I hope my project will help ecologists and rangers to manage the park and protect it for the future.”

**Tactics and Results:** After getting necessary permissions, Sam set up two transects, or lines, at Mission Trails Regional Park in San Diego in the fall of 2014. For his experimental group, Sam used a square meter quadrat to frame areas along a line in the burned area. His control group consisted of square meter areas along the other transect in an unburned area. For each area he marked off, Sam recorded his observations of which new plants grew. Last summer, he also added 3- x 8-meter quadrats in the burned and unburned areas, where he counted and measured *Artemisia californica*, or California sagebrush. “Many more non-native plants were in the burned area, though the number of non-natives decreased and the species diversity increased over time,” Sam reports. California sagebrush plants in the burned areas were also larger and more plentiful. Sam muses, “This could be due to reduced competition for space and sunlight, and higher nutrients in the soil.” He plans to continue the project for another year. He wonders whether weeding out non-native plants might affect the share of native ones that eventually grow there. Towards that end, he has laid out a new transect and has already started collecting data.

**Other Interests:** Sam is a Life Scout in Boy Scouts and enjoys camping, backpacking and hiking with his troop. He also likes Parkour, an athletic activity developed in France. The sport uses the surrounding environment as an obstacle course. As far as his career ambitions, Sam says, “If I got a job in marine biology, I would have the opportunity to study marine wildlife, particularly marine mammals like dolphins, which have brains comparable to chimpanzees.”
OLIVIA LAZORIK
Fort Pierce, Florida | Age: 15

Climate Change Problem: The Effect of Ocean Acidification on the Growth and Coloration of Lysmata wurdemanni

Project Background: “I am fortunate to live on the beach, and its natural beauty inspires me,” says Olivia. This passion fuels her concerns about the impacts of climate change on the oceans. One of its impacts is that oceans absorb more carbon dioxide from the atmosphere. That lowers the pH of the ocean water and causes ocean acidification. Olivia wanted to find out how this condition would affect the Atlantic Peppermint Shrimp.

Tactics and Results: Olivia randomly assigned groups of three shrimp to each of 12 aquarium tanks. She kept her six control tanks at a pH of 8.1, which is the ocean’s current level. Alternately, she infused the experimental tanks with enough carbon dioxide to lower the pH to 7.5. That’s the level that climate scientists forecast the oceans to drop to in the year 2100. On the day she started, Olivia measured the mass, length, luminosity and color of the shrimp in each tank. She also calculated the averages of shrimp in each tank because Atlantic Peppermint Shrimp generally look alike. She repeated those measurements and calculations on the 24th day, then used statistics to analyze the data. Olivia found that the shrimp in the tanks with a lower pH grew less than those in the control tanks. “Perhaps the shrimp were put under more stress and using more of their resources” for normal body functions, she says. The shrimp in these futuristic ocean tanks also grew darker and more intense in their coloring. This could make the shrimp more noticeable to predators. “Based on this study, a lower pH environment negatively impacts shrimp,” Olivia concludes.

Other Interests: Olivia loves playing the piano. “I find that music, largely driven by algorithms, marries mathematics and creativity.” She also enjoys tennis and its demands for fitness, skill and mental discipline. The sport incorporates geometry and physics as well, she notes. Olivia’s other activities include her school’s Model United Nations Club and Student Council. She hopes to become a neurologist and perhaps use research with marine organisms to help people with Alzheimer’s and Parkinson’s diseases.

PROJECT BACKGROUND: The right side of our four-chambered heart sends blood to the lungs for oxygen. Blood then comes back to the left side, where the lower chamber, called the left ventricle, has the huge job of pumping blood out to the rest of the body. Some people have weakened hearts that need extra help from an artificial pump, called a left ventricular assist device, or LVAD. Ethan tested which of three types of LVAD devices would perform best on an artificial heart model he developed.

Tactics and Results: Working in his home garage, Ethan’s first challenge was to develop, build and program an artificial heart model. To do that, he used Lego NXT equipment. “I also developed, built, and programmed circuits to operate the valve as well as to collect data,” he says. He needed a way to compare how well the devices worked. Pulsatility refers to how fast the blood flows, based on the velocities both as the heart beats and in between beats. Ethan’s artificial heart had two gauges to provide measurements for pulsatility. He also wanted to know about effects on cardiac output, which refers to how much blood the heart can pump out as it beats. Ethan programmed the system to measure that output every half-second. Once he had the system working, Ethan set the artificial heart to mimic the heart of someone with heart failure as that person walked and, alternately, rested. He hooked up each of three types of assistive devices, collected data and compared the results. The best results for both pulsatility and cardiac output were achieved with a device known as the Next Generation Pulsatile Valve LVAD. This type of device is generally smaller and has fewer mechanical parts than other types.

Other Interests: Ethan hopes to become a surgeon. For now, he volunteers regularly at a nursing home in his community. “Every Friday, I go with my dog, Choco, and we walk from room to room, talking with the patients and making their week brighter,” Ethan says. His favorite hobbies and extracurricular activities include reading, playing chess, swimming and video games.
2016 Broadcom MASTERS Finalists

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**OLIVIA LAZORIK**
Miami, Florida | Age: 15

**ETHAN Z. LEVY**
Fort Pierce, Florida | Age: 14

**Comparing Pulsatile and Non-Pulsatile Left Ventricular Assist Devices (LVAD)**

**Project Background:** I am fortunate to live on the beach, and its natural beauty inspires me,” says Olivia. This passion fuels her concerns about the impacts of climate change on the oceans. One of its impacts is that oceans absorb more carbon dioxide from the atmosphere. That lowers the pH of the ocean water and causes ocean acidification. Olivia wanted to find out how this condition would affect the Atlantic Peppermint Shrimp.

**Tactics and Results:** Olivia randomly assigned groups of three shrimp to each of 12 aquarium tanks. She kept her six control tanks at a pH of 8.1, which is the ocean’s current level. Alternately, she infused the experimental tanks with enough carbon dioxide to lower the pH to 7.5. That’s the level that climate scientists forecast the oceans to drop to in the year 2100. On the day she started, Olivia measured the mass, length, luminosity and color of the shrimp in each tank. She also calculated the averages of shrimp in each tank because Atlantic Peppermint Shrimp generally look alike. She repeated those measurements and calculations on the 24th day, then used statistics to analyze the data. Olivia found that the shrimp in the tanks with a lower pH grew less than those in the control tanks. “Perhaps the shrimp were put under more stress and using more of their resources” for normal body functions, she says. The shrimp in these futuristic ocean tanks also grew darker and more intense in their coloring. This could make the shrimp more noticeable to predators. “Based on this study, a lower pH environment negatively impacts shrimp,” Olivia concludes.

**Other Interests:** Olivia loves playing the piano. “I find that music, largely driven by algorithms, marries mathematics and creativity.” She also enjoys tennis and its demands for fitness, skill and mental discipline. The sport incorporates geometry and physics as well, she notes. Olivia’s other activities include her school’s Model United Nations Club and Student Council. She hopes to become a neurologist and perhaps use research with marine organisms to help people with Alzheimer’s and Parkinson’s diseases.

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**Other Interests:** Ethan hopes to become a surgeon. For now, he volunteers regularly at a nursing home in his community. “Every Friday, I go with my dog, Choco, and we walk from room to room, talking with the patients and making their week brighter,” Ethan says. His favorite hobbies and extracurricular activities include reading, playing chess, swimming and video games.
Aerodynamics of Airfoils

Project Background: Omar first became interested in airfoils through his love of cars. Airfoils are streamlined structures with curved horizontal surfaces. The curve on an airfoil’s surface is also called its camber. The shape of an airfoil leads to differences in air pressure on each side. On a car, a spoiler is an airfoil: it produces downward pressure and increases traction with the ground. An airplane wing is also an airfoil, as upward pressure becomes lift and sets the plane in flight. “My research question was to find out which airfoil produced the most lift,” Omar says.

Tactics and Results: Omar built four types of airfoils with Styrofoam. One was symmetrical, with the same curves on top and bottom. One was semi-symmetrical, with both sides curved, but more mass focused on the top side of the airfoil. A third airfoil design had a flat bottom. The fourth was cambered on the bottom side which was curved outward near the front with a slight arch inward near the back. Omar also built a wind tunnel with polymer foam and Plexiglas. A fan blew air into the wind tunnel. A scale sat under the support for each airfoil. Each time Omar tested one of the airfoils, he measured how much the pressure on the scale decreased. The greater the reduction in pressure, the more lift an airfoil produced. After 20 trials for each design, he analyzed the results. “According to the data, the under-cambered airfoil had more lift than the other airfoils 100 percent of the time,” Omar reports. That meshed well with his prediction. “The shape of the lower camber is curved inward, so that gap becomes more space for condensed molecules,” which results in upward pressure, he says. In the future, he plans to do research on winglets found at the tips of plane wings.

Other Interests: Omar is captain of his soccer team and an avid fencer. He’s also the lead guitarist in his school’s rock band, as well as a budding pianist. On weekends he studies Arabic, which he can read and speak fluently. “When I grow up I want to be a cardiovascular surgeon,” Omar says.
AERODYNAMICS OF AIRFOILS

**OMAR MAJZOUB**

**Titusville, New Jersey | Age: 13**

**Project Background:** Omar first became interested in airfoils through his love of cars. Airfoils are streamlined structures with curved horizontal surfaces. The curve on an airfoil's surface is also called its camber. The shape of an airfoil leads to differences in air pressure on each side. On a car, a spoiler is an airfoil: it produces downward pressure and increases traction with the ground. An airplane wing is also an airfoil, as upward pressure becomes lift and sets the plane in flight. “My research question was to find out which airfoil produced the most lift,” Omar says.

**Tactics and Results:** Omar built four types of airfoils with Styrofoam. One was symmetrical, with the same curves on top and bottom. One was semi-symmetrical, with both sides curved, but more mass focused on the top side of the airfoil. A third airfoil design had a flat bottom. The fourth was cambered on the bottom side which was curved outward near the front with a slight arch inward near the back. Omar also built a wind tunnel with polymer foam and Plexiglas. A fan blew air into the wind tunnel. A scale sat under the support for each airfoil. Each time Omar tested one of the airfoils, he measured how much the pressure on the scale decreased. The greater the reduction in pressure, the more lift an airfoil produced. After 20 trials for each design, he analyzed the results. “According to the data, the under-cambered airfoil had more lift than the other airfoils 100 percent of the time,” Omar reports. That meshed well with his prediction. “The shape of the lower camber is curved inward, so that gap becomes more space for condensed molecules,” which results in upward pressure, he says. In the future, he plans to do research on winglets found at the tips of plane wings.

**Other Interests:** Omar is captain of his soccer team and an avid fencer. He’s also the lead guitarist in his school’s rock band, as well as a budding pianist. On weekends he studies Arabic, which he can read and speak fluently. “When I grow up I want to be a cardiovascular surgeon,” Omar says.

**SONJA MICHALUK**

**Titusville, New Jersey | Age: 13**

**A Novel Mathematical Model to Simulate the Impact of Potential Land Development on Chemical and Biological Stream Health**

**Project Background:** A meeting of freshwater scientists inspired Sonja to think about computer modeling for environmental science. Computer models simulate real world events with math, data and computer instructions. “Inspiration hit,” says Sonja. “Could a model simulate land development effects?” Perhaps people would make better decisions about land use if a model could accurately predict the future impacts on stream life, she thought.

**Tactics and Results:** Sonja got to work — out in the field, in a lab and on the computer. For six years, she had collected stream samples at sites in New Jersey. Her model drew upon data from more than 50 of those samples. “I’ve taken samples in rainstorms, snowstorms, and on uncomfortably cold days,” Sonja notes. “A few times the water level was so high that my waders were flooded.” Work in the lab let her measure the variety of invertebrate species found at each site. “Aquatic macroinvertebrates are good indicators of stream health,” Sonja explains. She also used measurements of each water sample’s turbidity, nutrient pollution and other details. Sonja entered the data into the computer and wrote algorithms. They gave weight to different variables based on known information about healthy and impaired streams. When the initial model was ready, Sonja compared its projections to known real-world conditions. “Initial projections from the model are promising,” she says.

**Other Interests:** Sonja’s athletic interests include Taekwondo, dancing, and competitive swimming. She participates in various clubs and activities, including 4-H, computer club, art club and yearbook. Sonja volunteers at the local water quality association and nature center. In these pursuits, she runs hands-on tables at festivals, leads nature walks and teaches sessions at science camps and classes. Sonja plays the piano and enjoys writing. She also does some fashion designing related to her interest in aquatic life. “I design artistic, ocean wearable mermaid tails,” Sonja explains. Sonja feels a deep connection with nature and hopes to become a biologist. “The mystery of what lies beneath the surface of bodies of water is a lifelong fascination,” she says.
ASHINI MODI
Shreveport, Louisiana | Age: 12

Project Background: Ashini loves visiting space observatories, so naturally, she joined a local astronomy society. At one society program, she learned about dark matter and dark energy. “I was driven to find out if dark matter is an existing force in our universe,” she says. To do that, she set out to observe the rotational speed of neutral hydrogen clouds in the Milky Way and Andromeda galaxies. Her hypothesis was that as distance from the galactic center increased, speed would also increase. If so, that would be contrary to one of Kepler’s laws for the motion of planets and satellites. And it would suggest the presence of some other force — dark matter.

Tactics and Results: Over a period of eight months, Ashini collected a total of 530 observations from two radio telescopes located in North Carolina and West Virginia. The observations came from either the Milky Way or the Andromeda Galaxy. Ashini converted galactic coordinates into longitude data. She used that and other information from her observations to calculate the velocity and distance from the center of the galaxy. Both the Milky Way and the Andromeda Galaxy showed a trend in velocities that was greater than Kepler’s Law would predict. “From this data I can conclude that there is a mysterious mass throughout the Milky Way and Andromeda galaxies,” Ashini says. “This invisible mass is affecting the velocity of the neutral hydrogen in these galaxies.” Between the two systems, Ashini concludes that the Andromeda Galaxy has more dark matter.

Other Interests: “I am passionate about dancing, and I have been taking professional classical Indian and ballet dance training since the age of five,” says Ashini. “I really enjoy playing the violin,” she adds, “because instead of dancing to another’s music, I can make beautiful music myself.” She recently helped start a library at the local Providence House for homeless families. “We now have over 1,500 books in the Reading Rainforest for children to find the beauty of reading,” she reports. Ashini hopes one day to become a neurosurgeon. “As intriguing as I find the mysteries of dark matter, I find the mysteries of our brains just as puzzling,” she says.

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ANUSHKA NAIRNAWARE
Portland, Oregon | Age: 14

Project Background: If one removes the dressing from a wound too early, it may not fully protect the injured area. On the other hand, if the dressing comes off too late, excess moisture can lead to softening and deterioration of the wounded area. “This project aims to create a sensor which detects levels of moisture in the dressing and monitors the wound in real time,” Anushka says. To do that, she used carbon nanoparticles — tiny particles measured in billionths of a meter.

Tactics and Results: Anushka reasoned that increased moisture in a wound dressing would alter the flow of electrical charge. That would change the resistance, which is measured in units called ohms. To detect that change, Anushka built sensors into an antimicrobial wound dressing. She printed patterns of ink containing carbon nanoparticles onto dry cotton paper. The paper had previously been soaked with a prepared solution of vinegar and chitosan, a natural polymer with antimicrobial properties. Chitosan can be helpful for preventing infection. For her experimental moisture, Anushka mixed up an artificial, pathogen-free pus solution. When everything was ready, Anushka squirted the artificial pus onto her sensors and recorded electrical resistance data. She calculated a ratio of the change in resistance versus the original value and analyzed her results. “I tried many different ink combinations and sensor designs before I found one that worked,” Anushka says. “But instead of giving up, I learned how to keep going and use failure as my inspiration until my prototypes finally worked.” She believes her approach “demonstrates promising pathways for mass production.”

Other Interests: “I have enjoyed figure skating since I was a little girl. It encourages me to try new things and take risks,” she explains. Other sports she enjoys are swimming and tennis, and she has a black belt in Taekwondo. Anushka’s musical talents include playing the piano and violin. Anushka is also active in student council and Girl Scouts. She plans to pursue a career in chemistry, as she believes “chemists have the power to change the world.”
ANUSHKA NAIKNAWARE
Portland, Oregon | Age: 14

Chitosan and Carbon Nanoparticle based Biocompatible Sensor for Wound Management

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NIKOLAI ORTIZ
Corpus Christi, Texas | Age: 13

Finding a Solution to Heavy Metal Water Pollution

Project Background: Nikolai ruined a lot of shoes last year as he collected water samples near places such as highways, industrial plants, golf courses, oil refineries, farms, plant nurseries and landfills. His work found varying levels of pollution by several types of metals, such as lead, mercury and cadmium. “This year, I wanted to start working on finding a solution and solving this problem,” Nikolai says. He tested several eco-friendly filter materials to see which would remove the most lead and copper from contaminated water sources.

Tactics and Results: Nikolai chose eight types of filter materials to test: calcite crystals, limestone, mollusk shells, crushed coral, magnesium oxide, rose quartz, volcanic zeolite and bentonite clay. He prepared three different concentrations of a copper sulfate solution and three different concentrations of a lead nitrate solution. For each trial, Nikolai poured 10 milliliters of a solution into a paper cone with one of the filter materials. He measured the copper or lead concentration in the liquid that flowed out and calculated how much had been removed. He then poured more solution into each filter and repeated the process until the filter would no longer remove any lead or copper. “My biggest obstacle was time,” Nikolai says. “Doing 800 water tests takes forever!” Five of the filter materials were relatively effective, and magnesium oxide worked the best, Nikolai reports. It removed all the lead and copper from up to 100 milliliters of each solution. It also made each solution less acidic. “In the future, I would like to build a larger, multi-media-layered filter and test its ability to remove heavy metals from polluted runoff water,” Nikolai says.

Other Interests: “I want to be an Environmental Imagineer,” says Nikolai. That would be “an individual who designs environmental cleanup technology that is imaginative, fun, entertaining and educational.” Beyond participating in a variety of school activities and playing the violin, Nikolai loves zip-lining, rock-climbing and other outdoor activities. He has also done some commercial acting. “It’s really fun to get to be someone different for a day!” he says.

Project Background: One day Aalok’s dad woke up with a cracked tooth, which required him to undergo a root canal. It turned out that Aalok’s dad had bruxism, a condition where someone excessively clenches the jaw or grinds the teeth. Many people with bruxism experience jaw pain as a symptom. Oddly enough, Aalok’s dad had never known he had the condition. “I decided to make a device that would inform someone if they had bruxism before the lasting damage occurred,” Aalok says.

Tactics and Results: Aalok learned that bruxism involves a distinctive movement of the jawbone. He decided to detect that kind of movement with an accelerometer, an instrument that can sense and measure changes in the rate of movement. Aalok put an accelerometer, processor, USB and MicroSD chip on compact TinyDuino® circuit boards. Then he packed it into a case that could be attached to someone’s chin with hospital-grade cloth tape. Aalok programmed the system to take and store about 40 readings per second. He also wrote algorithms to break the data into five-second windows. His program would determine if motion occurred, and classify motion as teeth grinding, jaw clenching, or another type of head movement. The device achieved an 81 percent accuracy rate when volunteers wore it for a total of 13 nightly trials. Aalok thinks the device could help bruxism patients, and suggests that it might detect various sleep disorders, too. He exclaims, “In general, it is possible to make a device that improves the thing we love the most: sleep!”

Other Interests: “I love soccer because of the different skills needed to excel at it,” Aalok says. “Of course, fast footwork is compulsory, but what is also needed is a mastery of strategy.” He also plays the piano and is involved in his school’s math team, engineering club, scouting and other activities. Aalok plans to become a computer scientist. He enjoys designing things to solve problems. “Last year, I created a self-balancing bicycle in the hope that it would lead to less people falling off their bikes,” he explains.
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Do I Grind? A Wearable System that Detects Bruxism Ahead of Its Effect on Teeth

AALOK NITAL PATWA
San Jose, California | Age: 13

Project Background: One day Aalok’s dad woke up with a cracked tooth, which required him to undergo a root canal. It turned out that Aalok’s dad had bruxism, a condition where someone excessively clenches the jaw or grinds the teeth. Many people with bruxism experience jaw pain as a symptom. Oddly enough, Aalok’s dad hadn’t known he had the condition. “I decided to make a device that would inform someone if they had bruxism before the lasting damage occurred,” Aalok says.

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Other Interests: “I love soccer because of the different skills needed to excel at it,” Aalok says. “Of course, fast footwork is compulsory, but what is also needed is a mastery of strategy.” He also plays the piano and is involved in his school’s math team, engineering club, scouting and other activities. Aalok plans to become a computer scientist. He enjoys designing things to solve problems. “Last year, I created a self-balancing bicycle in the hope that it would lead to less people falling off their bikes,” he explains.
Can a Modified Windmill Generate Electricity in an Interstate Traffic Setting?

Project Background: Each wind turbine on a wind farm converts the kinetic energy of moving air into electricity. Better still, wind power is renewable energy, as opposed to fossil fuels that produce greenhouse gases and other pollutants. Rachel had seen wind farms on family car trips and noticed how much wind whooshes by cars as they drive along highways. “This was the ‘Eureka’ moment when I thought about mounting turbines along the sides of the highway to generate electricity,” Rachel says.

Tactics and Results: Rachel designed and tested two versions of her roadside wind turbine. To do that, she used a discarded bicycle wheel rim, a salvaged motor and other recycled materials. “Although the inspiration for the project was windmills on a wind farm, my turbine design was based on a water wheel used in a grain mill,” Rachel notes. She mounted the wheel to spin parallel to the ground. Cardboard blades were attached to the rim. First, Rachel set each blade perpendicular to the tangent at the point where it attached to the wheel. She then had her father drive by in a compact car at five different speeds. He repeated that 100 times. Each time, Rachel recorded the voltage of the resulting current. Next, she set the blades at a 30-degree angle and conducted another 100 trials. For each speed tested, the turbine produced a higher voltage output with the blades in that angled position. “Harnessing the wind from a moving vehicle to drive a turbine will definitely generate electricity,” Rachel says.

Other Interests: Rachel has won medals for trampoline competitions and gymnastics at both the state and national level. She has also competed in beauty pageants for eight years and won over 50 titles. “Of course, I want to compete in the 2024 Olympics and win the Miss USA, but I know the most important part of my life will be the knowledge I gain by studying and expanding my mind through projects like this,” Rachel says. She hopes to become an aeronautical engineer. “The power of flight is amazing,” she says.

Due to a drought, experts have encouraged California households to conserve water by not watering their lawns. Another water-saving choice is to use grey water. Grey water might not be safe for drinking, but it might still work for other purposes. Used laundry water is one example, but, as Shreya notes, “many commercial laundry detergents have harmful chemicals.” In contrast, she says, soap nuts are a natural detergent made from the Indian soap berry. Shreya tested how wastewater from using soap nuts might work for irrigation.

Tactics and Results: Shreya planted 48 samples of tall fescue grass. One half grew in sandy soil. The other half was in sandy loam. Every three to four days, Shreya watered samples with one of four types of water. Regular tap water served as a control. Grey water from soap nuts, an organic detergent and a non-organic detergent were the three other types of water. Each week Shreya measured plant height and health conditions. She also took weekly samples of leachate, the liquid that passed through the soil. After six weeks, Shreya measured the biomass of the plant tissue in each sample, and performed a chemical analysis on the plants, soils and grey water. “The soap nut greywater treatment led to similar levels of soil and plant nutrients when compared to the regular water treatment,” she reports. In other words, it worked just as well. In contrast, Shreya found, the non-organic detergent led to high levels of boron in both soils and plant tissue. And while organic detergent wastewater did not have that problem, plant growth for those samples was less, on average. Also, Shreya notes, the organic detergent cost more than twice as much as the soap nuts.

Other Interests: Shreya loves participating on debate teams. She also enjoys Indian classical music, especially singing and playing a stringed instrument called the veena. Reading, bicycling, art and gardening are among her other favorite pastimes. Shreya hopes to become a medical doctor. “I think it is a great way to help people,” she says.
Can a Modified Windmill Generate Electricity in an Interstate Traffic Setting?

The Effect of Soap Nut Grey Water on the Environment

Metairie, Louisiana | Age:12
Fremont, California | Age:13

RACHEL PIZZOLATO
SHREYA RAMACHANDRAN

Project Background: Each wind turbine on a wind farm converts the kinetic energy of moving air into electricity. Better still, wind power is renewable energy, as opposed to fossil fuels that produce greenhouse gases and other pollutants. Rachel had seen wind farms on family car trips and noticed how much wind whooshes by cars as they drive along highways. “This was the ‘Eureka’ moment when I thought about mounting turbines along the sides of the highway to generate electricity,” Rachel says.

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Tactics and Results: Shreya planted 48 samples of tall fescue grass. One half grew in sandy soil. The other half was in sandy loam. Every three to four days, Shreya watered samples with one of four types of water. Regular tap water served as a control. Grey water from soap nuts, an organic detergent and a non-organic detergent were the three other types of water. Each week Shreya measured plant height and health conditions. She also took weekly samples of leachate, the liquid that passed through the soil. After six weeks, Shreya measured the biomass of the plant tissue in each sample, and performed a chemical analysis on the plants, soils and grey water. “The soap nut greywater treatment led to similar levels of soil and plant nutrients when compared to the regular water treatment,” she reports. In other words, it worked just as well. In contrast, Shreya found, the non-organic detergent led to high levels of boron in both soils and plant tissue. And while organic detergent wastewater did not have that problem, plant growth for those samples was less, on average. Also, Shreya notes, the organic detergent cost more than twice as much as the soap nuts.

Other Interests: Shreya loves participating on debate teams. She also enjoys Indian classical music, especially singing and playing a stringed instrument called the veena. Reading, bicycling, art and gardening are among her other favorite pastimes. Shreya hopes to become a medical doctor. “I think it is a great way to help people,” she says.
Using a Towable Conductivity-mapping System to Locate Springs or Septic Leachate

Project Background: Some people fish at McGilvray Lake or Whitefish Lake in Montana to catch trout, pike or other tasty food. Luke went fishing for answers. Where was the spring that supplied water to McGilvray Lake? Could septic leakage from nearby homes or camps get into the scenic lakes? To find out, Luke designed a towable system to measure differences in electrical conductivity. The more ions in a particular spot, the easier it is for the water to carry an electric current. Those ions can come from dissolved salts, chlorides, alkalis and other chemicals. Luke reasoned that water coming in from a spring would likely contain more ions. Furthermore, chemicals in wastewater could also add ions if septic systems leaked into a lake.

Tactics and Results: Using a Raspberry Pi microcomputer, RasPiRobot Board and other equipment, Luke built and programmed a system he calls TASC. That stands for Towable Aquatic Sensor Craft. “It is a small boat which samples and records conductivity and location every ten feet,” Luke explains. He performed two tests with the equipment on McGilvray Lake and two more tests at Lazy Bay on Whitefish Lake. The system located the spring at McGilvray Lake in the northeast area, a finding that matched Luke’s suspicions due to water flow and winter ice coverage patterns. The system also found an area with raised conductivity near an old house close to Lazy Bay. Luke concluded that septic leachate could have caused those higher readings.

Luke thinks his low-cost system could help environmental scientists. “Lake-monitoring organizations could easily build TASCs, resulting in a wealth of conductivity data that could be used to detect environmental abuse,” he says.

Other Interests: “Being a robotics engineer interests me because it combines engineering and computer programming,” Luke says. He loves being outdoors and is a Life Scout in Boy Scouts. Luke’s favorite activities include kayaking, sailing, swimming, running, bicycling and archery. He also plays the alto saxophone for his school’s concert, honor and jazz bands.

Project Background: When SpaceX first tried to land its Falcon 9 rocket, the spacecraft touched base on a drone barge, toppled over and exploded. As Eleanor read more, she learned about cold gas rockets. Small versions help astronauts move around in space when they venture outside their craft. Larger versions control the Falcon 9’s orientation and stabilize it as it lands. But, Eleanor learned, various details about cold gas rockets rely on rules of thumb – guidelines that generally work in practice, but may not be verified by scientific data. She wanted to contribute to the engineering knowledge of the subject, so she experimented with cold gas rocket nozzles.

Tactics and Results: Nozzles on a cold gas rocket force gas through a narrow area. Gas then exits through an angled section. Eleanor wanted to compare nozzles with different half-angles for the angled section. To do that, she used a 3-D printer to design and make nozzles with different half-angles. She built an apparatus to force pressurized gas through nozzles. And she designed and programmed a system to detect and record data on force, pressure and temperature as gas came out of the nozzles. Eleanor tested her different nozzles with compressed air, nitrogen, helium and carbon dioxide. “My independent variables were the divergent section half-angle and length of the nozzles,” Eleanor explains. “My dependent variable was the force produced by each nozzle.” Eleanor’s earlier calculations suggested that a 15-degree half-angle would be the best compromise between a nozzle’s length and its thrust. When Eleanor analyzed the data, however, 20 degrees turned out to be the best compromise. “My experiment supports further questioning of the engineering rules of thumb,” she says.

Other Interests: Eleanor designs and sews quilts for preemie babies at a local hospital. “I love quilting because I can be creative and use my imagination and math to design a beautiful quilt,” she notes. She enjoys a variety of outdoor and water sports. She plays the violin and other musical instruments, as well. Eleanor hopes to become an astronaut. “I love space,” she says.
ELEANOR WREN SIGREST

Woodbridge, Virginia | Age: 13

Rockets, and Nozzles, and Thrusts,
Oh My

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Project Background: When Santiago lived in Columbia, he witnessed that many people live in homes with dirt floors in the tropical environment. Those unfinished floors can’t be cleaned properly and can become muddy. “As a result, living with these floors can lead to disease, diarrhea, and death, especially among children,” Santiago notes. To help those people, he set out to find a material that could work as affordable flooring for their homes.

Tactics and Results: Concrete is typically made by mixing water and cement with broken stone or gravel, but it can be made with other materials, too. Santiago mixed different batches of concrete using bits of clay brick, rubber, coconut shells, and a plastic blend. He also made a batch with a mixture of clay brick, rubber and coconut shells. He tested each batch to see how well it could be used for a construction job. Santi then prepared six samples of each experimental batch and cured them for 28 days. As a control, he also prepared samples of a traditional concrete made with gravel. Next, Santi performed tests to gauge each material’s strength, durability, water resistance and alkalinity. The results were promising. “I invented multiple alternative concrete mixes for eco-friendly, strong, durable, sustainable, and safe flooring,” Santi says. Clay brick fragments, coconut shells, and the plastic blend are “great options” that would also help reduce waste, he notes. The clay brick mix was the strongest and most durable, followed by the concretes made with coconut shells and the plastic blend. Santi found that the samples made with clay brick and the plastic blend were also the most water-resistant.

Other Interests: Last winter, Santi organized a winter coat drive in his community for disadvantaged families. He enjoys playing soccer and is also active in various science and robotics activities. Santi would love to pursue a career as a civil engineer. “I love to learn about how things are built and design new structures, devise solutions to issues, and come up with improvements to already existing structures,” he explains.

Project Background: Large amounts of organic waste chemicals wind up in waterways every year, due to oil spills and other pollution. “Unfortunately, no current solutions exist that can treat this problem in an environmentally friendly and effective manner,” Emhyr reports. He decided to see if a commercially available super-absorbent polymer could efficiently remove organic waste from water. If this was possible, Emhyr wanted to develop a new polymer that could both complete that job and biodegrade afterwards.

Tactics and Results: To begin, Emhyr tested whether a super-absorbent polymer really could remove organic waste chemicals from water. He mixed diesel oil into separate containers of de-ionized water, stream water and seawater to mimic oil spills. He followed a similar process with three different groups of soil, then treated each experimental group with a commercially available product called CAS 100. The product repels water, but otherwise acts like a super-soaker: it can absorb other types of liquids by up to ten times its weight. In Emhyr’s tests, the CAS 100 worked well, as it absorbed almost all the waste from each experimental group of polluted water. He reasoned that the concept could work, at least with spills on water. Even so, those tests were inconclusive because the treatment product picked up chemicals from the soil.

Next, Emhyr set out to develop a biodegradable super-absorbent polymer. He identified one promising compound, but unfortunately, one component cost too much for him to produce enough testing material. “The experiment was a partial success,” Emhyr concludes. He is now working with companies to get the component for future work.

Other Interests: “I feel that if I were to become an environmental engineer, I could develop effective solutions to help solve climate change and change the world,” Emhyr says. “I love that if I were to become an environmental engineer, I could develop effective solutions to help solve climate change and change the world,” Emhyr adds. In addition to performing with the school orchestra, Emhyr regularly plays his violin at local farmers’ markets. His goal is to raise money for schools in South and Central America as well as recruit ambassadors for a non-profit organization he started.
SANTIAGO STONE

**Project Background:** When Santiago lived in Columbia, he witnessed that many people live in homes with dirt floors in the tropical environment. Those unfinished floors can’t be cleaned properly and can become muddy. “As a result, living with these floors can lead to disease, diarrhea, and death, especially among children,” Santiago notes. To help those people, he set out to find a material that could work as affordable flooring for their homes.

**Tactics and Results:** Concrete is typically made by mixing water and cement with broken stone or gravel, but it can be made with other materials, too. Santiago mixed different batches of concrete using bits of clay brick, rubber, coconut shells, and a plastic blend. He also made a batch with a mixture of clay brick, rubber, and coconut shells. He tested each batch to see how well it could be used for a construction job. Santiago then prepared six samples of each experimental batch and cured them for 28 days. As a control, he also prepared samples of a traditional concrete made with gravel. Next, Santiago performed tests to gauge each material’s strength, durability, water resistance, and alkalinity. The results were promising. “I invented multiple alternative concrete mixes for eco-friendly, strong, durable, sustainable, and safe flooring,” Santiago says. Clay brick fragments, coconut shells, and the plastic blend are “great options” that would also help reduce waste, he notes. The clay brick mix was the strongest and most durable, followed by the concretes made with coconut shells and the plastic blend. Santiago found that the samples made with clay brick and the plastic blend were also the most water-resistant.

**Other Interests:** Last winter, Santiago organized a winter coat drive in his community for disadvantaged families. He enjoys playing soccer and is also active in various science and robotics activities. Santiago would love to pursue a career as a civil engineer. “I love to learn about how things are built and design new structures, devise solutions to issues, and come up with improvements to already existing structures,” he explains.

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EMHYR SUBRAMANIAN

**A Study of Super-Absorbent Polymers and Their Effectiveness in Organic Waste Extraction**

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**Other Interests:** “I feel that if I were to become an environmental engineer, I could develop effective solutions to help solve climate change and change the world,” Emhyr says. “The two things I love the most are playing the violin and solving Rubik’s cube,” Emhyr adds. In addition to performing with the school orchestra, Emhyr regularly plays his violin at local farmers’ markets. His goal is to raise money for schools in South and Central America as well as recruit ambassadors for a nonprofit organization he started.
DAVEN YADAV
Atlanta, Georgia | Age: 14

Bruxism: Using Myoelectric Signals to Treat a Health Problem

**Project Background:** Bruxism is the habitual grinding of teeth and clenching of the jaw. It causes pain from overuse of a jaw muscle. Daven’s sister has bruxism, and so does his project partner, Ananya Ganesh. Together, Ananya and Daven set out to design a non-invasive way to measure overexertion of the jaw muscle. A device with this system could alert someone to the issue. The team believes that that knowledge could lead a person to modify their behavior and reduce pain and damage.

**Tactics and Results:** Daven and Ananya reasoned that as the jaw muscle tires from overexertion, the electric signal generated by the movement would decrease. Before designing a device based on that hypothesis, they had to test the concept. To do that, the pair designed a circuit board to record electric signals detected by sensors. After recruiting six volunteers, they attached electrodes to skin near a forearm muscle. Each person flexed that arm hard for a standard time period. Next, Ananya and Daven attached the electrodes to the volunteers’ faces near the jaw muscle. They told the subjects to clench their jaws. Light displays and sounds signaled the testers when to relax their jaws. As Ananya and Daven expected, the amplitude of the electric signals from the muscle contractions decreased over time. This reflected that fatigue had set in. More work would be necessary to make a practical biofeedback device, including further testing and greater design detail. Even so, the team achieved the first big step. They showed a correlation between measurable electric signals from the jaw muscle and muscle fatigue.

**Other Interests:** Daven plays tennis one to two hours daily and competes in tournaments often. “The matches can be very long and it can be very hot, so you have to be mentally and physically tough,” he notes. Daven also plays several musical instruments, including piano, drums, and bass guitar. Daven hopes to become a surgeon and says he has a great sense of humor. “They may be able to make a robot as good looking as me, but I don’t think they could make it as funny,” he says.
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iDiagnostic: Invention of an Early Detection Tool for Major Depressive Disorder

Project Background: Major Depressive Disorder can seriously interfere with someone’s life. Kaien first became interested in the brain because a family member had suffered from severe headaches and mood swings. Imaging technology revealed shrinkage of part of his relative’s brain near the back of the skull. Even so, Kaien notes, doctors often don’t look at the brains of people they treat for Major Depressive Disorder. Kaien developed an early detection tool for mental illness. It combines a psychological evaluation with data from magnetic resonance imaging, or MRI.

Tactics and Results: Kaien collected MRI data on the brains of approximately 7,000 patients with Major Depressive Disorder. His sources were 135 peer-reviewed medical research journals published between 2000 and 2015. He experimented with different methods for data analysis, including linear regression, machine learning and logistic regression. After several months, he hit a roadblock, until he learned about the irrational number $e$ in math class. This number works as a natural logarithm, and is also known as Euler’s number or Euler’s coefficient. Kaien also learned about a statistical method called logistic regression, which also worked for his analysis. Kaien looked for correlations between Major Depressive Disorder and 14 independent variables. Those variables related to measurements for different parts of the brain. After reviewing the results, Kaien concluded that shrinkage of an area called the limbic system is associated with Major Depressive Disorder. As a result of his statistical analysis, Kaien says his tool could predict the risk for that mental illness with an accuracy of 93 percent.

Other Interests: “I love classical music and have played the violin for six years,” Kaien says. He is also an avid tennis player. “I have learned so much from the sport I love: character, endurance, tenacity, and strategy,” he notes. “Tennis taught me that there are times of success and times of failure, and both are equally valuable.” Kaien also participates in a variety of school and community activities, including scouting, 4-H club and yearbook. He hopes to become a medical doctor and looks forward to helping patients who suffer from devastating brain disease.
# 2016 Broadcom MASTERS
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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 shop class.

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 Ltd.

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.