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ROBOT REVOLUTION

MEET THE TEENS WHO ARE DESIGNING TOMORROW'S ROBOTS

SPECIAL ISSUE: ENGINEERED BY STUDENTS

SAVING FIREFIGHTERS' LIVES

PERFECTING THE BASEBALL PITCH

PROTECTING TEEN DRIVERS

ADVANCING HUMAN SPACE TRAVEL

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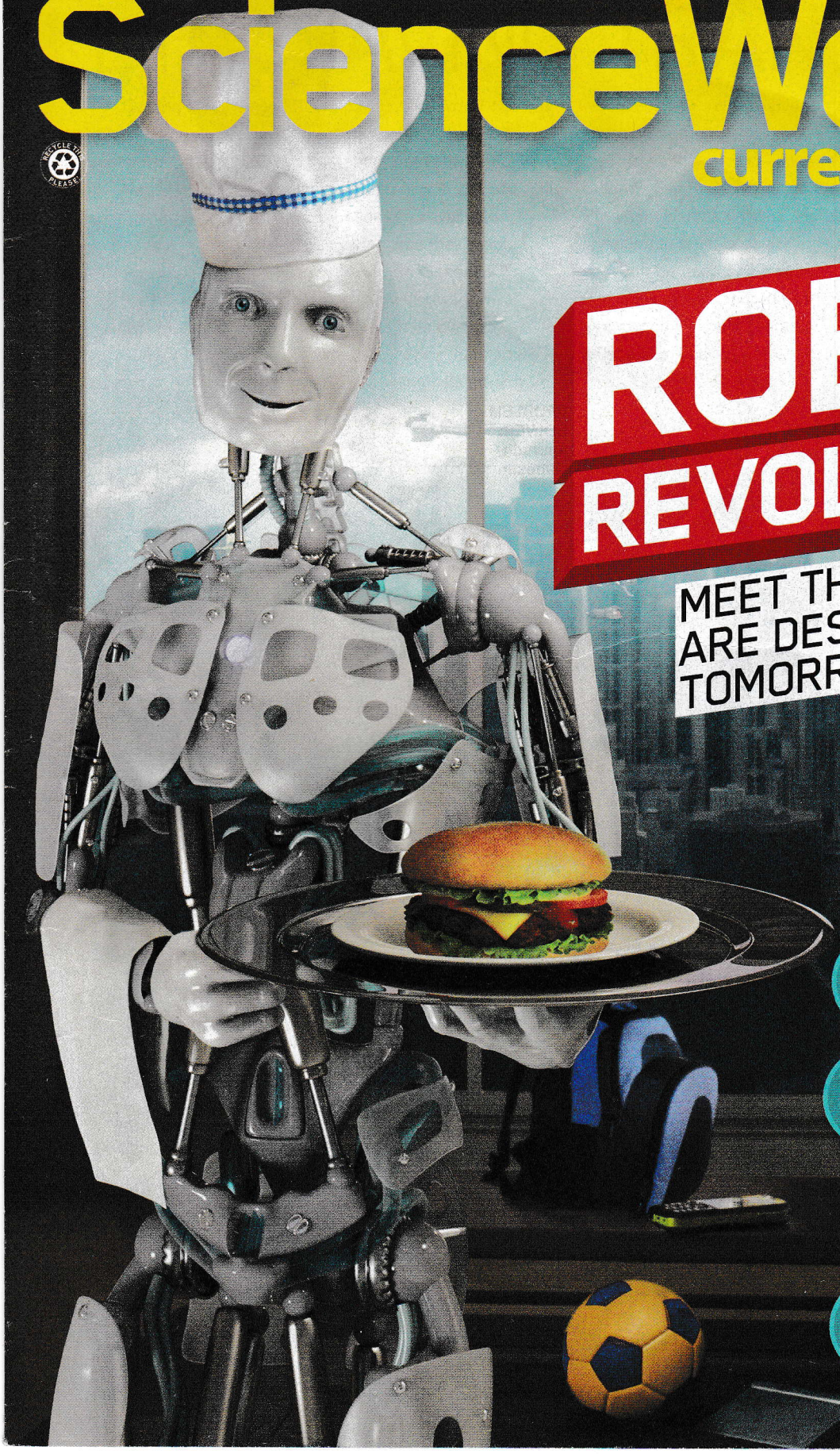

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OCTOBER 10, 2016 VOL.73, NO.3

2 **SCIENCE NEWS**

FEATURES

8 **THE EVOLUTION OF ROBOTS** Bots built by students go head-to-head in a competition.

12 **INVENTING A SAFER DRIVE** T.J. Evarts helped create a device that keeps drivers focused on the road.

14 **DNA BLASTS OFF!** A teen's genetics project rockets into space.

18 **PITCH PERFECT** A student's invention helps improve the accuracy of baseball pitches.

20 **BEATING THE HEAT** A team of teens finds a new way to protect firefighters.

23 **GROSS OUT!**

24 **DISTRACTED DRIVING**

SCIENCE WORLD OCTOBER 10, 2016
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SCIENCE NEWS

PROBLEM SOLVER: Anurudh Ganesan

LIFE-SAVING TRANSPORT

Getting medicines to some parts of the world can be challenging. For example, *vaccines*, which protect the body from diseases, must be kept cool to stay effective.

Usually vaccines are shipped on ice or in electric refrigerators. In areas where those aren't available, many vaccines are ineffective by the time they reach clinics. That's why 16-year-old Anurudh Ganesan, of Clarksburg, Maryland, invented the Vaxxwagon—a portable cooling system that generates its own power.

The Vaxxwagon is a two-wheeled device that can be pulled by a bicycle, a vehicle, or an animal. Its turning wheels can power a small refrigeration system for about 10 hours.

This April, Anurudh attended the White House Science Fair to demonstrate the Vaxxwagon for President Barack Obama. He hopes to start selling his invention to relief organizations by the end of the year so it can be used in the field.

"In my mind," Anurudh says, "the Vaxxwagon will be a success as soon as it saves a life."

—Hailee Romain

DANIEL BEDELL (GANESAN, VAXXWAGON)

HOW VAXXWAGON WORKS

PRESSURE GAUGES display the pressure of the *refrigerant*—the gas that keeps the vaccines cold.

THERMOMETERS display temperature within the refrigerator.

COLD CHAMBER holds vaccines.

WHEEL turns gears to operate the compressor.

COMPRESSOR squeezes the refrigerant into a small space. When the refrigerant later expands, it cools, chilling the cold chamber.

BIOLOGY: ANIMAL ANATOMY

Two-Nosed Dog

DOUBLE TAKE: Toby is a healthy dog with two noses.

No, you aren't seeing double: Toby, an Australian shepherd, has two noses—each with one nostril. His remarkable anatomy may be the result of abnormal *genes*, or units of hereditary material, says Adam Boyko, who studies canine genetics at Cornell University's College of Veterinary Medicine.

At least three dog breeds commonly display similar double noses, but Australian shepherds aren't among them. Two-nosed dogs don't seem to mind their extra sniffer and are perfectly healthy.

In fact, their widely separated nostrils might help the animals better gauge which direction a scent is coming from, says Boyko. Toby's owner, Todd Ray of Venice, California, says that Toby excels at tasks such as finding hidden objects.

–Adam Hadhazy

ENGINEERING: PROGRAMMING

Password Protector

Mira Modi, who lives in New York City, runs a thriving internet business—and she's just 12 years old. Mira creates and sells online passwords, using nothing but a die and a method known as *Diceware*.

Technology consultant Arnold Reinhold invented Diceware in 1995. Using Reinhold's technique, Mira rolls a six-sided die five times to generate five random digits. Together they make up a number that corresponds to a word in a list compiled by Reinhold. Each word is just three to six letters long.

Mira completes the process six times to create a six-word password that's hard to crack but easy to memorize. Mira charges $2 each for the passwords, which are stronger than regular passwords. "A six-word password can only be broken by a huge organization, like a government agency," says Mira.

–Jeanette Ferrara

SECURITY PRO: Mira Modi

ANOTHER EARTH?

Astronomers have found an Earth-like planet circling Proxima Centauri, our solar system's closest neighboring star. The *exoplanet*—a planet outside our solar system—is named Proxima b. It may be the right temperature and size to support life.

Scientists observed tiny movements of Proxima Centauri to detect the planet. The gravity of Proxima b tugs on the star as the exoplanet orbits it. That causes the star to wobble slightly.

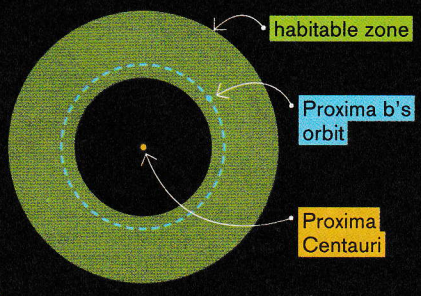
Proxima b's distance from its star suggests that life could exist on the planet. That's because it orbits within Proxima Centauri's *habitable zone*, where it receives just enough warmth for liquid water to occur on the planet's surface. Astronomers hope to observe Proxima b more closely for signs of life soon. —*Hailee Romain*

THE EXOPLANET PROXIMA B: Proxima b circles its star every 11.2 days and is about 1.3 times the mass of Earth.

THE STAR PROXIMA CENTAURI: Proxima Centauri is 4.2 *light-years* away from Earth. A light-year is the distance light travels in one year: 6 trillion miles.

THE HABITABLE ZONE

Our galaxy has many planets that receive enough warmth from their stars to have liquid water on the surface. Newfound exoplanet Proxima b is the nearest to Earth.



EARTH: NATURAL RESOURCES

HARNESSING THE WIND

Five new wind turbines will start spinning later this year off the coast of Rhode Island. The project, called the Block Island Wind Farm, is the first *offshore* wind farm in the U.S. Offshore wind farms are located in the ocean.

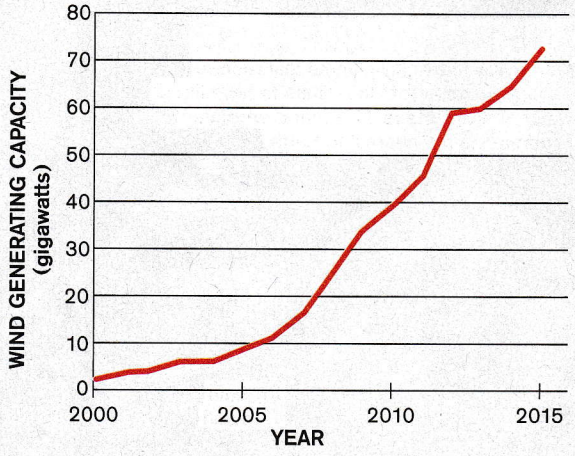
Offshore turbines work just like ones on land. The breeze turns the turbines' blades, spinning generators that produce electricity. The advantage of offshore wind farms over land-based farms is that they can harness the strong, steady winds that blow over oceans.

"There is a huge potential for offshore wind power in the U.S.," says Cristina Archer, an environmental engineer at the University of Delaware. Wind doesn't produce pollution and is a *renewable* energy source. That means it will never run out.

—Hailee Romain

WIND POWER ON THE RISE

About how many more gigawatts of wind capacity did the U.S. have in 2015 than in 2005?



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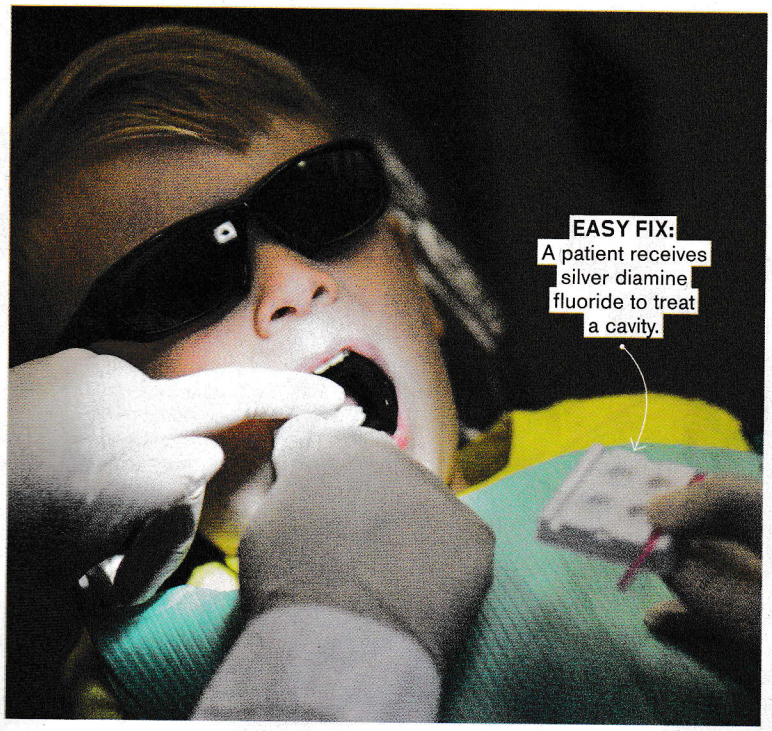


EASY FIX: A patient receives silver diamine fluoride to treat a cavity.

CHEMISTRY: COMPOUNDS

No More Drilling?

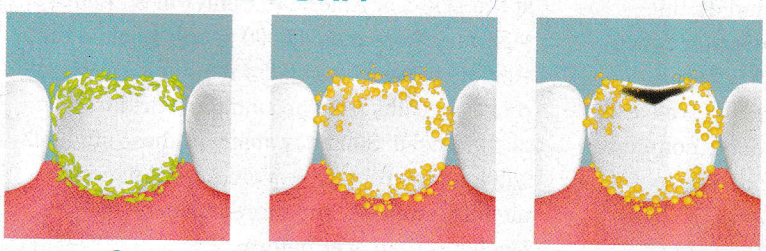
No one likes to have a cavity filled. Luckily, an alternative treatment could reduce the need for some small fillings.

In 2014, the U.S. Food and Drug Administration approved the use of a *compound*—a combination of two or more elements—called silver diamine fluoride (SDF). It kills harmful bacteria that cause tooth decay. These bacteria produce acids that can eat through the protective *enamel* coating on your teeth—creating a cavity. The substance can treat small cavities and prevent them from getting worse.

Dentists typically drill to remove the decay and then fill the cavity. "SDF is much easier," says Richard Niederman, a professor at New York University College of Dentistry. "You just paint it on teeth, which is great for kids."

—Jeanette Ferrara

HOW CAVITIES FORM

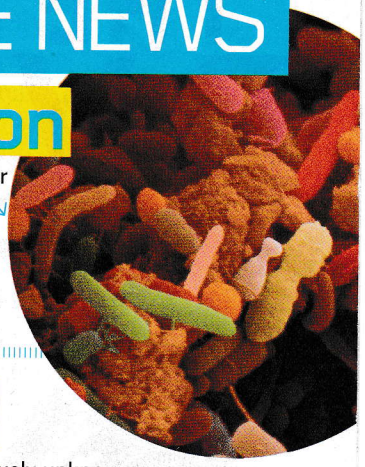


1. Bacteria feed on sugars and other particles in food, releasing acids.
2. Acids dissolve the minerals that make up tooth enamel.
3. Once the enamel is weakened, the interior of the tooth becomes vulnerable to decay, and a hole forms.

NUMBERS IN THE NEWS

1 trillion

Estimated number of microbe species on Earth, according to a new study.



1,300

Number of previously unknown galaxies recently spotted by the MeerKAT radio telescope in South Africa.

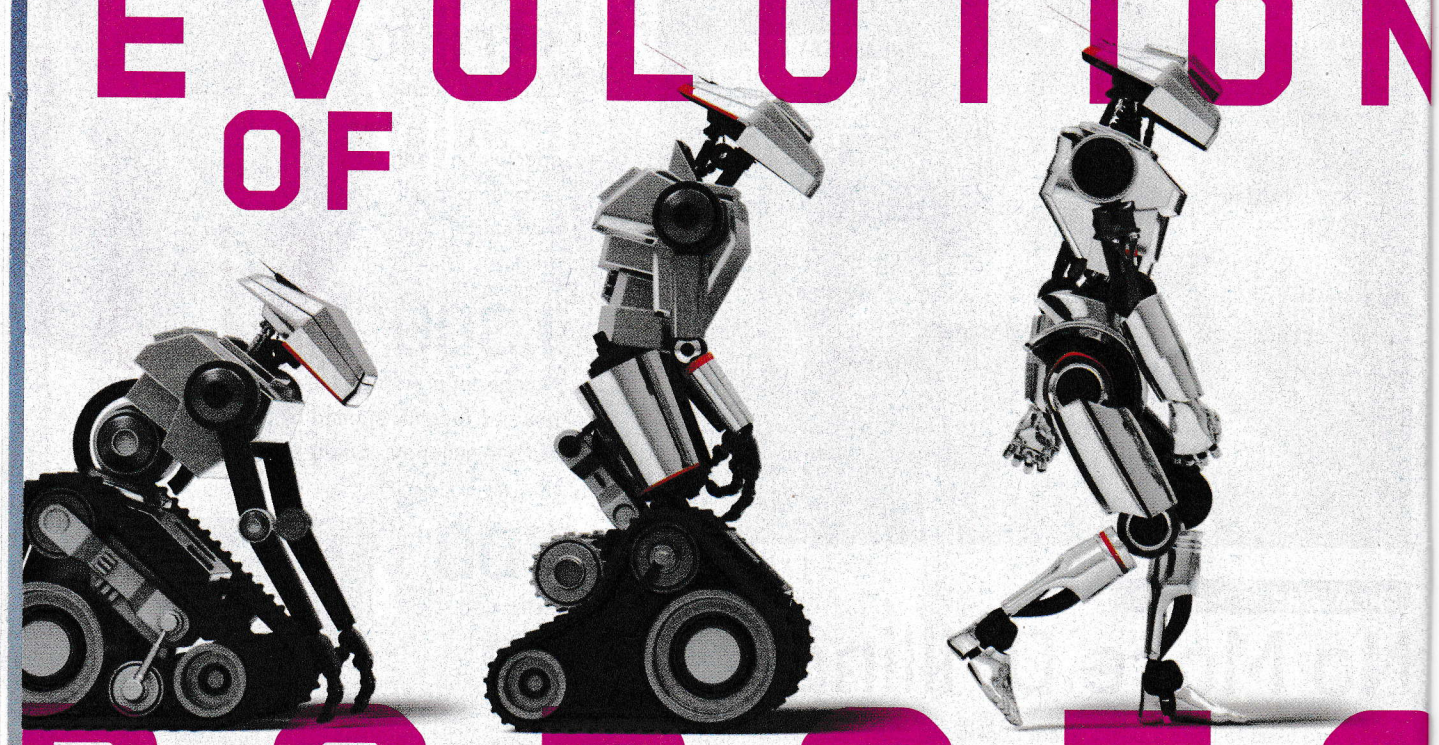
700

Estimated minimum number of years that wild monkeys in Brazil have been using stone tools to crack open nuts, according to an archaeological excavation. That's at least 100 generations of monkeys!

176 Number of kids or teens who end up in U.S. emergency rooms each day because of skateboarding accidents, according to researchers at Nationwide Children's Hospital in Columbus, Ohio.

22 Estimated percentage by which internet traffic grows every year. Service providers in many parts of the world are struggling to keep up.

THE EVOLUTION OF ROBOTS



High school students advance the field of robotics with a competition like no other

ESSENTIAL QUESTION: What types of tasks might robots be better suited to perform than people?

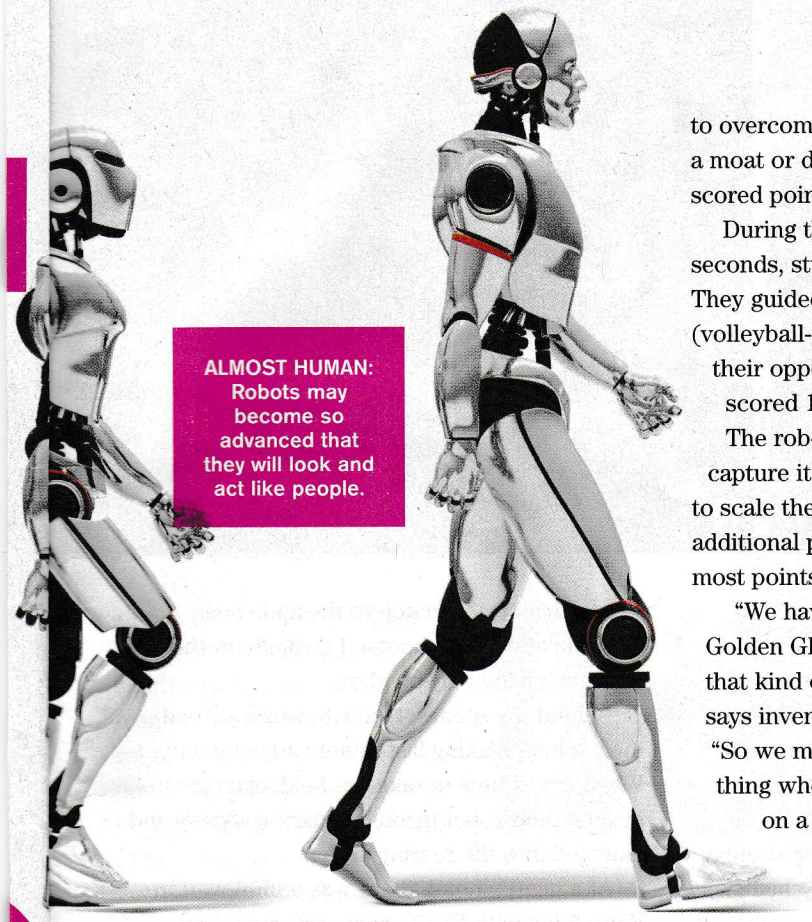
Robots are no longer science fiction. Today, these machines cook food in restaurants, assist people with disabilities, and provide companionship. They go places and do things we can't; for example, entering disaster zones like the one in Fukushima, Japan, where a nuclear power plant exploded in 2011, releasing dangerous levels of radiation. Robots continue to evolve as engineers create models to tackle almost any task (*see Today's Robots, p. 11*).

When it comes to advancing the field of robotics, teens are leading the way. Each year, teams of high school students compete using robots they design, program, and build themselves as part of the FIRST Robotics program. FIRST stands for "For Inspiration and Recognition of Science and Technology."

The program's biggest competition is the FIRST Championship. This year, it took place at the Dome at America's Center in St. Louis, Missouri. More than 40,000 people packed the stadium to watch as 600 of the top high school robotics teams from around the world went head-to-head. Someday, many of these students will lead the robotics revolution, engineering nimbler, stronger, and more independent machines than ever before.

CAPTURE THE FLAG

The FIRST Championship is like a sporting event, except with games played by robots



ALMOST HUMAN: Robots may become so advanced that they will look and act like people.

instead of human athletes. Each year, students and their bots must complete a different task. The 2016 challenge was dubbed "FIRST STRONGHOLD" (*see Storming the Castle, p. 10*). It required an alliance of four randomly paired teams, working together to beat another alliance. The goal: to use their robots to capture their opponent's castle.

For the first 15 seconds of the competition, robots operated *autonomously*. The bots had to overcome their opponents' defenses, such as a moat or drawbridge, on their own. The teams scored points if their robots were successful.

During the remaining 2 minutes and 15 seconds, students took control of their bots. They guided the machines to shoot "boulders" (volleyball-sized foam balls) through goals in their opponents' tower. When an alliance scored 10 shots, the castle's flag went down.

The robots then surrounded the castle to capture it or pulled themselves up on rungs to scale the tower. These tasks racked up additional points. The alliance that earned the most points advanced in the competition.

"We have a Super Bowl for football and the Golden Globes for Hollywood, but where is that kind of celebration for math and science?" says inventor Dean Kamen, FIRST's founder. "So we made FIRST a sporting event, something where the winners aren't given a grade on a quiz but are celebrated in a big way."

BUILDING A BOT

When the FIRST STRONGHOLD challenge was announced, teams had six weeks to build their robots. The Nutrons, a team of 50 students from five Boston-area high schools, gathered to discuss strategy. Then they divided into small groups to focus on specifics, like electrical and mechanical engineering.

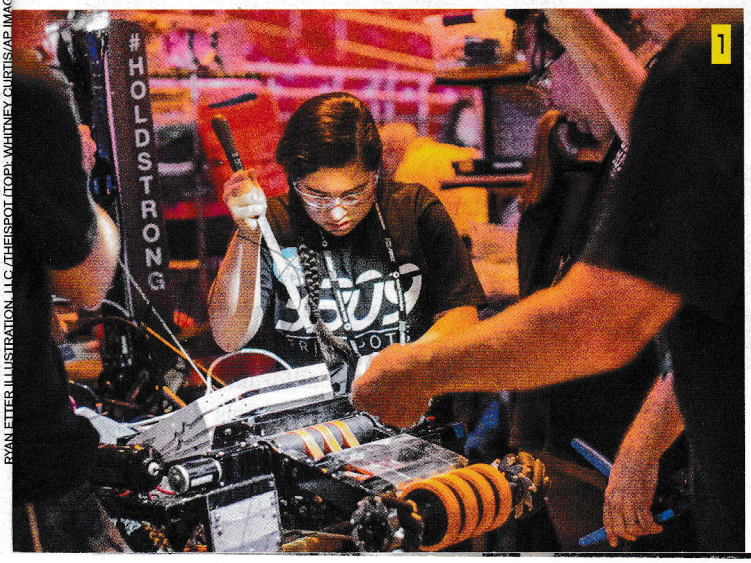
The Nutrons' lead programmer, Camilo Gonzalez, had to write the *code*, or computer instructions, so the robot could accurately shoot balls into goals. "Throwing a ball in a small

Continued on the next page →

BOT BATTLE

1 A team makes repairs before a match.

2 Two bots duke it out in the finals.



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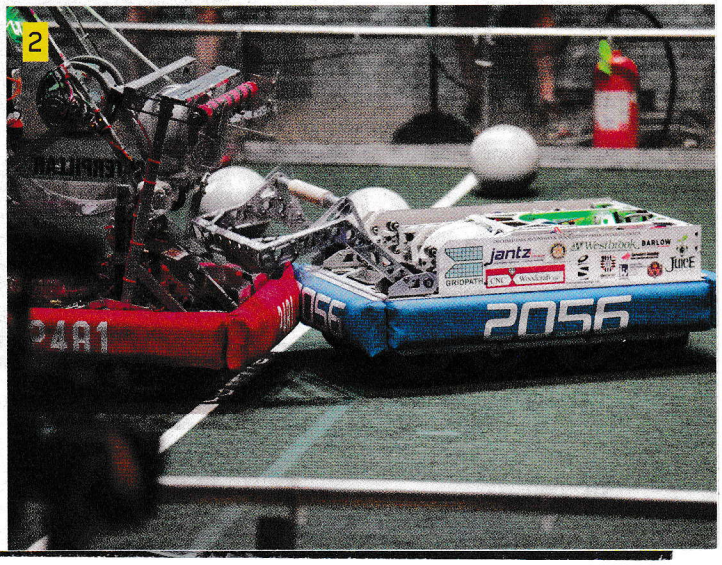

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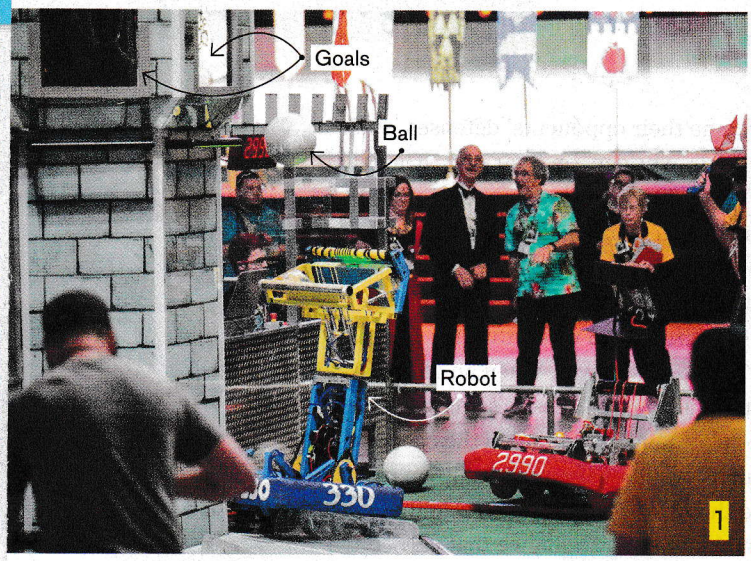

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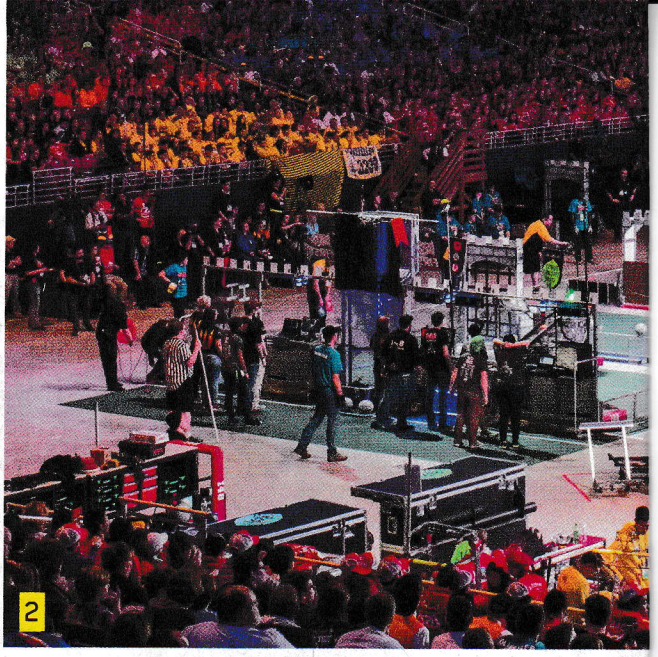
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PLAY TO WIN

1 A robot shoots a ball toward a goal.

2 The championship field and stands

3 Teams cheer at the playoffs.

4 The Nutrons at a practice match

hole is hard to do manually, so we wanted to automate it," says Camilo.

To do that, the team attached a green light to the robot to shine on reflective tape inside the goals. The light bounces back to the robot, which allows it to calculate the angle to throw the ball and make a successful shot. It scores more than 90 percent of the time. Their strategy worked: The Nutrons advanced to the championship in St. Louis.

ENTERING THE RING

Eight playing fields were set up inside the stadium at this year's FIRST Championship, along with a massive video screen to broadcast each match to the audience. Announcers' voices boomed throughout the stadium, giving play-by-plays.

Behind the scenes, teams hovered around their robots making last-minute adjustments. When it was time to take the field, each team pushed their robot through a dark walkway and emerged into the roaring arena.

At a nearby hotel, there was an Innovation Faire filled with FIRST sponsors, including NASA, Disney, the Girl Scouts, and Qualcomm. These organizations provide funds to help teams build their robots, and they attend the championship to meet aspiring student engineers.

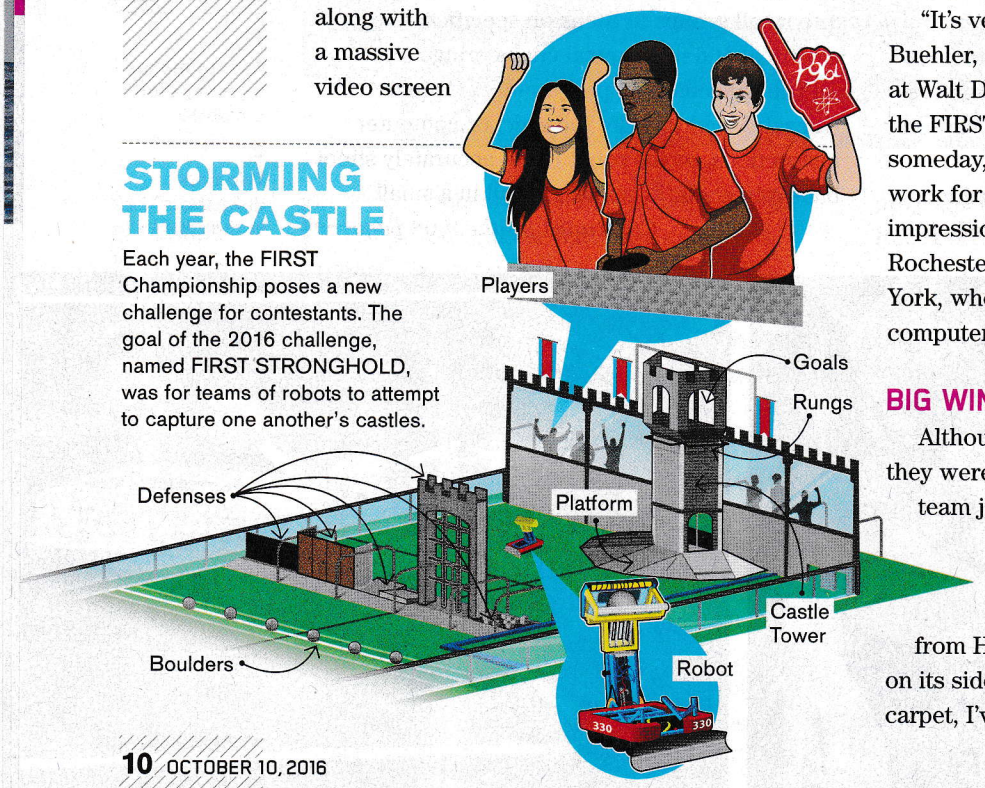
"It's very exciting to be here," says Martin Buehler, a research and development executive at Walt Disney Imagineering who helped design the FIRST STRONGHOLD game. "We hope that someday, some of these students will come work for us." The competition left a lasting impression on Camilo. He is now attending the Rochester Institute of Technology (RIT) in New York, where he plans to major in electrical and computer engineering.

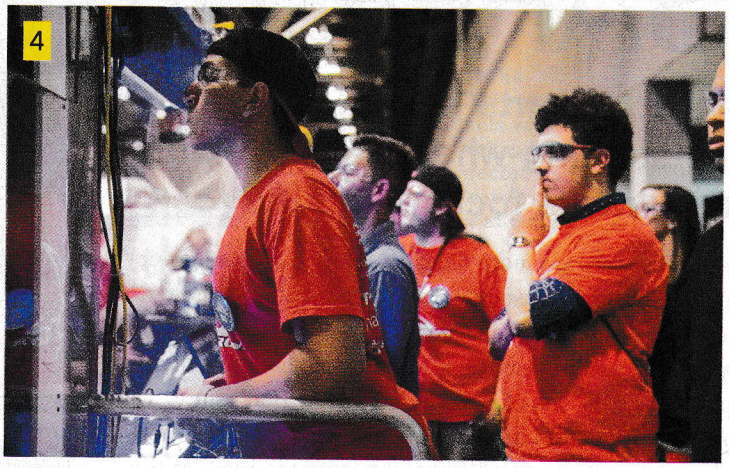
BIG WINNERS

Although the Nutrons won several matches, they were eliminated in the quarterfinals. The team joined fans in the stands to watch the remaining games, including an intense semifinal in which a robot created by the Beach Bots, a team from Hermosa Beach, California, flipped on its side. "Once the robot's wheels leave the carpet, I've lost all control," says Zac Couch, the

STORMING THE CASTLE

Each year, the FIRST Championship poses a new challenge for contestants. The goal of the 2016 challenge, named FIRST STRONGHOLD, was for teams of robots to attempt to capture one another's castles.





CORE QUESTION

Think about some of the skills students needed to design their robots. How might these skills help them as future engineers?

Beach Bots' driver. "Tipping over when you need to be scoring is devastating." The team struggled to right the robot as the clock ticked down. They used the bot's arm to flip it upright and moved on to the championship.

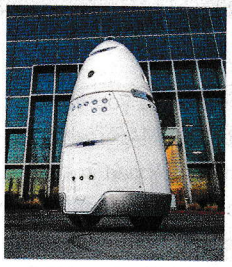
The Beach Bots had only nine students on the team. They met nearly every day after school and on weekends, putting in some 650 hours to get their robot in fighting shape. It was worth it. After a nail-biting final that required a tiebreaker challenge, their alliance (which included Cleveland's Team, from Cleveland, Ohio; the Roboteers, from Tremont, Illinois; and Blue Cheese, from Glen Allen, Virginia) won first place. The crowd went wild as confetti rained down.

"It's an incredible feeling to know that after all of those nights working on the robot, we did it," says Zac.

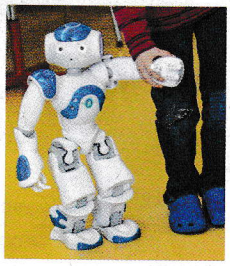
—Amy Barth

TODAY'S ROBOTS

Engineers are designing robots to help make people's lives easier and safer. Take a look at some of the ways robots are lending a helping hand.



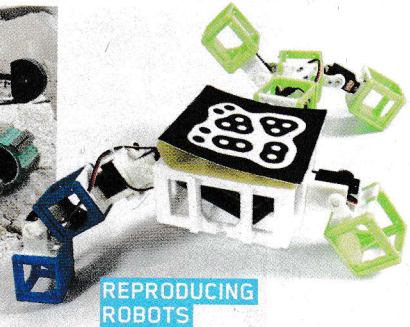
SECURITY GUARDS
K5 Security Robots currently patrol shopping malls and parking lots in California. The bots snap photos of unusual behavior, sniff out suspicious scents, and alert authorities to alarming noises.



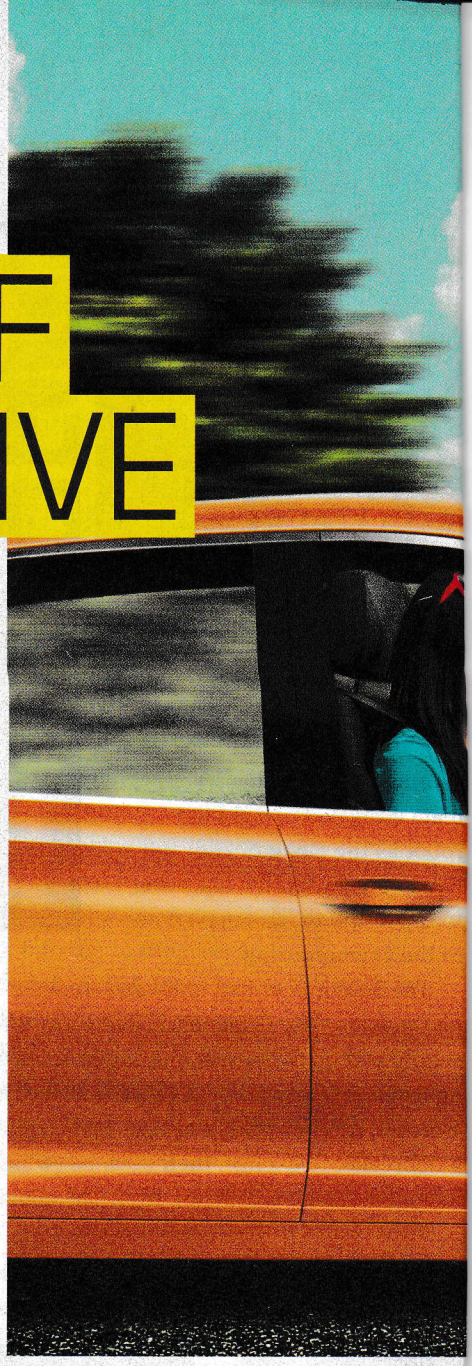
SOCIAL COMPANIONS
Interacting with robots like this one called NAO could help improve the language and social skills of children with *autism*. This condition affects a person's ability to communicate with other people.

HOUSEHOLD HELPERS
The PR2 is a robot chef that can flip pancakes and make pizza. Its designers hope that similar robots could someday perform household chores like cooking, cleaning, and doing laundry.

SEARCH AND RESCUE
Teams used the KOHGA3 to assess damage to buildings too dangerous for people to enter after a tsunami struck Japan in 2011. Similar bots are doing the same for a nuclear plant damaged by the massive wave.



REPRODUCING ROBOTS
For the first time ever, scientists have designed robots that can share data to make a new robot with a mix of the same traits as the original robots. The new bots are created with 3-D printers.



INVENTOR OF A SAFER DRIVE

At age 14, T.J. Evarts helped create a high-tech steering-wheel cover to keep distracted drivers focused on the road

As new drivers, teenagers are more likely than any other age group to be involved in collisions caused by distractions like cell phones, passengers, or navigation systems, according to the National Highway Traffic Safety Administration. Frightening facts like that are what prompted T.J. Evarts of Londonderry, New Hampshire, to take action. In 2010, Evarts and a group of friends invented the SMARTwheel—a device to keep drivers focused on the road. At the time, he was just 14 years old.

The SMARTwheel is a steering-wheel cover that buzzes when it senses risky driving behaviors, such as taking one or both hands off the wheel. The clever invention caught a lot of people's attention. T.J. and his friends were invited to demonstrate it for President Barack Obama at the 2010 White House Science Fair. Three years later, the group took its SMARTwheel for a spin on *Shark Tank*, a reality show where inventors pitch their ideas to a panel of investors. Evarts, now 20, has started his own company and is about to release the device for sale to the public.

BIG MOMENT: T.J. Evarts (*far left*) explains the SMARTwheel to President Barack Obama at the 2010 White House Science Fair.

What inspired you to invent the SMARTwheel?

In 2010, I took part in a science and engineering competition where the theme was "driving safety." In cars, technologies like cameras and sensors record speed and braking behaviors, but they don't actively help drivers avoid collisions. For the competition, my team and I wanted to invent something that would alert

LOOK OUT! The SMARTwheel detects when drivers may be distracted and buzzes to get their attention.

drivers to dangerous situations and allow them to correct their behavior immediately. Our hope was that this real-time feedback would prevent accidents.

What was it like to bring this invention to life?

Inventions start with an idea but evolve over time. We came up with the idea for the SMARTwheel pretty quickly, but creating a real product has taken years. First, we came up with a *prototype*. Then we spent years developing and refining our initial model. Most recently, we've been getting feedback from parents and young drivers and incorporating it into the design to prepare the device for market.

How were you involved in the different stages of development?

Early on, I was involved in the technical aspects of the SMARTwheel. I participated in science and technology competitions and did an internship with an engineer who taught me how to develop and produce my ideas. I helped create the device's sensor technologies, hardware, and software. I also designed and programmed the first few versions of our mobile app. The app tracks risky driving behaviors so young drivers and their parents can review, discuss, and correct bad habits. I still work in software development now that we've formed the company. I draw on the expertise of my colleagues to make decisions about things like manufacturing, publicity, and design.

What's it like to be a young entrepreneur?

People want to see young inventors succeed and are usually willing to help however they can. But it can also be difficult for professionals to take teens seriously. Sometimes you have to prove yourself. If you're serious and passionate about your idea, you can really inspire people.

What advice would you give to other young inventors?

Don't wait! Middle or high school is a great time to start on your invention. Parents and teachers can be your best mentors, and the financial risks are low. The rewards, on the other hand, might just change your life! *—Hailee Romain*

MATT HERRING, THINKSTOCK/GETTY IMAGES (ILLUSTRATION); OFFICIAL WHITE HOUSE PHOTO BY PETE SOUZA (OBAMA)
BLOOMBERG VIA GETTY IMAGES (WHEEL)

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The SMARTwheel is a steering-wheel cover that buzzes when it senses risky driving behaviors, such as taking one or both hands off the wheel. The clever invention caught a lot of people's attention. T.J. and his friends were invited to demonstrate it for President Barack Obama at the 2010 White House Science Fair. Three years later, the group took its SMARTwheel for a spin on *Shark Tank*, a reality show where inventors pitch their ideas to a panel of investors. Evarts, now 20, has started his own company and is about to release the device for sale to the public.

BIG MOMENT: T.J. Evarts *(far left)* explains the SMARTwheel to President Barack Obama at the 2010 White House Science Fair.

What inspired you to invent the SMARTwheel?

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LOOK OUT! The SMARTwheel detects when drivers may be distracted and buzzes to get their attention.

drivers to dangerous situations and allow them to correct their behavior immediately. Our hope was that this real-time feedback would prevent accidents.

What was it like to bring this invention to life?

Inventions start with an idea but evolve over time. We came up with the idea for the SMARTwheel pretty quickly, but creating a real product has taken years. First, we came up with a *prototype*. Then we spent years developing and refining our initial model. Most recently, we've been getting feedback from parents and young drivers and incorporating it into the design to prepare the device for market.

How were you involved in the different stages of development?

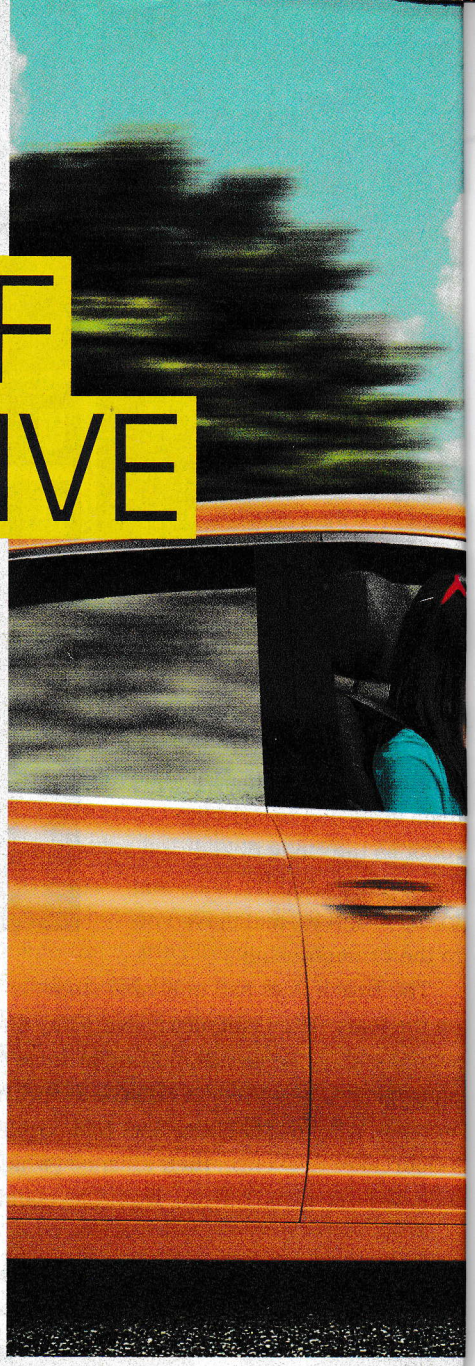
Early on, I was involved in the technical aspects of the SMARTwheel. I participated in science and technology competitions and did an internship with an engineer who taught me how to develop and produce my ideas. I helped create the device's sensor technologies, hardware, and software. I also designed and programmed the first few versions of our mobile app. The app tracks risky driving behaviors so young drivers and their parents can review, discuss, and correct bad habits. I still work in software development now that we've formed the company. I draw on the expertise of my colleagues to make decisions about things like manufacturing, publicity, and design.

What's it like to be a young entrepreneur?

People want to see young inventors succeed and are usually willing to help however they can. But it can also be difficult for professionals to take teens seriously. Sometimes you have to prove yourself. If you're serious and passionate about your idea, you can really inspire people.

What advice would you give to other young inventors?

Don't wait! Middle or high school is a great time to start on your invention. Parents and teachers can be your best mentors, and the financial risks are low. The rewards, on the other hand, might just change your life! ❀ *—Hailee Romain*



INVENTOR OF A SAFER DRIVE

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MATT HERRING, THINKSTOCK/GETTY IMAGES (ILLUSTRATION); OFFICIAL WHITE HOUSE PHOTO BY PETE SOUZA (OBAMA)
BLOOMBERG VIA GETTY IMAGES (WHEEL)

DNA BLASTS OFF

A teen's genetics research project rockets to the International Space Station

ESSENTIAL QUESTION: Why is it important to study the effects of space on the human body?

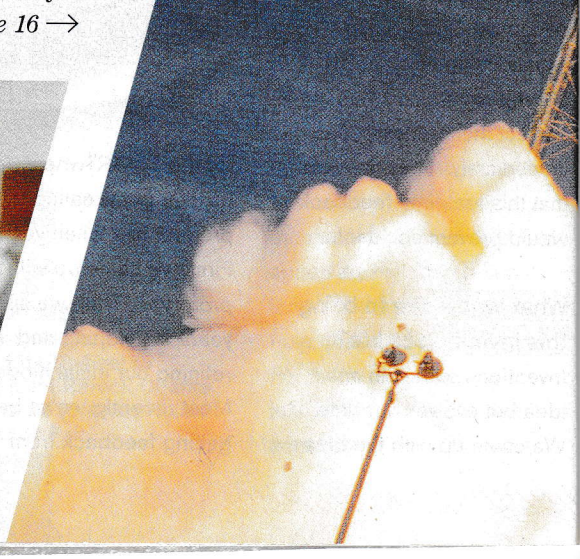
When Anna-Sophia Boguraev was 4 years old, she decided she wanted to go into space. Now 17, Anna-Sophia has just taken one giant leap toward her childhood dream: NASA launched her research project into space this April. It flew aboard a Falcon 9 rocket to the International Space Station (ISS), a research laboratory orbiting Earth. A few days after that, an astronaut on the ISS carried out her experiment—one that will help scientists learn more about how space travel affects the human body. More than 300 middle and high school students entered the first-ever Genes in Space contest—but only Anna-Sophia's project was selected. The contest aims to promote a better understanding of how to keep astronauts healthy as they explore the solar system.

SPACE VS. EARTH

In space, astronauts experience *microgravity*—gravity much weaker than that on Earth. They might also be exposed to higher levels of *radiation*—high-energy particles or rays—since they're no longer protected by

Continued on page 16 →

LAB WORK: Anna-Sophia prepares samples for her experiment.



LIFTOFF! SpaceX's Falcon 9 rocket carried DNA samples prepared by Anna-Sophia to space.

EARTH TWIN, SPACE TWIN

Anna-Sophia isn't alone in her quest to find out how space travel affects the human body. NASA scientists are studying a set of twins to learn more. This past March, astronaut Scott Kelly returned from a full year aboard the International Space Station. Away from Earth's gravity, his body stretched two inches, his muscles weakened, and his skin became very sensitive. Scientists are now studying Scott and his identical twin brother, Mark, a retired astronaut who remained on Earth during Scott's mission. The pair share the same genes, so scientists think any difference in the twins' health can be attributed to their vastly different environments for the year.

MENTAL HEALTH
Psychologists will compare the twins' moods, stress levels, and cognitive function.

IMMUNE SYSTEM
The twins received identical flu vaccines during Scott's year in space. Scientists are studying how their disease-fighting immune systems reacted.

CARDIOVASCULAR SYSTEM
Microgravity changes the distribution of fluids in the body. Biologists are comparing how this affected the twins' blood pressure, heart rate, and blood vessels.

VISION
Changing fluid distribution in space can cause swelling in the eyes that affects vision. Scientists will study the twins' eyes to see how they differ.

MICROBIOME
Microbiologists will study bacteria essential to digestion in the twins' guts to find out how space travel affected them.

COURTESY OF ANNA-SOPHIA BOGURAEV/GENES IN SPACE PROJECT/MINDTOUCH SCIENTIST; SPACEX VIA FLICKR/ROCKET; MARCO GROB/TRUNK ARCHIVE (SPACE TWINS)
DAMIEN SCOGIN: ILLUSTRATIONS

Earth's atmosphere. And they have to endure a stressful spaceflight. All of these things may affect astronauts' health (*see Earth Twin, Space Twin, p. 15*).

"When I was younger, I learned that astronauts get sick a lot when they go to space, much more often than the average person on Earth," says Anna-Sophia. "Their *immune* system [which fights infections] gets weaker."

Anna-Sophia began learning about space and the human body. She started by reading her biology textbook, speaking with her teacher at Fox Lane High School in Bedford, New York, and studying articles in scientific journals.

Anna-Sophia learned that spaceflight causes many changes in a person's *DNA*. In humans and other organisms, DNA molecules carry genes—units of hereditary information (*see Structure of DNA, below*). From her research, Anna-Sophia found that one way the environment can affect a person's health is through subtle *epigenetic changes* to DNA. These changes happen when diet, stress, toxic substances, and other environmental factors cause small chemical markers to be added to or removed from DNA. They can affect many biological processes in the body, including how the immune system functions.

COPY MACHINE

The Genes in Space contest asked entrants to come up with an experiment using one of the ISS's new instruments, a *miniPCR machine*. The device makes millions of copies of small chunks of DNA to help scientists study this important molecule.

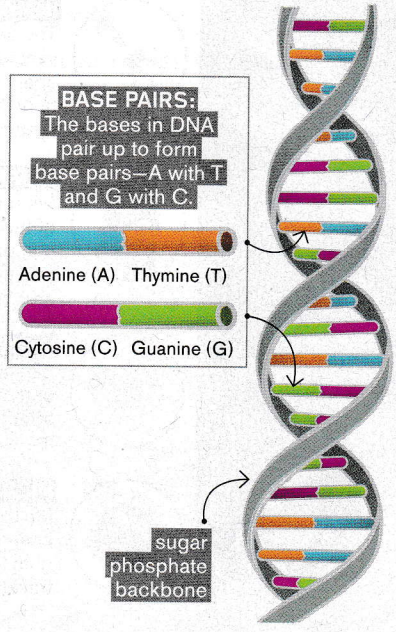
When Anna-Sophia learned that the miniPCR machine could be used to detect epigenetic changes, her project idea was born. Working with her mentor, biology graduate student Holly Christensen of the Massachusetts Institute of Technology, Anna-Sophia developed two identical procedures—one to be carried out on Earth and one on the ISS. The goal was to find out if the miniPCR machine would work the same way on Earth as in space. "We don't know for sure because it's never been used in space," she says.

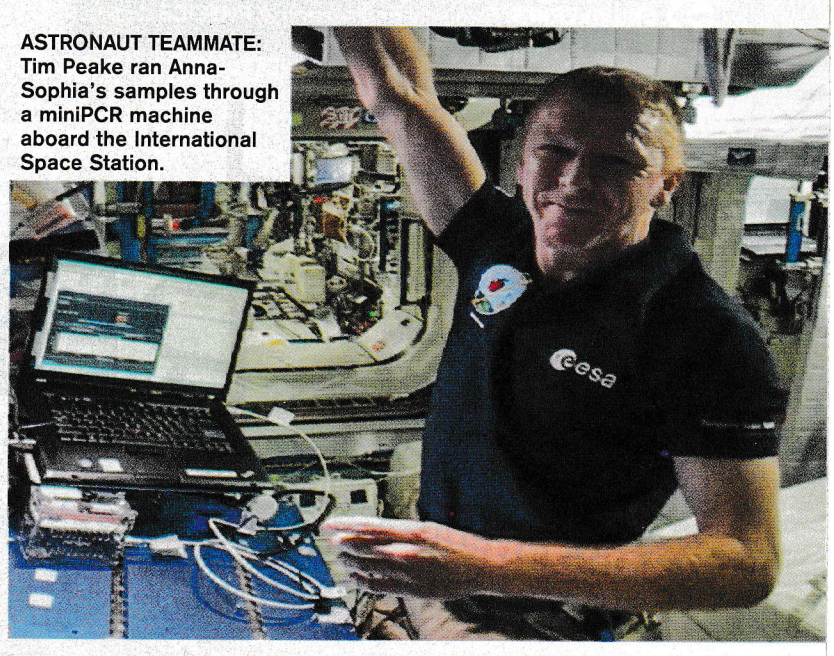
Once Anna-Sophia's proposal was selected as the winner of the Genes in Space contest, she took samples of DNA from baby zebrafish. "I prepared two identical sets of DNA samples," she says. "One set was to be sent into space with the miniPCR machine, and the other was to be kept on Earth with an identical miniPCR machine," she says. The samples left on Earth would act as a *control*—a constant against which she could compare the results of her space experiment.

BACK FROM SPACE: Anna-Sophia analyzes samples that have returned to Earth.

STRUCTURE OF DNA

This molecule of hereditary material is made of long strings of smaller molecules called bases, represented by the letters A, C, T, and G. The bases are connected to a chain of sugar and phosphate that forms the molecule's "backbone." The bases are organized into *genes*, which carry hereditary information. But environmental factors also affect an organism's characteristics and health. They can cause *epigenetic changes*, which alter how genes operate and behave. These biochemical disruptions can lead to diseases such as cancer and heart disease.



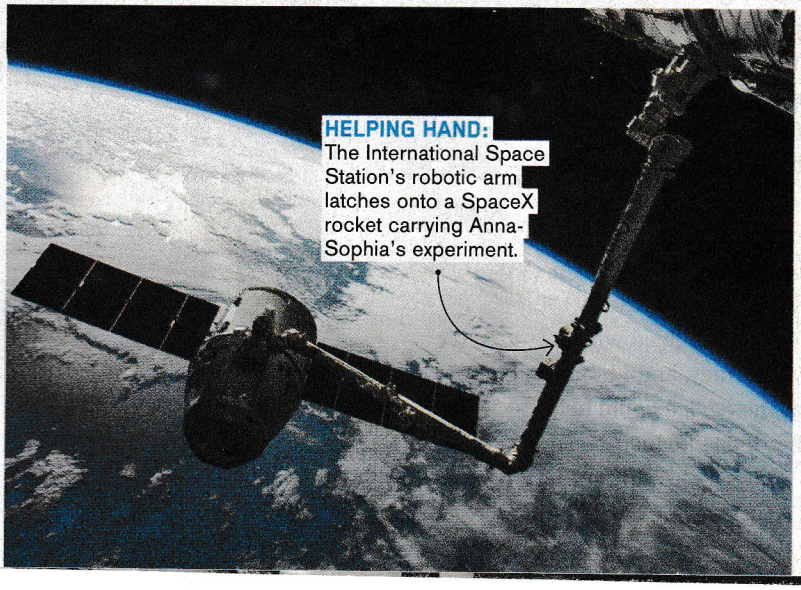


ASTRONAUT TEAMMATE: Tim Peake ran Anna-Sophia's samples through a miniPCR machine aboard the International Space Station.

Anna-Sophia chose zebrafish DNA for her experiment because when zebrafish are young, they go through known epigenetic changes. Anna-Sophia could look for these markers and use them as a *standard*, or established reference, to verify that the miniPCR in space was working as it does on Earth.

3 . . . 2 . . . 1 . . . LIFTOFF!

In April, a SpaceX rocket carried the space-bound portion of the experiment from Kennedy Space Center in Titusville, Florida, to the ISS.



HELPING HAND: The International Space Station's robotic arm latches onto a SpaceX rocket carrying Anna-Sophia's experiment.

Anna-Sophia attended the launch. "It was surreal to watch," she says. "I almost couldn't believe it was happening."

After the experiment reached the ISS, British astronaut Tim Peake placed Anna-Sophia's samples in the miniPCR machine and turned it on. It was the first time anyone had made copies of small chunks of DNA in space. "Both sets of samples—on Earth and in space—were put through the exact same *protocol* [or set of steps]," says Anna-Sophia. In May, Peake sent the samples back to Earth in a spacecraft that landed safely in the Pacific Ocean, and a ship set out to retrieve it. "On behalf of all of us involved in human spaceflight, we thank you for your contributions," said Peake in a video message to Anna-Sophia from the ISS.

After the samples returned from space, Anna-Sophia analyzed and compared them with the ones that had remained on Earth. Just as she had hoped, they looked identical. The results confirmed that the miniPCR machine really does work in space. "Now, hopefully, we can use it to look for changes to astronauts' DNA that might affect their health."

—Jennifer Barone

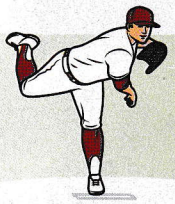
CORE QUESTION

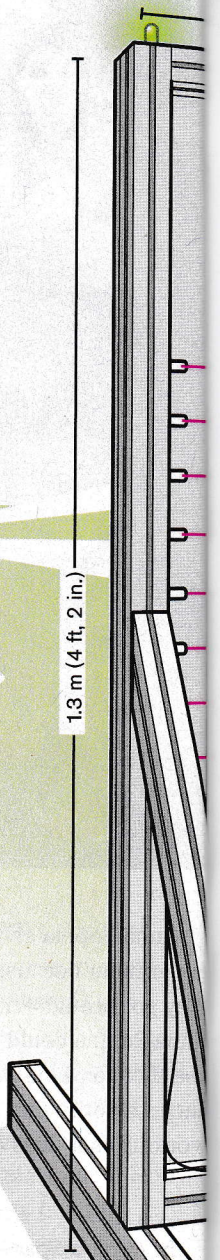
How is living in space different from living on Earth? Explain how two of these differences might affect astronauts' health.

COURTESY OF ANNA-SOPHIA BOGURAEV, GENES IN SPACE PROJECT/MINIPCR (SCIENTIST); DAMIEN SCOGIN (DNA DIAGRAM); ISS/NASA (ASTRONAUT); JOHNSON/NASA (SPACEX DRAGON)

PITCH PERFECT

A teen invents a device to improve a baseball pitcher's accuracy





ESSENTIAL QUESTION: What steps do people follow to design a new invention?

Major League pitchers can hurl a fastball at more than 160 kilometers (100 miles) per hour. But baseball experts say that a pitcher's aim—not speed—is the real key to striking out batters (*see Taking Aim, far right*).

Nick Anglin, a 14-year-old student at Sutherland Middle School in Charlottesville, Virginia, pitches for his local recreational league. But Nick had trouble with his aim. "I was wild and inaccurate," he says. Nick came up with a way to improve his pitching—an electronic strike-zone target that gives pitchers feedback to improve their technique.

BIG-LEAGUE IDEA

"Young pitchers have trouble consistently throwing strikes," says Brian Cammarota, a physical therapist and athletic trainer at Penn Therapy and Fitness in Radnor, Pennsylvania. "It's difficult for them to repeat their pitching mechanics." (*Read more about pitching mechanics in the 3/23/15 issue of* Science World.)

A pitcher should throw pitch after pitch at a clear target to improve accuracy, says Cammarota.

This idea inspired Nick while taking a design and engineering workshop at his school called Maker Corps. Students were asked to improve upon something they enjoyed by using technology. Nick decided to focus on his pitching. He came up with an invention he dubbed Strikey Sensors. It uses lasers to determine whether a pitch is in the strike zone.

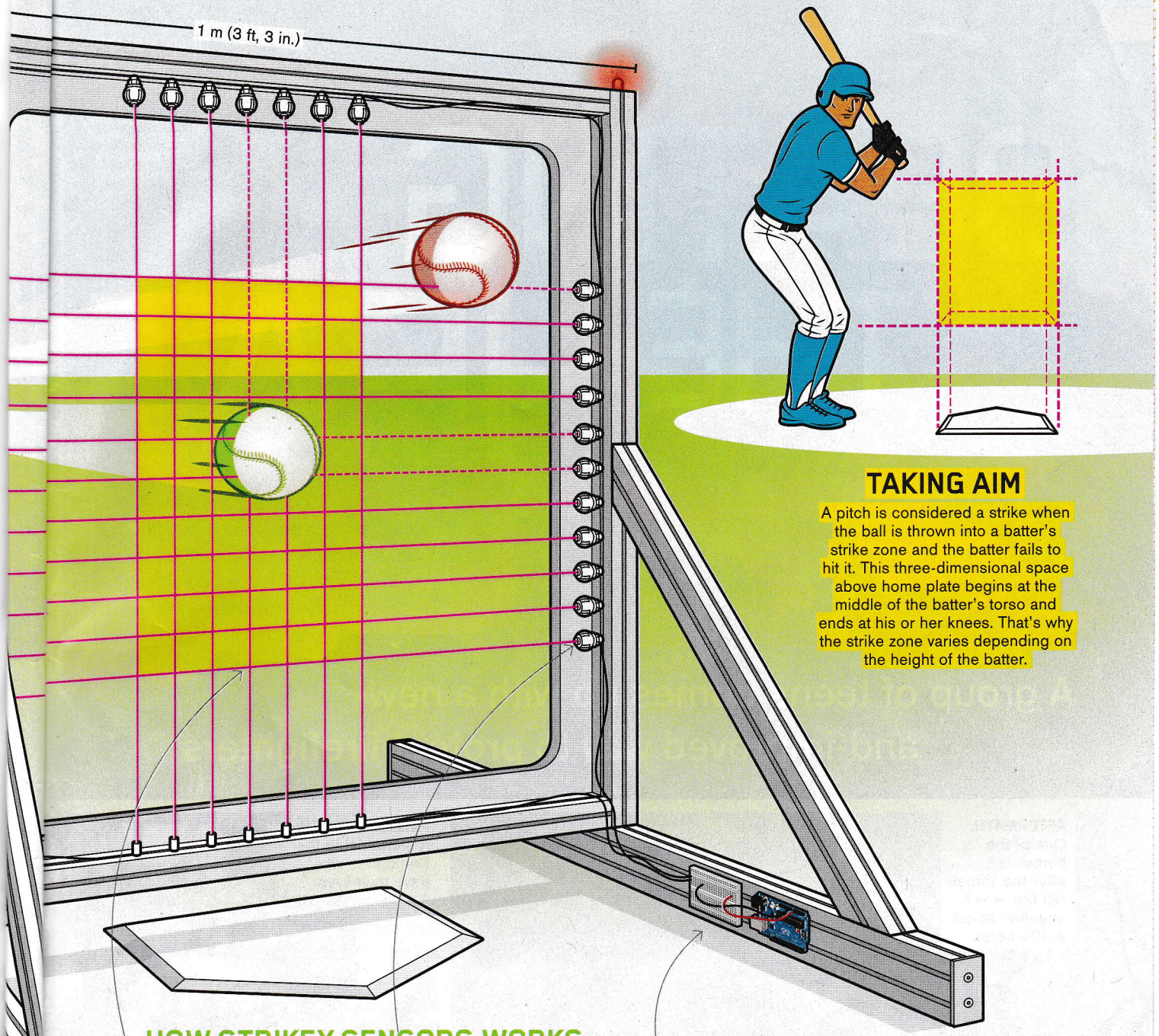
TARGET PRACTICE

To create his device, Nick constructed a rectangular frame lined with *lasers*. These concentrated beams of light shine into the center of the frame, where they intersect to form a grid. When a ball passes through the grid, a computer analyzes the pitch. A light signals whether the throw was a strike or a ball, a pitch thrown outside the strike zone (*see How Strikey Sensors Works, right*). Pitchers can then adjust their technique as needed.

Nick hopes to sell Strikey Sensors to pitchers like himself who want to improve their game. "I struggled with my accuracy, and I hope that the device could help other kids like me," he says.

—Andrew Klein

Nick Anglin with an early, wooden prototype of Strikey Sensors.



TAKING AIM

A pitch is considered a strike when the ball is thrown into a batter's strike zone and the batter fails to hit it. This three-dimensional space above home plate begins at the middle of the batter's torso and ends at his or her knees. That's why the strike zone varies depending on the height of the batter.

HOW STRIKEY SENSORS WORKS

Nick Anglin invented a laser target to help pitchers improve the accuracy of their throws. It determines whether a pitch is thrown inside or outside of the strike zone.

LASER BEAMS:
Lasers—similar to those found in laser pointers—line the frame, 7 along the bottom and 11 along the left side. The laser beams intersect in the center of the frame, forming a 181 square centimeter (28 square inch) strike zone.

PHOTORESISTORS:
Each laser beam hits a *photoresistor* positioned on the opposite side of the frame. These electronics sense changes in light intensity. As a ball passes through the grid, it temporarily blocks some of the lasers. The photoresistors detect the brief dip in light intensity in the location where the ball crosses the grid of lasers.

ARDUINO MICROCONTROLLER:
This small computer is programmed to interpret signals from the physical environment. In this case, it senses the decrease in light intensity from the photoresistors. The computer is *coded*, or programmed, to know when a throw is a ball or a strike based on the location where it crosses the grid of lasers. The computer then alerts the pitcher by lighting up the appropriate bulb—green for "strike" or red for "ball."

CORE QUESTION

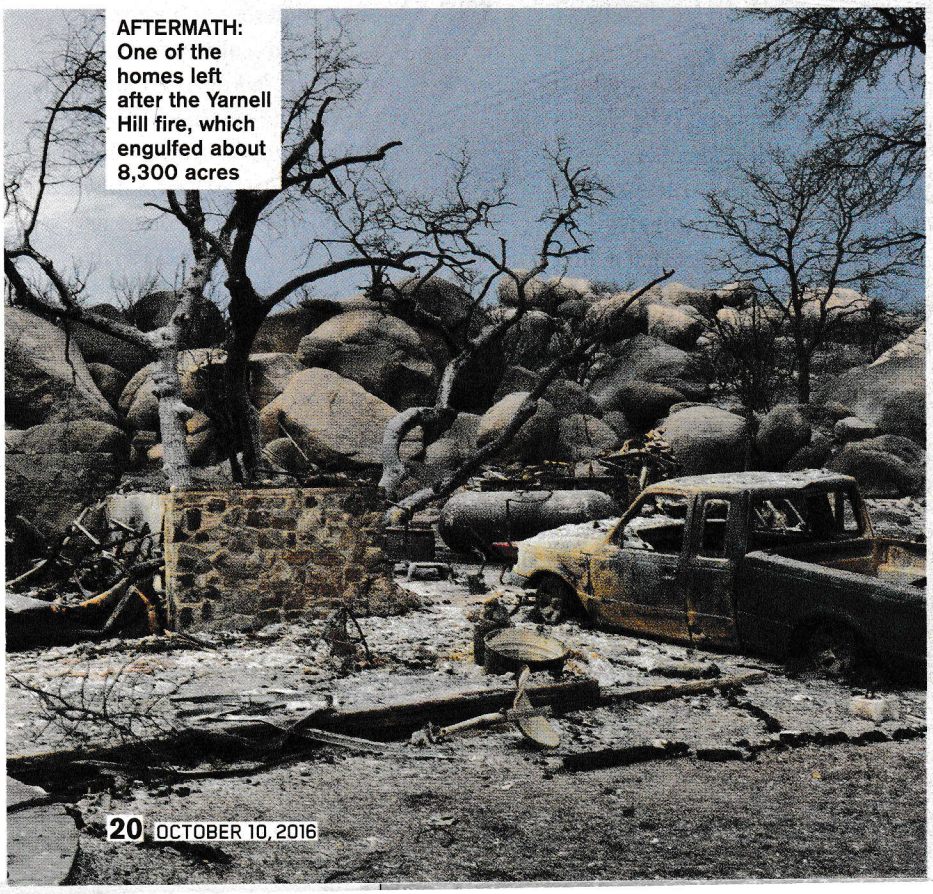
In your own words, describe how Nick used technology to improve the accuracy of his pitch.

EARTH SCIENCE: Natural Disasters // **ENGINEERING:** Design Process // **CHEMISTRY:** Materials and Chemical Reactions

DEADLY BLAZE: In 2013, a wildfire at Yarnell Hill in Arizona claimed the greatest number of firefighters' lives in 80 years.

BEATING THE HEAT

A group of teens comes up with a new-and-improved way to protect firefighters



AFTERMATH: One of the homes left after the Yarnell Hill fire, which engulfed about 8,300 acres

FALLEN HEROES: A memorial to the firefighters who gave their lives

ESSENTIAL QUESTION: How does a firefighter's gear help protect the person while he or she battles blazes?

During the summer of 2013, Ohio high school sophomore Savannah Cofer and her family traveled to Arizona for a hiking trip. They weren't expecting what greeted them. "Everywhere we went, we saw wildfires," says Savannah, now 18.

One of those blazes was among the worst firefighting disasters in U.S. history. On June 28, 2013, a bolt of lightning ignited Yarnell Hill, near the city of Prescott. Firefighters from the Prescott Fire Department's elite Hotshot crew went to battle the flames. Wielding chainsaws, the Hotshots were clearing brush and trees to divert the fire from nearby homes. Suddenly the wind shifted. The crew found themselves trapped by a 30 meter (100 foot) wall of flames. There was no way out, and 19 firefighters lost their lives.

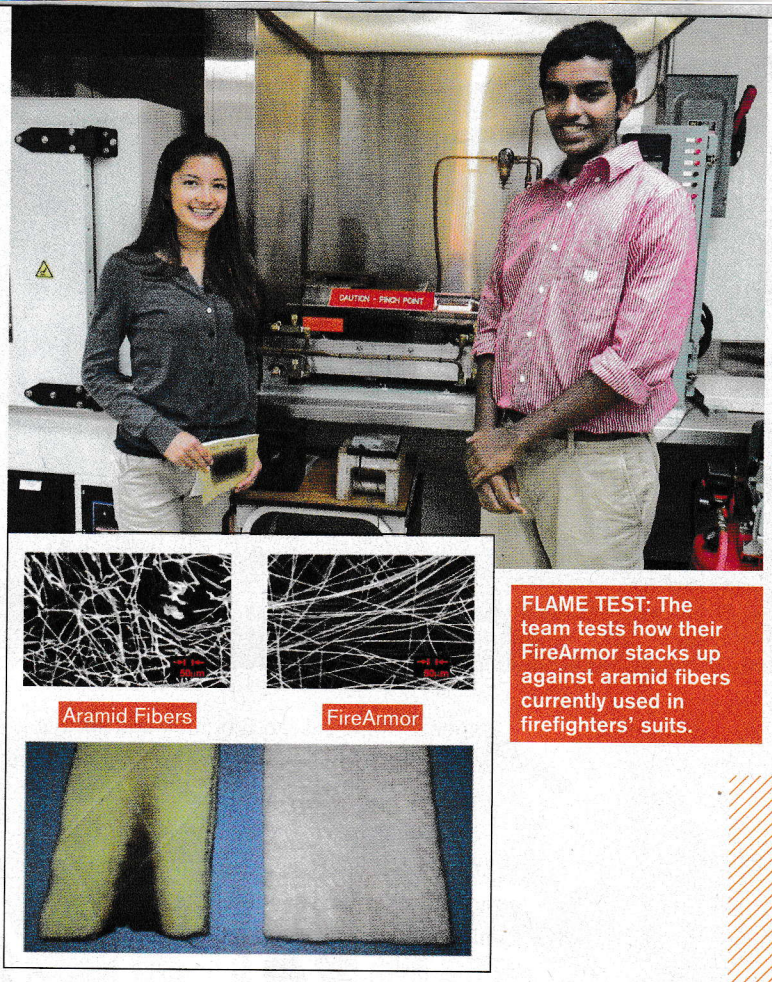
The tragedy shook Savannah. She wondered: Could better gear have saved the firefighters? She teamed up with three friends, and together they set out to upgrade firefighters' uniforms—a quest that would take them all the way to the White House Science Fair in Washington, D.C.

FACING THE FLAMES

As soon as Savannah got home from her vacation in Arizona, she called up her friend Varun Vallabhaneni, now also 18. They began researching how firefighting suits are made. "We found out that they haven't changed much in 40 years," says Varun. "There was a lot of room for improvement."

Current suits are made out of a material woven from *aramid fibers*, which are also used to make bulletproof vests. This human-made synthetic fiber is composed of densely packed *polymer* molecules. The material's chemical structure allows it to withstand a lot of stress, including high temperatures. Aramid fibers do a great job of protecting firefighters from the heat of flames—but only up to about 300°C (572°F). Any hotter and the fibers start to disintegrate.

Savannah and Varun hoped to do better. They wanted to find a material that would keep firefighters alive in the worst-case scenario: a *flash fire*. A flash fire starts when oxygen is suddenly introduced to flammable substances, causing them to ignite. The result is a rapidly moving fire that can reach temperatures of more than 1,000°C (1,832°F). Experts suspect this may have happened at Yarnell Hill. A gust of wind may have pushed the fire into a trapped pocket of air, causing its flames to surge.

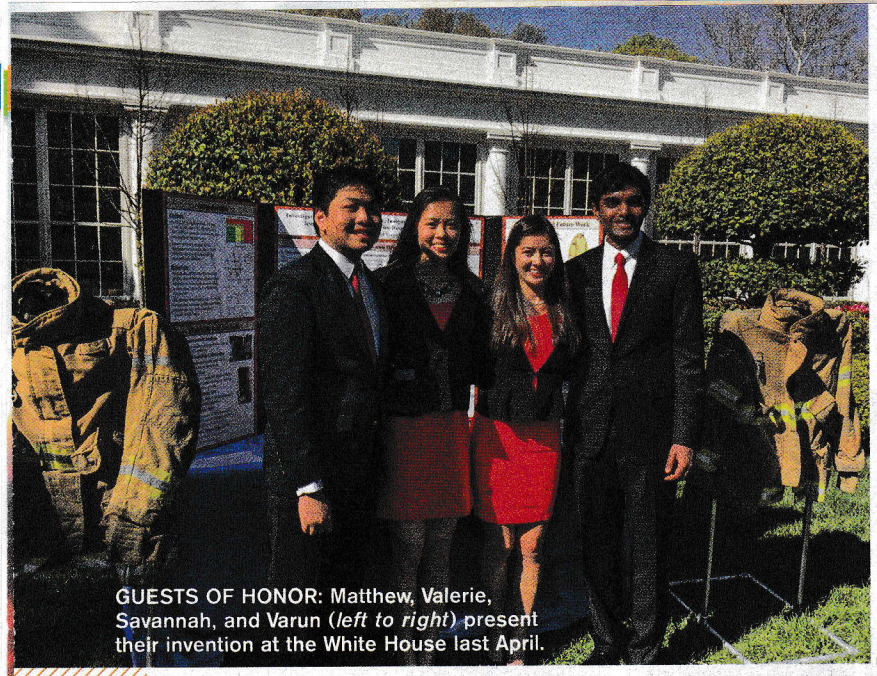


FLAME TEST: The team tests how their FireArmor stacks up against aramid fibers currently used in firefighters' suits.

A SPARK OF INSPIRATION

Savannah and Varun had been researching new materials for several weeks when inspiration struck. "I thought of instant ice packs, the kind that you crack and they get really cold," says Savannah. Cracking them allows one chemical to come in contact with another. This causes an *endothermic reaction* that absorbs heat energy, which makes the packs cold.

The duo began hunting for a material that would soak up heat from the environment and keep firefighters cool in the midst of flames. It also needed to be soft and flexible, so that firefighters could wear it comfortably while putting out blazes. After interviewing



GUESTS OF HONOR: Matthew, Valerie, Savannah, and Varun (*left to right*) present their invention at the White House last April.

experts, doing research online, and studying scientific journals, the teens found a material that met all their requirements: *alumina-silica hydrate fibers*. Temperatures above 100°C (212°F) trigger the fibers to undergo an endothermic reaction. The two friends named their new product FireArmor.

CORE QUESTION

Cite some of the differences between the traditional fire-resistant material used in firefighters' suits and FireArmor.

TRIAL BY FIRE

Savannah and Varun now needed to test their creation. First, they visited commercial laboratories to pit the old aramid fiber material against their FireArmor in a battery of tests. In one test, they looked at the fibers under a high-powered *scanning electron microscope*. They saw that heat weakens aramid fibers, so suits made with them provide less protection over time. But FireArmor's endothermic reaction actually makes its molecules knit together and become 50 percent stronger.

In another test, they heated one side of each material to 1,000°C (1,832°F) and measured how hot the other side got over time. That simulated what a firefighter wearing the material in a blaze would feel. "We found that with the traditional material, the firefighter would survive for only about six seconds," says Savannah. "FireArmor can protect the firefighter for five minutes—enough time to get out of the situation."

The results impressed John Clay, a chemical engineer at Ohio State University who advised the team on their invention. "They took a fresh look at something that's been around for a long time," he says. "I think it's a really novel solution."

HOT TOPIC

Convinced that their material was superior, Savannah and Varun called on two friends from Virginia, Valerie Chen and Matthew Sun, to create a business plan for producing FireArmor. With their idea for a marketable product in hand, the four teens decided it was time to share their findings. In 2015, they entered and won the Conrad Spirit of Innovation Challenge, an annual competition that encourages high school students to develop technology-based products for commercial use. They were soon invited to present their project at the annual White House Science Fair last April.

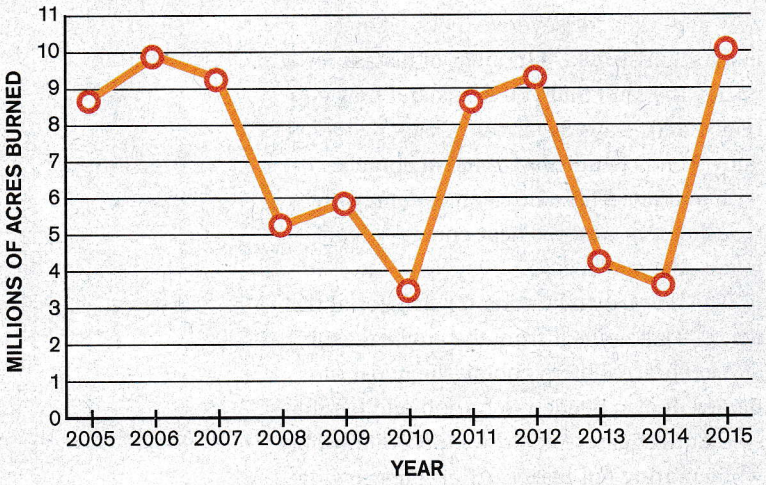
The teens set up a booth on the White House's East Lawn and spoke about their project to guests like Adam Savage, host of the TV show *MythBusters*. "That was cool," says Varun. "But the coolest part was actually meeting other students there."

The team is currently meeting with manufacturers about making FireArmor suits. What's their advice to other kids searching for a winning idea? "Look into the issues facing your communities," says Varun. "Once we learned about the problems firefighters face, we became really passionate about finding a solution."

—Stephanie Warren Drimmer

FIRE ZONE

Battling wildfires is a big job. This graph shows how many millions of acres have burned in the U.S. over the past decade as a result of wildfires.



SOURCE: NATIONAL INTERAGENCY COORDINATION CENTER

PECKY EATERS: Oxpeckers get their name from the pecking movements they make when feeding from their animal hosts.

NOSY BIRDS

Why are these oxpeckers sticking their heads into the ears and nostrils of this buffalo in the African nation of Tanzania? They're looking for things to eat—like earwax, snot, and ticks!

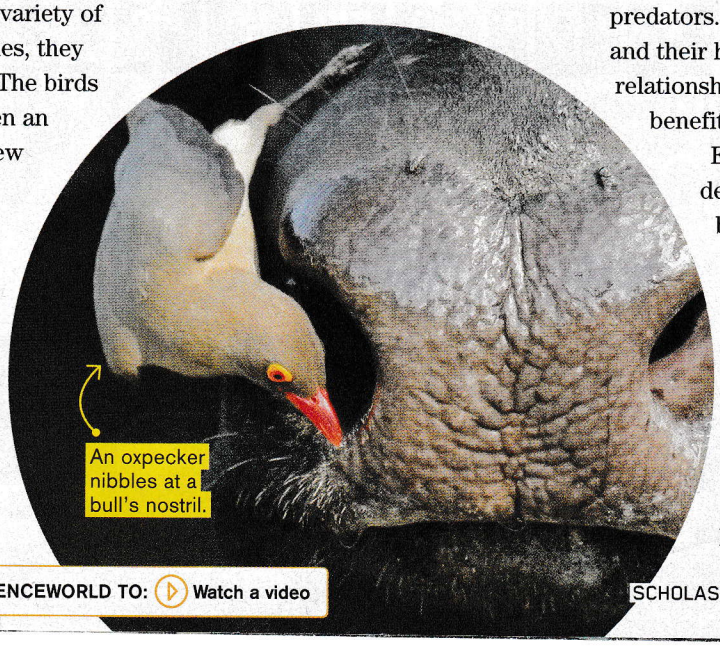
Oxpeckers also perch on other hooved mammals, such as rhinos, giraffes, and zebras, to feed. Although oxpeckers eat a variety of things off their hosts' bodies, they prefer to consume blood. The birds land on an animal and open an old wound—or create a new one—to feed on blood. Other times, oxpeckers will nibble on ticks attached to animals. Ticks are small *arachnids*, related to spiders, that drink animals' blood. The birds pick off these *parasites* to eat the blood they've collected.

"Oxpeckers love eating ticks," says Judith Bronstein, a biologist at the University of Arizona in Tucson. But "there are almost no nutrients in blood. It's almost all water." So the birds have to eat a lot of these parasites to get enough nourishment.

Oxpeckers clearly benefit from their relationship with their hosts, as the mammals provide the birds with a food source. But biologists suspect that the mammals may benefit too, since the birds remove blood-sucking parasites from the mammals' bodies.

There's also some evidence that oxpeckers produce warning cries that may alert their hosts of nearby predators. If that's true, the birds and their hosts share a *mutualistic* relationship—where each species benefits from the other.

Either way, if an oxpecker decides to peck at a buffalo's ears or nose, the big mammal may have little choice in the matter. "Imagine you're a buffalo with a bird in your nose," says Bronstein. "What are you going to do to get rid of it? You don't have hands!" —*Kathryn Free*



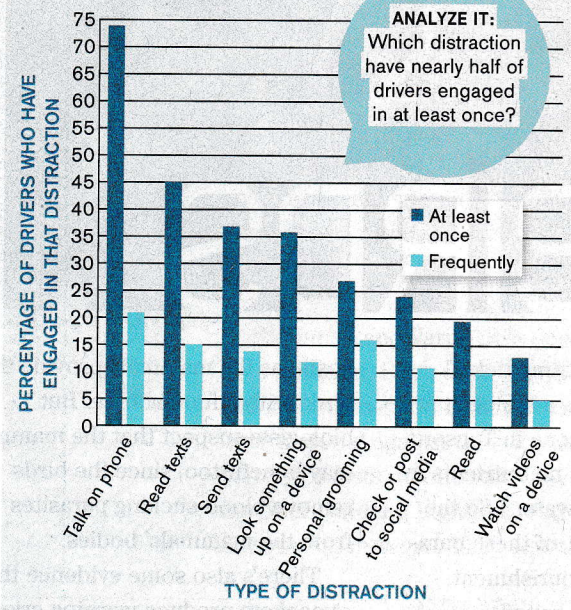
An oxpecker nibbles at a bull's nostril.

VISIT SCHOLASTIC.COM/SCIENCEWORLD TO: Watch a video

DISTRACTED DRIVING

As you read in "Inventor of a Safer Drive" (p.12), distracted driving is a huge safety risk—particularly for teens. Check out these stats to learn more.

MOST COMMON DRIVING DISTRACTIONS

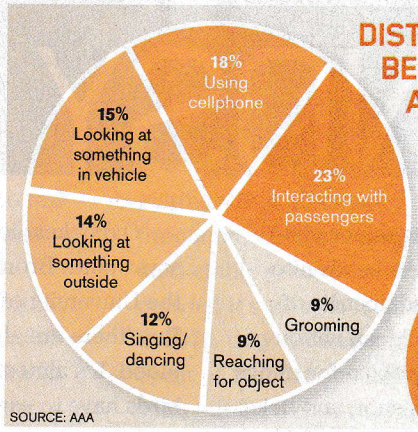


ANALYZE IT: Which distraction have nearly half of drivers engaged in at least once?

SOURCE: HARRIS INTERACTIVE/STATISTA

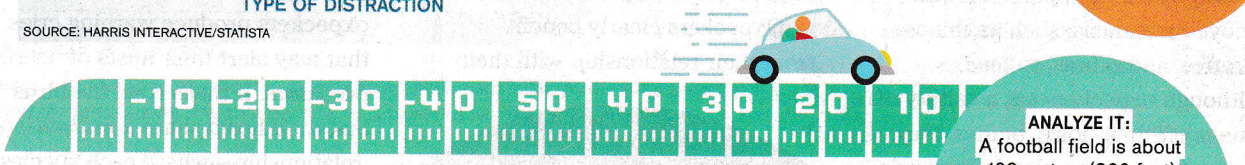
6 OUT OF 10 TEEN CRASHES INVOLVE DRIVER DISTRACTION

DISTRACTIONS BEHIND TEEN ACCIDENTS



SOURCE: AAA

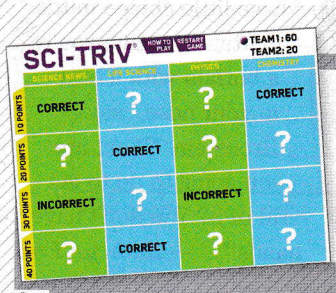
ANALYZE IT: Which is the most common type of distraction that causes accidents among teenage drivers?



WATCH OUT! THE AVERAGE DISTRACTION TAKES YOUR EYES OFF THE ROAD FOR **5 SECONDS**. MOVING AT 90 KILOMETERS (55 MILES) PER HOUR, THAT'S ENOUGH TIME FOR A CAR TO COVER THE LENGTH OF A FOOTBALL FIELD.

ANALYZE IT: A football field is about 109 meters (360 feet) long. About how far could a car going 90 km (55 mi) per hour travel while the driver is distracted for 2.5 seconds?

SOURCE: DISTRACTION.GOV/VIRGINIA TECH TRANSPORTATION INSTITUTE



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