MARCH 5, 2018
VOL. 74 NO. 9
ISSN 1041-1410

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PHYSICS

## FACT MEETS FICTION

Explore the Nobel Prize-winning science behind the sci-fi adventure *A Wrinkle in Time*

INSIDE

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ScienceWorld
current science
MARCH 5, 2018 VOL. 74, NO. 9



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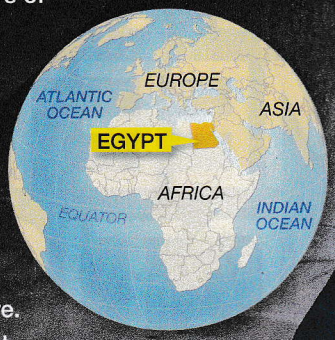
# SCIENCE NEWS

**PHYSICS:** SUBATOMIC PARTICLES

# PYRAMID SECRET?

A team of scientists recently announced the discovery of a mysterious empty space within the Pyramid of Khufu, or the Great Pyramid of Giza, in Egypt. This 4,500-year-old tomb is considered one of the ancient wonders of the world.

To study the inside of the pyramid, researchers used an imaging technique that detects *muons*. Muons are fast-moving, charged *subatomic particles* that are smaller than an atom. They are created when *cosmic rays* traveling through space strike molecules in Earth's atmosphere.

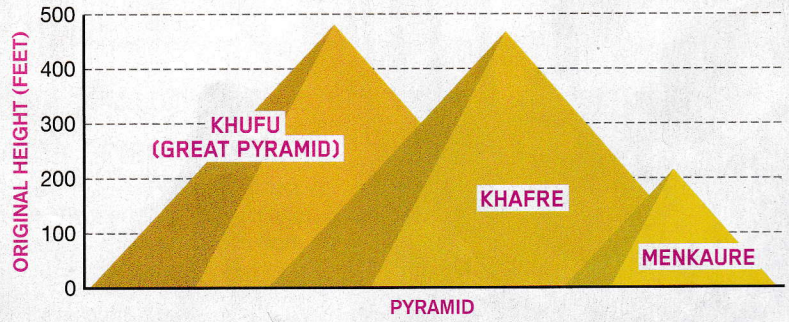



Muons scatter as they pass through solid materials. Using this knowledge, researchers placed muon-detecting sensors in the Queen's Chamber (*right*). The pattern of muons the sensors detected revealed the existence of a large, empty space about 30 meters (100 feet) long inside the structure.

"I was very surprised because the big void was not predicted by anyone until our investigation used cosmic ray imaging," says Kunihiro Morishima, a physicist from Nagoya University in Japan who took part in the project. —*Greg Uyeno*

## THE PYRAMIDS OF GIZA

The Pyramid of Khufu is one of three main pyramids found together at a site near El Giza, Egypt. How does the height of the Pyramid of Khufu compare with the height of the Pyramid of Menkaure?




SOURCE: ENCYCLOPEDIA BRITANNICA


HIGH-TECH: Researchers examine their findings using augmented-reality glasses.

SETTING UP: Researchers place muon detectors in the Queen's Chamber.

**LINKED UP** The participants were connected to each other by ropes to reduce the chance of getting tangled.

**PHYSICS:** FORCES & MOTION

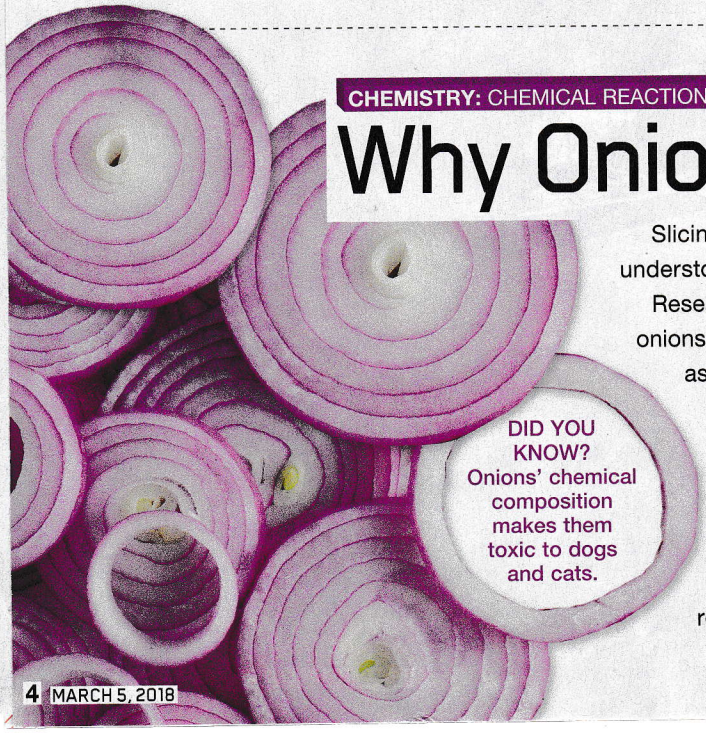
# Human Pendulum

This past October, 245 daredevils wearing harnesses attached to ropes jumped off a 30 meter (98 foot)-tall bridge near São Paulo, Brazil, in an attempt to set a world record. Thanks to physics, the stunt was a success—and no one got hurt.

The daredevils needed to ensure they wouldn't *decelerate*, or slow down, all at once when they reached the end of their ropes. That's why they chose to use climbing ropes with plenty of *elasticity*. This ability to stretch helped to slow the jumpers' descent gradually. "If the rope is too stiff, the deceleration will be very fast, which could be damaging," says Jim LaBelle, a physicist at Dartmouth College in New Hampshire. Rapid deceleration is what causes the harmful whiplash effect in a car accident, he says.

After the rope stretched to its limit, the *pendulum effect* took over. The jumpers began moving in a side-to-side motion typical of a pendulum. The *friction* from air resistance then slowed the jumpers until they came to a complete stop.

*—Spenser Mestel*



**DID YOU KNOW?** Onions' chemical composition makes them toxic to dogs and cats.

**CHEMISTRY:** CHEMICAL REACTIONS

# Why Onions Make You Cry

Slicing into an onion will bring tears to your eyes. But no one understood why this vegetable could make you cry until recently.

Researchers at Case Western University in Ohio discovered that onions contain a *protein*—a large biological molecule—called alliinase, as well as a chemical called sulfenic acid. These two substances are usually kept apart within an onion's cells. But when you chop an onion, the two substances mix, causing a chemical reaction. It creates a new molecule called *lachrymatory factor*.

"This new molecule evaporates into a gas and floats up, eventually reaching our eyes," says Josie Silvaroli, the lead author of the study. The molecule irritates our eyes, which react by making tears to flush it out.

*—Jeanette Ferrara*

NOT A DINO: Although pterosaurs like the one illustrated here are often called flying dinosaurs, they come from different evolutionary groups.

**BIOLOGY:** PREHISTORIC LIFE

# COLOSSAL CREATURE

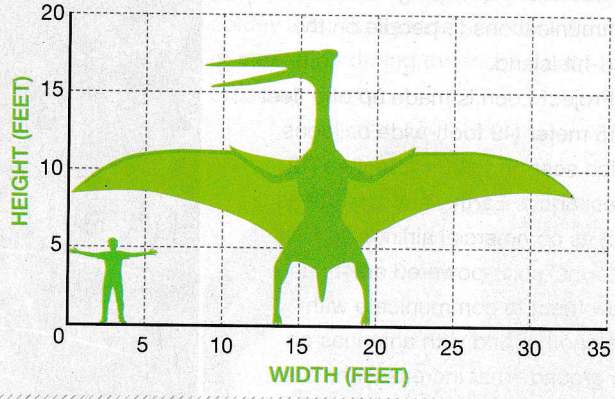
Scientists recently announced the discovery of ancient remains from a giant winged creature in the Gobi Desert in Mongolia. The now-extinct *giant pterosaur* was one of the largest living things to ever take flight.

Pterosaurs lived around the same time as dinosaurs, more than 100 million years ago. They were the first *vertebrates*—animals with a backbone—to evolve the ability to fly.

The recently discovered giant pterosaur was the first ever found in Asia. "This new find shows that giant pterosaurs had spread over most of the world before being wiped out," says Brian Andres, a paleontologist at the University of Texas at Austin. —*Jeanette Ferrara*

## WINGED GIANT

This chart shows the height and wingspan of a giant pterosaur compared with the height and arm span of an average adult male. About how many humans would need to stand together with their arms outstretched to equal the pterosaur's wingspan?




SOURCE: NATIONAL GEOGRAPHIC

IN THE DARK: Nearly half of Puerto Rico's residents still lacked power months after Hurricane Maria hit.

**ENGINEERING:** CIVIL ENGINEERING

# GETTING CONNECTED

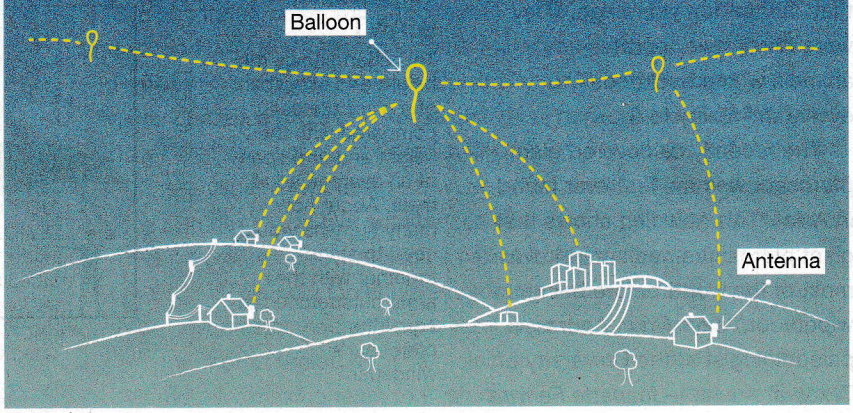
LIFTOFF: A Project Loon balloon heading to Puerto Rico is launched in Nevada.

Months after Hurricane Maria devastated Puerto Rico last September, many residents still lack food, clean water, and electricity. The storm destroyed much of the U.S. territory's infrastructure, leaving people without cell phone service or access to the internet. Now a network of hi-tech balloons, called Project Loon, is helping restore communications to people on the hard-hit island.

Project Loon is made up of a fleet of 15 meter (49 foot)-wide balloons, which soar up to 20 kilometers (12 miles) above Earth—about twice as high as commercial airlines fly. The balloons' solar-powered antennas allow them to communicate with one another and with antennas on the ground. That increases the area where people can receive internet service. So far, Project Loon has provided more than 100,000 Puerto Ricans with a wireless connection. —*Spenser Mestel*

## HOW PROJECT LOON WORKS

All a user on the ground needs to get online is an internet-enabled device and an antenna. Data travels from a user's computer or phone to the antenna and then up to the nearest balloon. From there, the signal travels to other balloons in the floating network and eventually links back to existing networks on the ground.



PICKY EATER: This *Cratena peregrina* prefers to eat creatures with full stomachs.

**BIOLOGY:** ANIMAL BEHAVIOR

# Sneaky Slugs

A type of brightly colored sea slug has a clever trick to get two meals for the price of one. *Cratena peregrina* is a species of nudibranch found in the Mediterranean Sea that likes to eat tiny sea creatures called hydroids. But according to scientists, *C. peregrina* prefers hydroids that have themselves just eaten plankton. Eating a stuffed hydroid is like getting a double helping of supper.

Researchers call the newly discovered feeding behavior *kleptopredation*, from the Greek word for thief. "We are now asking whether the phenomenon of kleptopredation is found in other marine species," says Trevor Willis, a marine biologist at the University of Portsmouth in England.

—*Greg Uyeno*

## STARTLING CREATURES

Sea slugs, or nudibranchs, are known for their brilliant colors and wild shapes. More than 3,000 species of sea slugs are known to exist, and scientists believe there may be 3,000 more yet to be discovered.

The Spanish Dancer, or *Hexabranchus sanguineus*, swims away from predators in a wild dancing motion.

The dragon-like *Glaucus atlanticus* uses stinging cells from the jellyfish it eats to attack predators.

The *Melibe leonina* exudes a sweet, fruity smell. A group of them is called a "bouquet."

# NUMBERS IN THE NEWS

**4.62 billion**

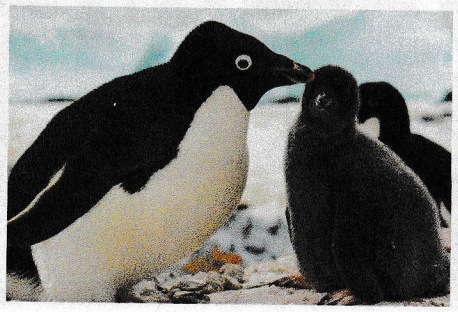
The total number of acres of cropland on Earth, according to a recent study by the U.S. Geological Survey.

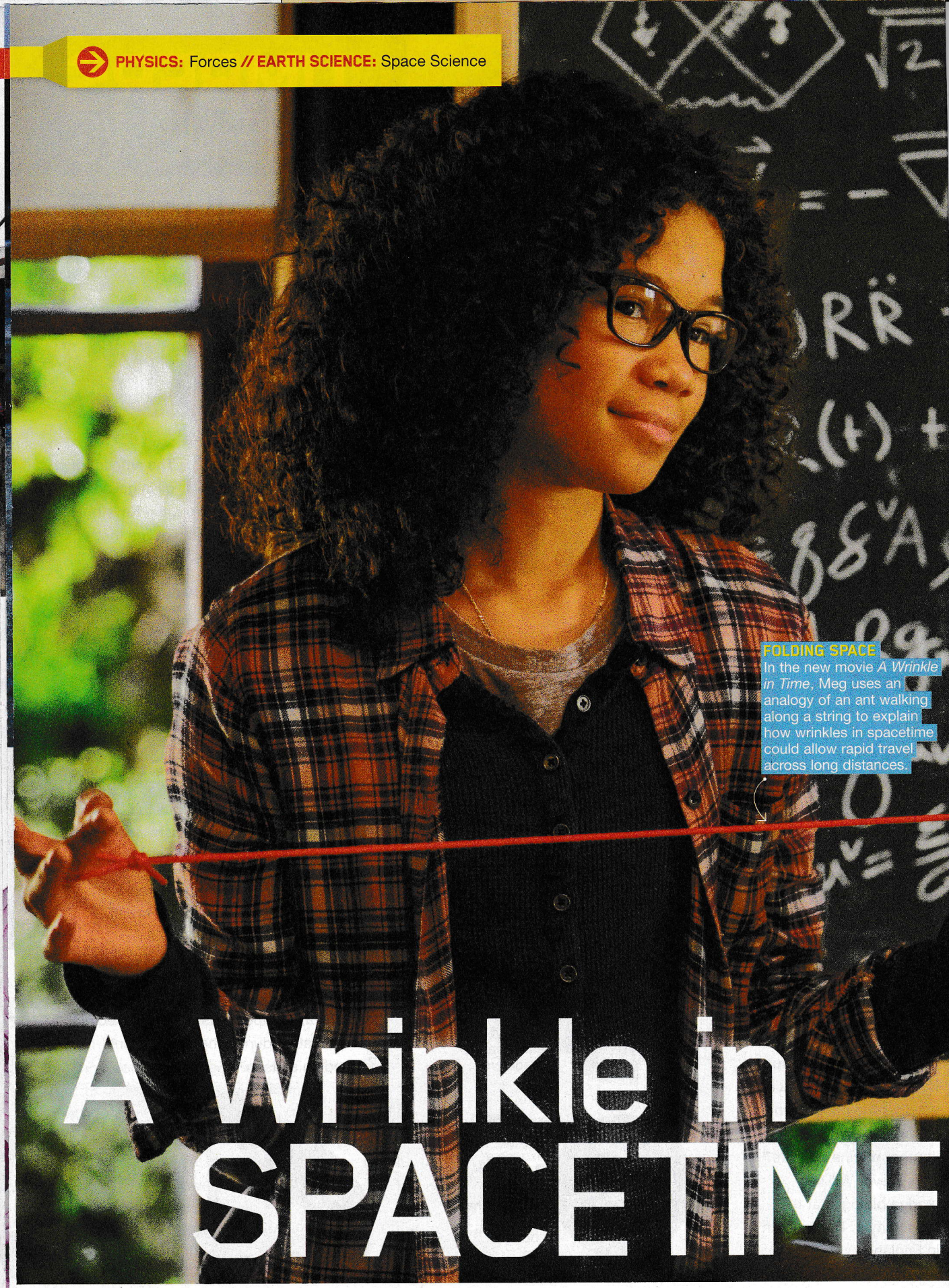
**210,000** The amount of oil in gallons spilled last November from the Keystone Pipeline—a controversial pipeline that crosses parts of the U.S. and Canada.

**90** The percentage of accidents involving self-driving cars between 2014 and 2017 that were caused by human error.

**49** Number of states that had widespread flu outbreaks in January—every state except Hawaii.

**2** The number of Adélie penguin chicks remaining in one Antarctic colony after thousands of chicks died of starvation during the most recent breeding season.

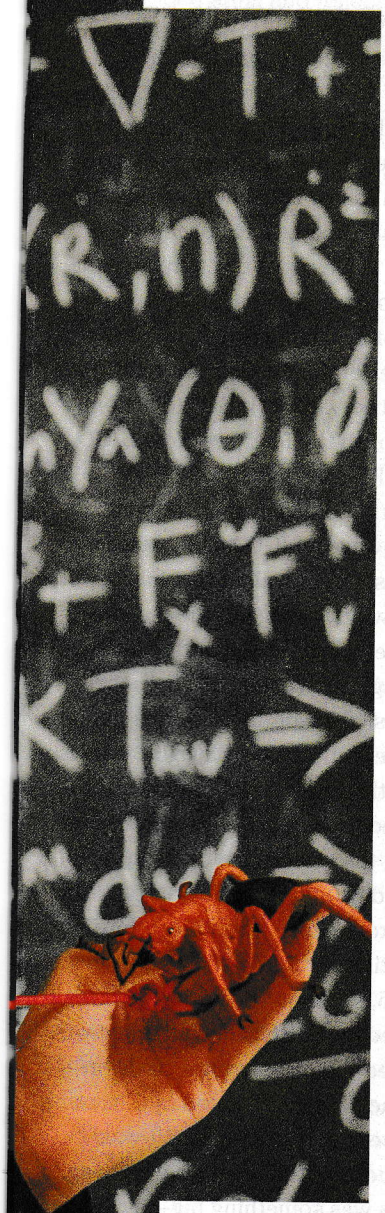




**FOLDING SPACE** In the new movie *A Wrinkle in Time*, Meg uses an analogy of an ant walking along a string to explain how wrinkles in spacetime could allow rapid travel across long distances.

# A Wrinkle in SPACETIME

# Scientists confirm a revolutionary theory about our universe that inspired a famous young adult novel and a new movie



**ESSENTIAL QUESTION:** How does science influence literature?

On March 9, a movie based on the beloved science fantasy novel *A Wrinkle in Time* hits the big screen. Although it is a work of fiction, Madeleine L'Engle's book was inspired by a real scientific principle proposed by renowned physicist Albert Einstein—a theory that researchers recently confirmed.

More than 100 years ago, Einstein suggested that space and time can warp and wrinkle. In the 1940s, L'Engle read a book about Einstein and his theories. She worked his idea about wrinkling spacetime into an interplanetary adventure, which she started writing in 1959. In the story, awkward teenager Meg Murry leads her little brother and a classmate on a quest to rescue her father, a brilliant physicist trapped on a distant planet during a top-secret experiment gone wrong. Einstein's wrinkles allow the trio of kids to jump through space, visiting other planets without a spacecraft.

L'Engle struggled to get *A Wrinkle in Time* published. Publishers said its concepts were too complex for young adults—her intended audience—to understand. And some feared readers wouldn't want a science fiction story with a female protagonist. Dozens of publishing companies rejected the manuscript. But after the book was finally published in 1962, it won the Newbery Medal for children's literature. It became a runaway success and is considered a classic.

L'Engle was far from the only person intrigued by Einstein's ideas about spacetime. Scientists have been trying to find ways to confirm or disprove his theory since it was first announced. In the past few years, they finally made some headway. They've discovered that our universe truly does ripple and wrinkle the way Einstein predicted.

Last November, three physicists who laid the foundation for detecting these wrinkles, called *gravitational waves*, received the prestigious Nobel Prize for their work. Scientists believe the groundbreaking discovery offers a radical new way to study the cosmos.

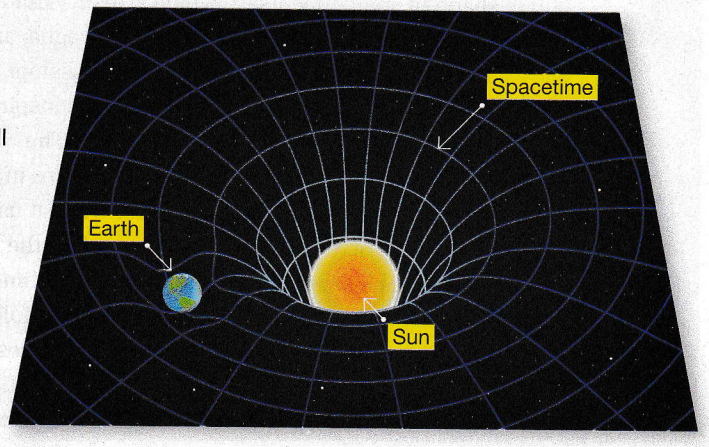
## EINSTEIN'S INSIGHTS

In 1915, Einstein published his theory of general relativity. It stated that three-dimensional space is connected to a fourth dimension: time. Einstein described this concept, known as *spacetime*. He proposed that the

*Continued on the next page* →

## WARPED SPACE

Imagine a rubber sheet stretched out tight. The sheet represents spacetime. Placing a massive object like a bowling ball on the sheet would cause it to stretch and bend. A marble placed near the bowling ball would roll toward it. Einstein proposed that a similar phenomenon in spacetime attracts objects to one another—the effect we know as gravity. A massive object like the sun, for example, bends the space around it, pulling Earth toward it.



INTERPLANETARY GUIDES: Mrs. Whatsit (*bottom left*), Mrs. Which (*left*), and Mrs. Who (*below*) aid the children on their journey in the new movie *A Wrinkle in Time*.

presence of matter and energy causes spacetime to curve. That curvature creates *gravity*, the force that attracts objects to one another (*see Warped Space, p. 9*).

General relativity predicts that in some areas of spacetime, called *black holes*, gravity is so strong that even light can't escape. Einstein's theory suggests that explosions and violent collisions in space, like one between two black holes, send gravitational waves through spacetime, much like the way a dropped pebble sends ripples across a pond. These waves "change the shape of spacetime itself, which stretches and shrinks as they move," says Marco Cavaglià, an astrophysicist at the University of Mississippi.

Einstein's idea of gravitational waves inspired the title and storyline of L'Engle's book. The children in the novel travel across wrinkles in spacetime. A character named Mrs. Whatsit uses an analogy of a traveling insect to explain the process. She says a bug would take a long time to walk across her skirt. But if she were to fold the fabric—similar to how gravitational waves bend spacetime—she could bring two distant sections closer together. The insect could then walk over the fold and take a shortcut from one side of her skirt to the other.

## THE HUNT FOR WRINKLES

Einstein thought that wrinkles in spacetime would be too small to detect. But as technology advanced, scientists took on the challenge. In the 1960s, they hatched a plan to use concentrated light from lasers to measure changes in spacetime as gravitational waves pass through it. In the 1990s, construction began on a giant pair of instruments called the Laser Interferometer Gravitational-Wave Observatory (LIGO) to accomplish the feat (*see How LIGO Works, right*).

To detect gravitational waves, LIGO has to sense a shift equivalent to a hair's-width change in the distance between the sun and its nearest neighboring star. "It's the most precise measurement device humans have ever built," says Cavaglià, who is a member of the LIGO collaboration.

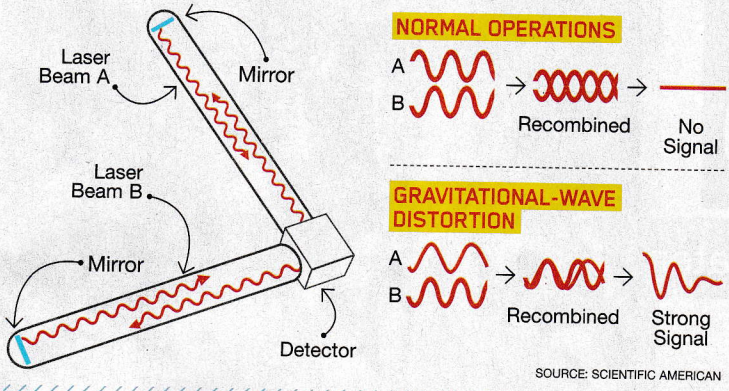
LIGO launched its hunt for Einstein's ripples in 2002. By 2010, the search had come up empty. But researchers didn't give up. They rebuilt the detectors to make them 10 times more sensitive. Days after scientists switched on LIGO's new detectors in 2015, the first gravitational waves directly measured on Earth rocked the sensors. And they matched the pattern for a collision between two black holes predicted by Einstein's theory. "When we saw these signals, it was amazing and almost a little scary," says Cavaglià. "We realized this was something big—a perfect signal." Since then, they've detected five more black hole collisions and a crash between two *neutron stars*, which form when giant stars explode and collapse.

## UNDERSTANDING THE UNIVERSE

Many scientists believe the biggest discoveries are yet to come. "Almost everything we know about the universe up to now comes from studying light," says Nergis Mavalvala, a LIGO member and physicist at the Massachusetts Institute of Technology. But some objects, like black holes, don't emit light. "Gravitational waves open up a new way to observe," she says.

## HOW LIGO WORKS

Inside LIGO, beams of light simultaneously travel down two 2.5-mile-long arms and reflect off a mirror at the end of each arm. Normally, the reflected light waves reach a detector at their starting point at the same time and cancel each other out, so no signal is detected. But if a gravitational wave passes through the arms, it distorts the light beams. As a result, they don't match up when they reach the detector, which registers a signal.




SOURCE: SCIENTIFIC AMERICAN

**LONG ARMS** An aerial view shows the LIGO detector in Hanford, Washington. An identical LIGO is located in Livingston, Louisiana.

Along with studying black holes, scientists could peer back into the early days of the universe after its explosive birth during the *big bang*. When the universe was young, it was so hot and dense that light couldn't travel through it. But gravitational waves streamed freely through spacetime. Their imprint may linger today, the way lines remain on a sandy beach after waves hit the shore. For events that emit light, like a neutron star collision, gravitational waves provide a rich new stream of information. "It's like transitioning from silent movies to movies with sound," says Cavaglià.

Does the discovery of gravitational waves mean it's possible to leap through space and time, like in L'Engle's novel? For now, no one knows. The waves might help researchers hunt for evidence of *wormholes*, says Mavalvala. Scientists have theorized the existence of these severely warped areas of space, which could represent shortcuts across the universe.

"We don't even know what such a thing would look like," she says, "but if we someday detected weird gravitational signals, it would be beyond exciting to think about."

—*Jennifer Barone*

**CORE QUESTION**

Were Einstein's predictions about gravitational waves correct? Support your answer with evidence.

CRASH! LIGO recently detected a collision of two black holes, seen here in a computer simulation. The data matched predictions from Einstein's theories.

# BAD FOR BEES

## Widely used pesticides threaten important insect helpers

**ESSENTIAL QUESTION:** What types of concerns might lead to a chemical being banned from use?

A lot of the food you eat would never have made it to your plate if not for bees. Along with other *pollinators*, these busy bugs help produce about one-third of the world's crops. Without bees, many flowering plants couldn't produce seeds, nuts, fruits, or vegetables. But bees could be in danger. That's because many farmers spray crops with common pesticides called *neonicotinoids*. The chemicals kill harmful insects—but some scientists worry they're also hurting helpful bees.

### TAINTED FOOD

Neonicotinoids became popular partly because they are safer for birds and mammals than older pesticides. Farmers apply neonicotinoids to about 95 percent of the corn grown in the U.S., half of the soybeans, and many fruit and vegetable crops. The chemicals are *neurotoxins*. They kill insects by disrupting their *nervous systems*—the network that transmits signals throughout the body (*see Killer Chemicals, p. 13*).



1 Farmers add neonicotinoids to water sprayed on crops. Plants absorb the water and take up the chemicals, which spread throughout the entire plant.

The pesticides are highly soluble in water. The roots of crops absorb the dissolved neonicotinoids from water in soil.

When bees feed on sweet *nectar* from the flowers of plants treated with neonicotinoids, the insects get exposed to them. The bees then turn the tainted nectar into honey, which is laced with the chemicals.

Scientists recently tested 198 honey samples from every continent except Antarctica and found that 75 percent contained neonicotinoids. No samples had levels known to harm humans, but about a third contained levels dangerous to bees.

### WORTH THE RISK?

Growing evidence shows that, in low doses, neonicotinoids can affect bees' disease-fighting *immune systems*, as well as their ability to

**2** Bees visit flowers to drink a sugary liquid called nectar. They also pick up powdery pollen grains, which plants use to reproduce. Both nectar and pollen contain traces of neonicotinoids.

**3** Bees carry the contaminated nectar they collect back to the hive, where it's turned into honey.

**4** Scientists found that three-fourths of the honey they tested from spots around the world contained traces of neonicotinoids.

communicate, fly, reproduce, and navigate. At high doses, the chemicals can kill the insects.

Concern over the pesticides has led regulators to take action. The European Union banned certain neonicotinoids on some crops and is considering a complete ban. The U.S. Environmental Protection Agency is conducting a safety review of the chemicals, including their effects on pollinators.

Protecting these insects is important, says Dave Goulson, a bee biologist at the University of Sussex in England. "If we didn't have pollinators, we wouldn't have tomatoes, chili peppers, blueberries, coffee, or chocolate," he says. In short, life would be a lot less sweet without bees.

*—Cici Zhang*

**CORE QUESTION**

What might be some pros and cons of banning pesticides?

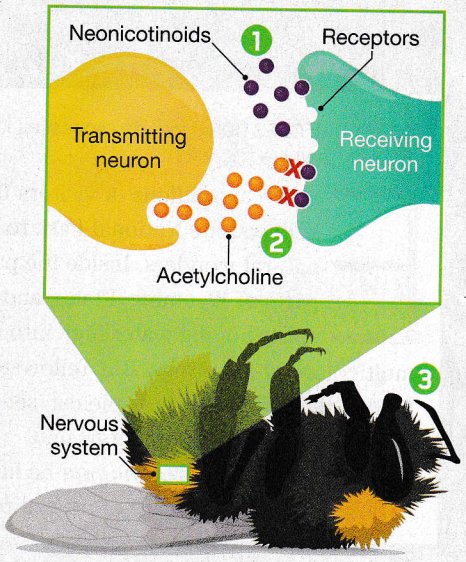
## KILLER CHEMICALS

Neonicotinoids are the most commonly used insecticides in the world. Here's how they kill bugs—including bees.

**1** Neonicotinoids permanently bind to *receptors*—specialized structures on nerve cells.

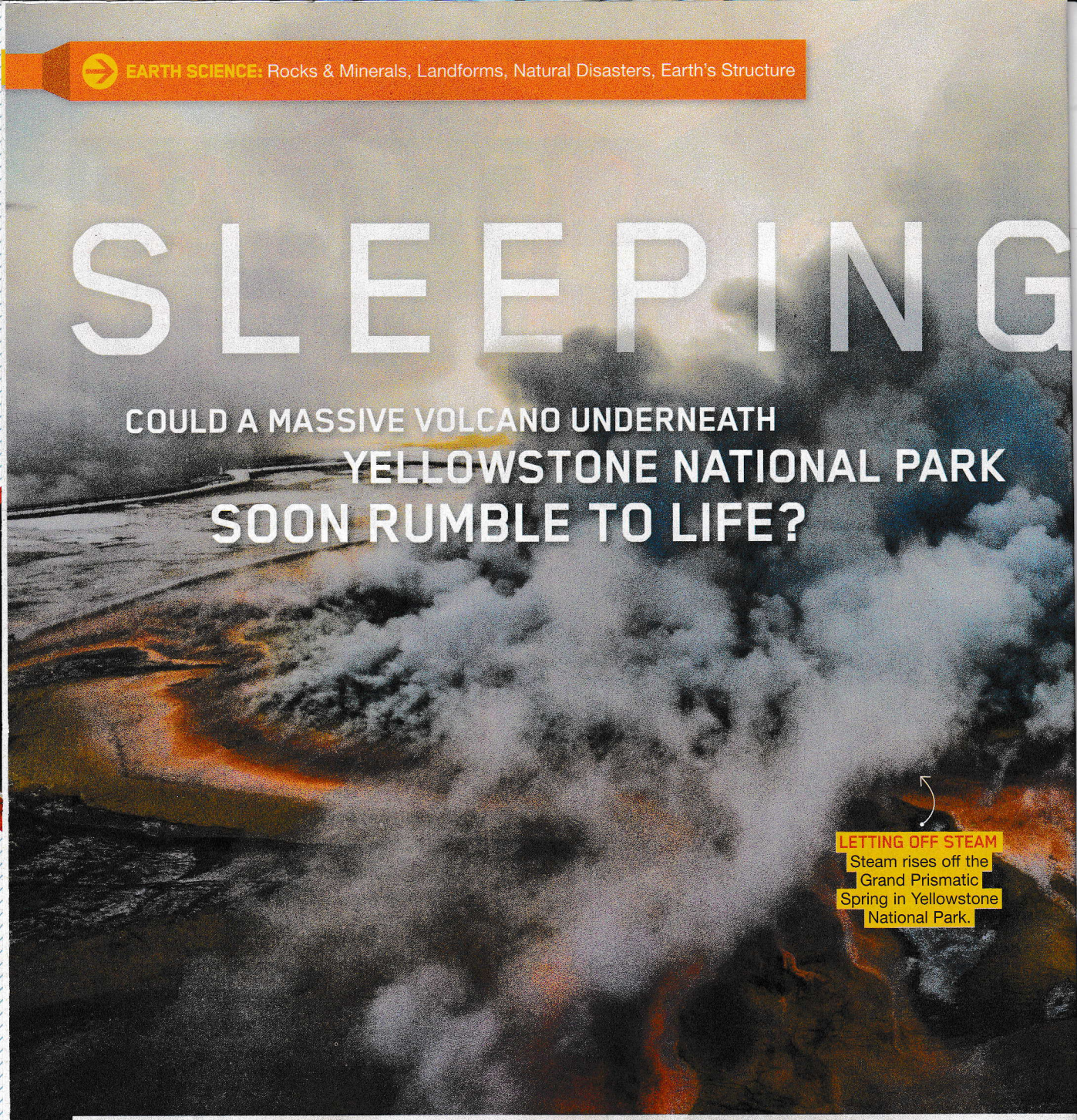
**2** The bound neonicotinoids block acetylcholine from binding to the receptors. Acetylcholine is a *neurotransmitter*—a chemical messenger that carries signals between nerve cells.

**3** By blocking an insect's acetylcholine receptors, which normally activate muscles, neonicotinoids can lead to paralysis and death.



# SLEEPING

## COULD A MASSIVE VOLCANO UNDERNEATH YELLOWSTONE NATIONAL PARK SOON RUMBLE TO LIFE?



LETTING OFF STEAM Steam rises off the Grand Prismatic Spring in Yellowstone National Park.

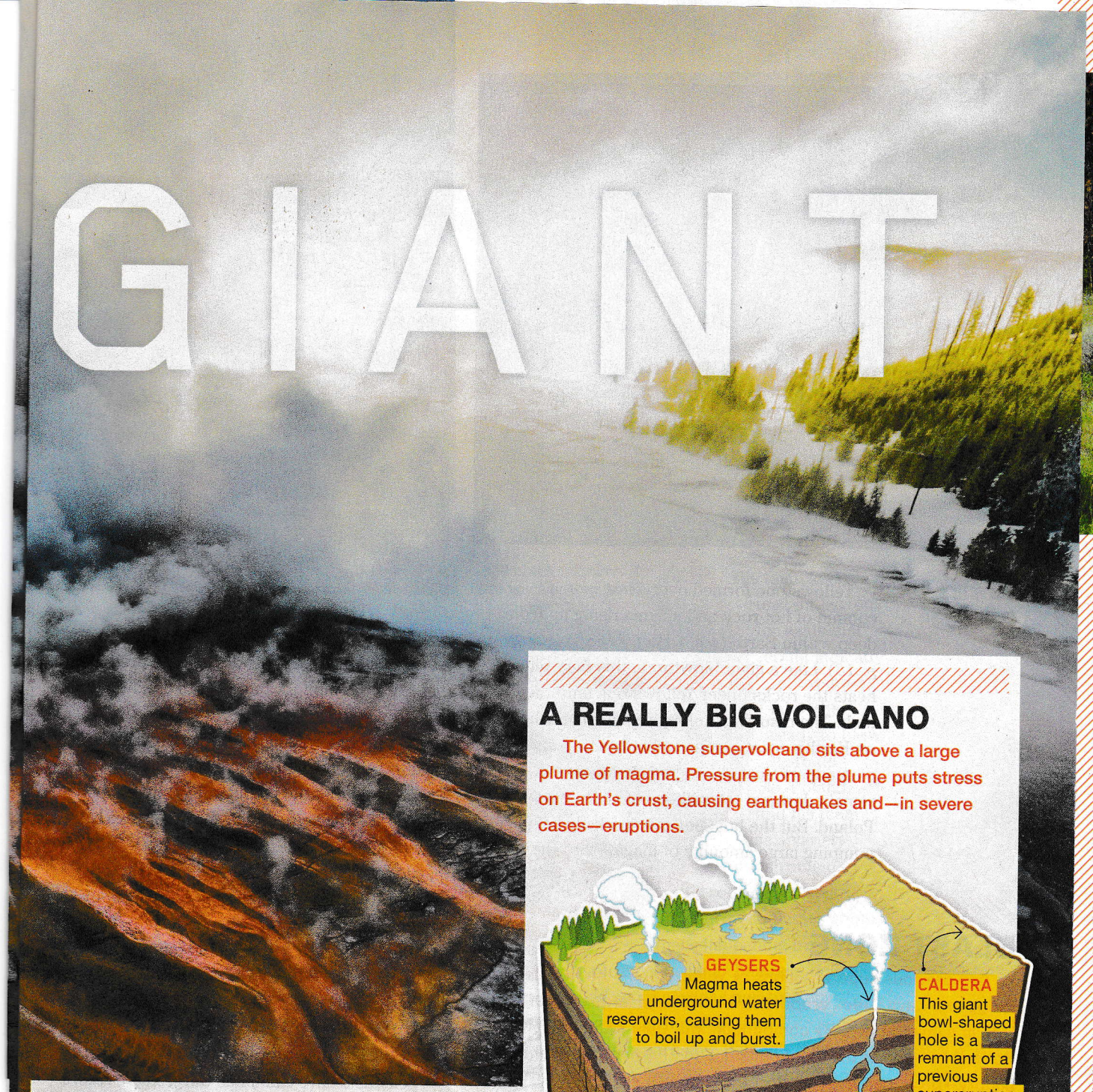
**ESSENTIAL QUESTION:** How do processes inside Earth shape the world as we know it?

Each year, millions of visitors flock to Yellowstone National Park to marvel at its natural wonders. Inside the park, which spans parts of Wyoming, Idaho, and Montana, *geysers* spray boiling water high into the air next to multicolored hot springs. But Yellowstone's most unique feature isn't something people can see—it's buried 8 kilometers (5 miles) underground.

Gigantic chambers of *magma* lie hidden beneath Yellowstone. This mixture of melted rock, crystals, and dissolved gases churns underground, providing the heat that fuels Yellowstone's geysers and hot springs. But the magma chambers aren't just furnaces for the park's natural wonders. They're also the heart of a *supervolcano*—an extremely large volcano that, if it were to erupt, could change the face of Earth.

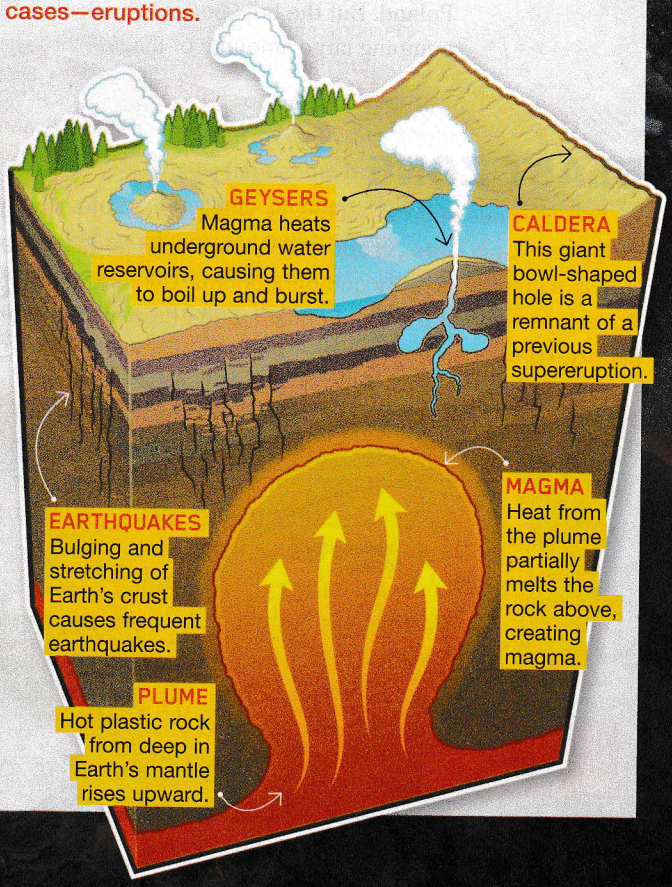
Scientists once believed supervolcanoes slowly built up from *dormancy*—a period of relative inactivity—to an eruption over thousands of years. But a recent study suggests that the time between dormancy and a supervolcano blowing its top could instead be decades. Today, researchers are working to learn more about

# GIANT



## A REALLY BIG VOLCANO

The Yellowstone supervolcano sits above a large plume of magma. Pressure from the plume puts stress on Earth's crust, causing earthquakes and—in severe cases—eruptions.




what's going on inside the Yellowstone supervolcano to better understand when and how it could erupt.

### SUPERSIZED ERUPTION

Yellowstone is just one of about 20 supervolcanoes scientists have found spread around the globe. "They're not the kind of volcano you see in a picture book," says Michael Poland, the scientist-in-charge at the Yellowstone Volcano Observatory. "There are no pointy mountains—they're all underground. But they're really, preposterously big."

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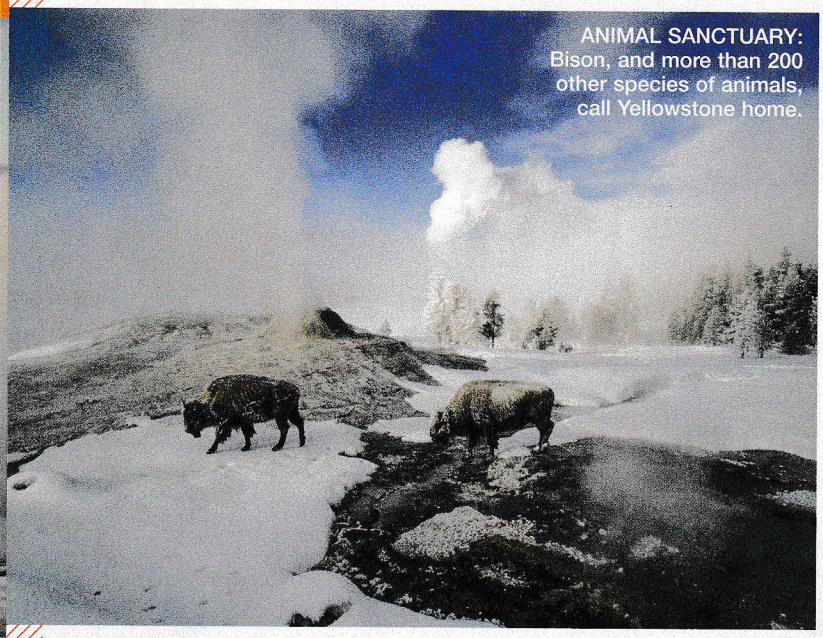
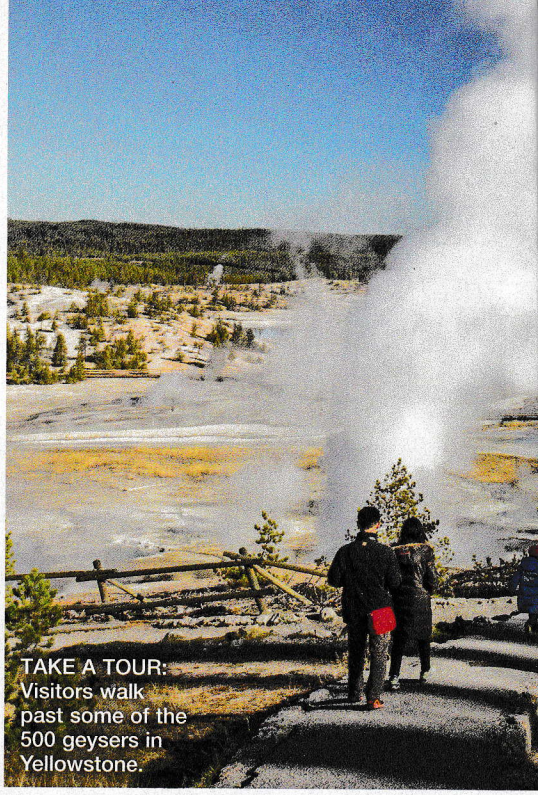


ANIMAL SANCTUARY: Bison, and more than 200 other species of animals, call Yellowstone home.



TAKE A TOUR: Visitors walk past some of the 500 geysers in Yellowstone.

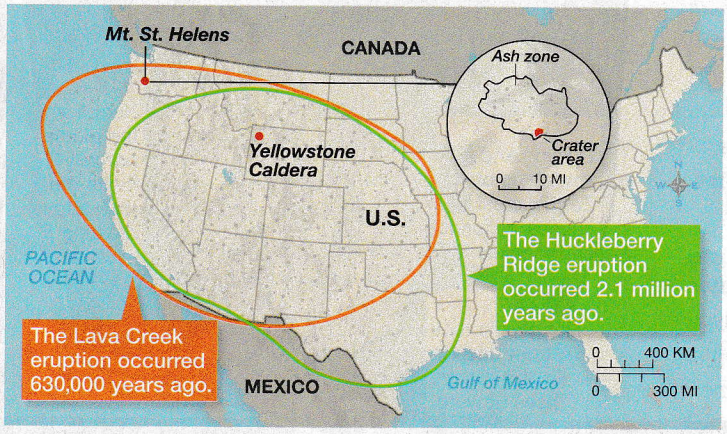
Yellowstone formed over a *hot spot*, a column of hot rock and magma rising up from deep within Earth (*see A Really Big Volcano, p. 15*). Like a giant blowtorch, this fiery plume heats the rocks under Yellowstone until they melt. The resulting buildup of magma pushes up on Earth's *crust*, or outermost layer.

A supervolcano's magma chambers can remain dormant for millions of years, says Poland. But the hot spot can suddenly begin pumping large amounts of magma into the system, causing the pressure inside the chambers to increase. And when the pressure becomes too high for the crust to contain, the supervolcano can erupt.

No one can predict the timing or size of the next supereruption at Yellowstone, but it's possible that the fallout could cover much of the U.S. in a layer of ash several inches to several feet deep (*see Blast Zone, left*). Volcanic particles spewed into the atmosphere could temporarily block sunlight and cool Earth by several degrees for as long as a decade. The resulting *volcanic winter* could make it hard to grow food—leading to food shortages and mass migrations of people and animals.

## BLAST ZONE

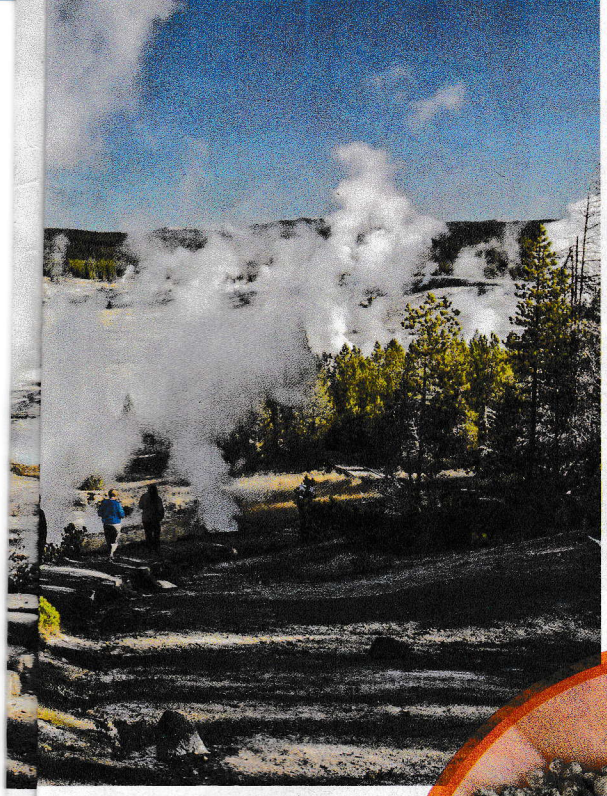
Two previous supereruptions at Yellowstone—the Huckleberry Ridge and Lava Creek eruptions—blanketed a large area of the U.S. in a layer of ash. By comparison, the 1980 eruption of Mount St. Helens—one of the most devastating eruptions in recent U.S. history—produced an ash zone only 19 miles wide.




## DIGGING INTO THE PAST

Scientists have examined the *geologic record* around Yellowstone. From this layer of rock left behind by sediment and volcanic activity, they learned about some of the volcano's past supereruptions. The oldest happened 2.1 million years ago, leaving a *caldera*, or crater, more than 97 km (60 mi) across—about twice as wide as Rhode Island. Most recently, an eruption 630,000 years ago ejected about 2,500 times more magma than the 1980 eruption of Mount St. Helens in Washington State, which killed 57 people.

Recently, a team of researchers hiked into Yellowstone to learn more about the supervolcano's most recent eruption. They collected




CLOSE WATCH: Scientists use these solar-powered GPS monitors to measure volcanic activity at Yellowstone.

CRYSTAL CLUES
Researchers examined these volcanic crystals to understand Yellowstone's past.

samples of ash and volcanic crystals, which form as magma cools, from deposits on Earth's surface. "The volcanic crystals reveal information about how the supereruption happened, as well as over what time frame," says Hannah Shamloo, a researcher from Arizona State University who worked on the project.

The researchers closely examined the crystals' layers with a *scanning electron microscope*. This instrument uses beams of negatively charged particles called *electrons* to scan an object's surface to determine its composition and structure. The outermost layer of the crystals formed during the time it took for magma to begin building beneath the supervolcano until its eruption. Shamloo and her colleagues expected to see that this layer grew over hundreds of thousands of years. Instead, it appeared that the layer had formed in a matter of decades. The scientists concluded that the supervolcano went from dormancy to eruption much more quickly than originally thought.

## NATURAL DISASTER

Yellowstone's supervolcano may sound like a disaster movie. But Poland says not to worry. His team keeps a constant eye out for signs that could indicate Yellowstone might be ready to blow.

To do so, Poland and his team use a variety of instruments to *infer*, or make educated guesses about, what's happening inside the volcano's magma chambers below. Devices called *seismographs* measure energy waves caused by earthquakes. And GPS sensors placed around the park give Poland's team information about *ground deformation*—how volcanic activity causes the land to shift.

Earthquakes and ground movement are common in such a geologically active area. It would take drastic changes for Poland to become concerned. Even if Yellowstone erupted, he says, it wouldn't be world-ending.

"I get letters and emails from students who are scared about supervolcanoes," says Poland. "But let me be clear—a supereruption is very rare, and there's no sign of it happening soon. A supereruption would be devastating to the region, but we would survive."

*—Jacob Batchelor*

**CORE QUESTION**

How do geologists know what occurred during Yellowstone's past eruptions?


SUCCESSFUL LAUNCH: Maia Weinstock signed copies of the set for fans in New York City last October.

# LEGO CREATOR

## Former *Science World* editor Maia Weinstock brings female scientists, engineers, and explorers to the world of LEGO®

A LEGO kit celebrating four pioneering female space scientists has become one of the company's hottest toys. The "Women of NASA" set is the brainchild of science writer and editor Maia Weinstock, a former editor at *Science World*.

Weinstock currently works as the deputy editor of news at the Massachusetts Institute of Technology (MIT). It's her job to help people understand the university's cutting-edge research. But her efforts to bring science to a wider audience don't stop there. For the past several years, she's also been designing her own LEGO mini-figures of real-life scientists, like those featured in the new kit, and sharing images of them online.

Then in 2016, Weinstock submitted her idea for the "Women of NASA" set to the LEGO Ideas website. Fans and the company selected her proposal to be developed for sale. When the set launched last November, it rocketed to the top of Amazon's best-selling toy list in a matter of hours. Weinstock spoke with *Science World* about how the inspiring set became a reality.


LEGO/NASA (LEGO SHUTTLE, LEGO HAMILTON, LEGO ROMAN); DRAPER LABORATORY/RESTORED BY ADAM CUERDEN/WIKIPEDIA (HAMILTON); NASA/SCIENCE SOURCE (ROMAN)


**MARGARET HAMILTON** coded software that helped humans reach the moon for the first time.

**hat led you to begin kering with LEGO ni-figures?**

2009, I was working on animated movie about e British mathematician da Lovelace. While I was earching for material bout her for the animators, discovered that someone ad made a mini-figure of ovelace. I thought it would e great to do the same ing for living scientists.

I made my first mini-gure of Carolyn Porco, planetary scientist and ood friend of mine. At rst I didn't know how to nd parts, but I mixed and matched pieces from other mini-figures. It came out really well, so I continued making more, posting photos of them online, and giving them to the people they were modeled after.

**How did you come up with the idea for the "Women of NASA" set?**

I had proposed a couple of previous projects on the LEGO Ideas website that didn't get to the 10,000-vote requirement to become a set. Then I got the idea to combine women and NASA. I chose software engineer Margaret Hamilton, astronauts Mae Jemison and Sally Ride, and astronomer Nancy Grace Roman. I had a feeling it would be pretty popular.

But I knew that I'd need more than just the mini-figures. Since it was a LEGO set, there would have to be a building element as well. So I created *vignettes*, or scenes—including a telescope and space shuttle—that people could put together to show the mini-figures at work.

**Why did you select these particular women?**

I had several criteria for the women I chose. First, I wanted to include people from different areas of NASA. Margaret Hamilton supported spaceflight as a software engineer. That's a very different job than that of an astronaut like Mae Jemison. I also wanted someone who had nothing to do with the human-spaceflight program. Nancy Grace Roman was a longtime astronomer who oversaw the plan to create the Hubble Space Telescope.

I chose people of different ages and backgrounds. And I chose a mix of some who were famous, like astronaut Sally Ride, and others who weren't as well known.

**What do you hope people will take away from the set?**

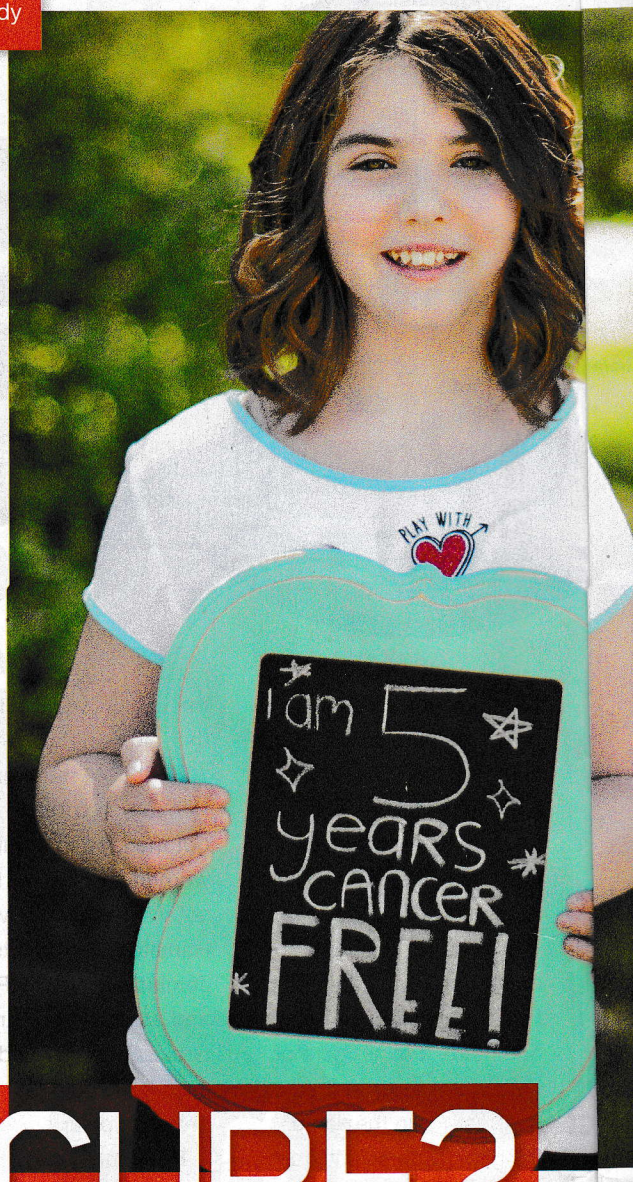
I hope that it will inspire boys and girls of all ages. It's especially exciting to showcase STEM (science, technology, engineering, and math) role models for girls. It's important for kids to see examples of scientists who look like them. What I'd ultimately love would be if kids who play with this set today go on to become the first Mars explorers, the engineers who helped them get to the Red Planet, or computer scientists who helped code the mission!

*—Jennifer Barone*


**NANCY GRACE ROMAN** planned and managed the Hubble Space Telescope.

**MAKE IT!**

Enter our DIY Challenge contest (p. 24) for a chance to win a "Women of NASA" LEGO set signed by Maia Weinstock.




# CANCER CURE?

## A revolutionary new treatment gives hope to people fighting a deadly disease

**ESSENTIAL QUESTION:** What is cancer? Why do you think this illness might be hard to treat?

When Emily Whitehead was 5 years old, bruises began to appear on her legs. Her gums bled when she brushed her teeth. Then she woke up one night in excruciating pain. Her parents rushed her to the emergency room. Doctors diagnosed Emily with a type of childhood blood *cancer*—a disease caused by abnormal cell growth. When two years of treatment with traditional medications failed to stop her cancer, Emily became the first kid to receive a groundbreaking new therapy. It would end up saving her life. "I was so happy because I knew I'd finally get to go home with my family," says Emily, now 12.

Emily suffered from a type of cancer called *acute lymphoblastic leukemia* (ALL). "Cancer in kids is rare, but ALL is the most common," says Dr. Stephan Grupp, a *pediatric oncologist*—a doctor who cares for children with cancer—who treated Emily at the Children's Hospital of Philadelphia in Pennsylvania.

About 3,000 kids are diagnosed with ALL each year. Roughly 85 percent of them recover





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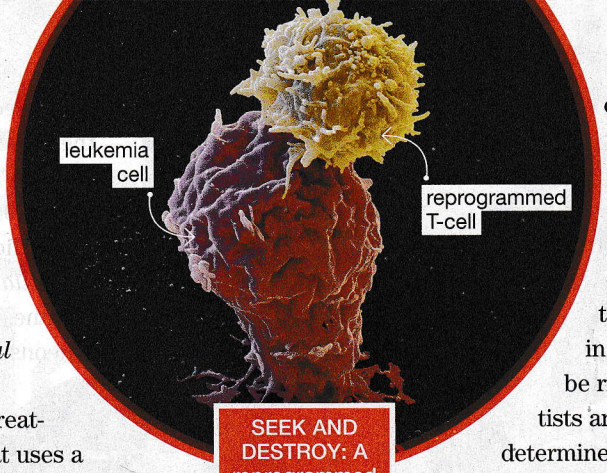
CANCER-FREE: Emily Whitehead during cancer therapy in 2012 (*far left*) and in May 2017 after being cancer-free for five years

from the disease after undergoing *chemotherapy*. In Emily's case, however, these medications didn't kill the cancerous cells in her body. Her last hope was a *clinical trial*, or experimental study. It would test a treatment called *CAR-T* that uses a patient's own cells to kill off cancer. For Emily, the treatment was a success. Five years later, she remains cancer-free. "I got to go back to the hospital to hang up my five years cancer-free photo," says Emily.

Last year, the U.S. Food and Drug Administration approved the therapy that helped Emily. It can now be used to treat other kids with ALL. The agency also approved a similar therapy to combat a blood cancer in adults called non-Hodgkin's lymphoma. Both therapies could help thousands of people suffering from previously untreatable forms of cancer.




SEEK AND DESTROY: A reprogrammed T-cell attacks a leukemia cell.

## DEADLY DISEASE

Cancer can strike any part of the body. Emily's leukemia originated within her *bone marrow*. This soft tissue within bones makes blood cells (*see Blood Breakdown, right*). "In leukemia patients, parts of their blood grow in ways that they shouldn't," explains Grupp.

In people with ALL, their bone marrow makes underdeveloped *B-cells*. This type of white blood cell normally helps the *immune system* fight infections. But Emily's cancer cells multiplied out of control, crowding out normal B-cells. Without enough healthy immune cells, Emily became extremely tired and experienced fevers, infections, and bleeding.

When an initial round of chemotherapy failed to cure Emily's cancer, she began a second, stronger round. Patients with ALL who need additional chemotherapy have only a 30 percent chance of being cured. Just four months after her second round of chemotherapy, Emily's cancer returned. "We knew we had to try something different or Emily would likely die," says Grupp.

## TRIAL TREATMENT

The only option was to enter Emily in a clinical trial, led by Grupp. It would test an experimental treatment on kids with ALL whose cancer didn't respond to chemotherapy. Enrolling in a clinical trial—particularly one in an early phase—can be risky, because scientists and doctors haven't yet determined if the treatment is safe or effective. For Emily and her parents, there was no other choice.

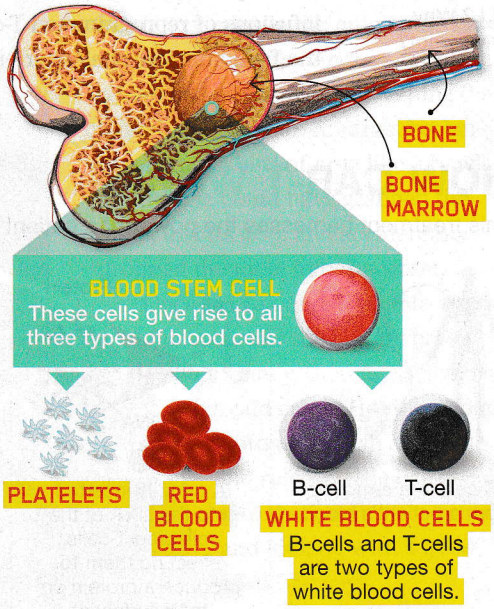
The clinical trial was studying the safety of *chimeric antigen receptor T-cell therapy*, or CAR-T for short. The treatment would use Emily's own immune cells—another type of cell called *T-cells*—to kill the cancerous B-cells (*see How CAR-T Works, p. 22*). T-cells naturally attack invaders in the body. But in ALL, they don't recognize the harmful B-cells.

During the trial, doctors collected T-cells from Emily's blood. All cells contain *DNA*—a

*Continued on the next page* →

## BLOOD BREAKDOWN

Blood is made up of three main types of cells—all made within bone marrow inside bones. *Platelets* help to form clots that stop a wound from bleeding. *Red blood cells* carry oxygen to other cells throughout the body. And *white blood cells* protect the body against disease.



HELPING KIDS WITH CANCER: Dr. Stephan Grupp led the experimental study that saved Emily's life.

GIVING BACK: Emily speaks onstage at a fundraiser for cancer research.

molecule that carries instructions for how a cell functions. In the lab, scientists inserted a new *gene*—a unit of hereditary material—into the DNA of the T-cells they'd gathered. The gene told the cells to produce a *protein*—a large, biological molecule—to recognize cancerous B-cells.

The reprogrammed T-cells were then injected back into Emily's bloodstream, where doctors hoped they would seek out and destroy the malfunctioning B-cells. "The therapy teaches a person's own cells how to do something new that they couldn't do before," explains Grupp.

**CORE QUESTION**

Do you think CAR-T should completely replace chemotherapy to treat ALL? Why or why not?

## OVERCOMING COMPLICATIONS

In April 2012, Emily received the first of three infusions of reprogrammed T-cells. But after the final infusion, she experienced a dangerous side effect. The immune response triggered by the reprogrammed T-cells caused inflammation in Emily's body. Her temperature rocketed to 41°C (105°F). Her blood pressure fell, and she had difficulty breathing. Doctors put Emily on a *ventilator*—a machine that helps a patient breathe. Then they induced a *coma*—a state of unconsciousness—to keep her alive.

Grupp had to act quickly to reduce the inflammation without also stopping the reprogrammed T-cells that were fighting Emily's cancer. He tried something out of the ordinary—a medication normally used to treat *arthritis*, a disease that causes inflammation throughout the joints of the body. Grupp made the right call, and Emily's condition quickly stabilized. Two weeks later, she woke up from her coma to discover she was cancer-free. "All of us just started hugging and crying," says Tom, Emily's dad.

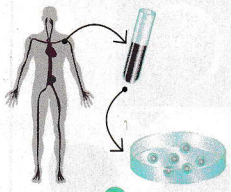
"I always tell people to keep fighting," says Emily. "Never give up."

The lessons learned from Emily's treatment helped pave the way for curing others. Since the start of the clinical trial, CAR-T has cured more than 150 kids, almost half of whom experienced the same side effects that almost killed Emily. Today, more than 500 trials are testing similar immunotherapies to treat different forms of cancer. "These new therapies are an important and powerful new tool in the toolbox to fight cancer," says Grupp.

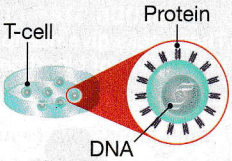
*—Andrew Klein*

## HOW CAR-T WORKS

This treatment harnesses the power of a patient's own immune system to fight off cancer cells within his or her body.

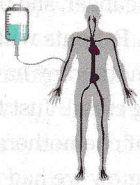


1 T-cells are removed from a patient's blood.

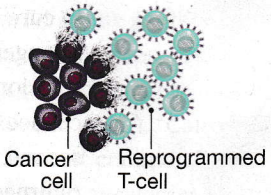



2 A gene is inserted into the DNA of the collected T-cells, directing them to produce a protein on their surfaces.

3 The reprogrammed cancer-killing T-cells are grown in a lab.



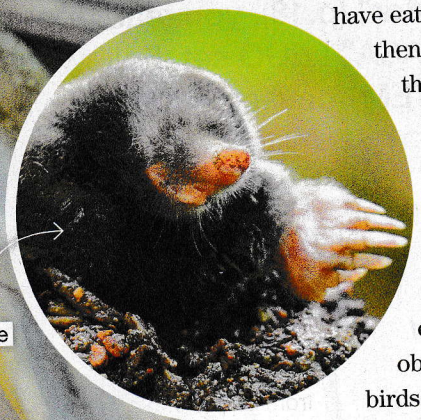
4 The T-cells are infused back into a person's bloodstream.




5 The protein on the surface of the reprogrammed T-cells recognizes a protein on cancer cells, allowing the T-cells to kill them.

CHILDREN'S HOSPITAL OF PHILADELPHIA (GRUPP); JAMIE MCCARTHY/GETTY IMAGES FOR GABRIELLE'S ANGEL FOUNDATION (EMILY SPEAKING); COURTESY OF PARKER AUSTIN; CO... MONROE MACKINNEY/CAL EHS NEWS AGENCY (POST MOUNT); MACKINNEY/CAL EHS NEWS AGENCY (POST MOUNT)

# Fish Eats Mole



SURPRISED FISHERMAN: Monroe MacKinney with his strange catch

Last May, Monroe MacKinney reeled in a fish from a pond in Fair Grove, Missouri, only to discover that he'd caught two animals instead of one. Inside the throat of the largemouth bass MacKinney had hooked, he found a surprising stowaway—a mole. When the fisherman saw the small furry mammal, he was so startled he dropped his catch.

MacKinney thinks the fish must have eaten the mole, which then drowned inside the fish's mouth as it swam underwater. Largemouth bass usually prey on small fish, which they swallow whole. But bass aren't picky eaters and have been observed gulping down birds, turtles, and snakes. "If it can fit in their throat, they'll try to eat it," says MacKinney.

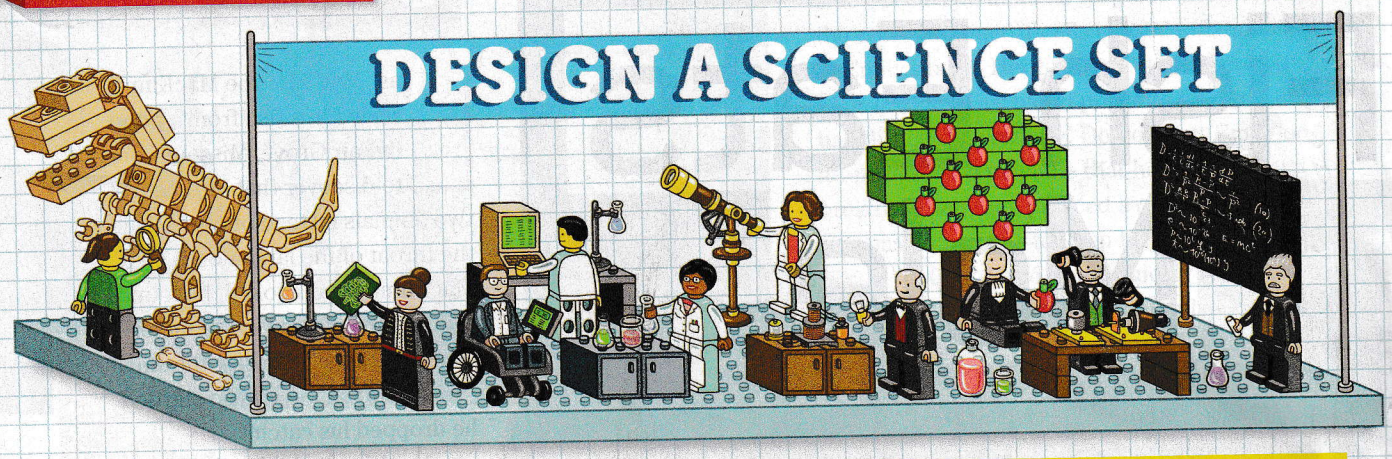
The real mystery is how the mole ended up in the water—giving the bass a chance to snag it—in the first place. Moles are *subterranean* animals. They live underground, digging tunnels and feeding on earthworms and insects. But heavy rains in the area could have flooded the mole's *burrow*—a hole where an animal lives—sweeping the mole into the pond. Another explanation is that a bird of prey like a hawk or an eagle could have grabbed the mole, lost its grip, and accidentally dropped the mole into the water.

Once in the pond, the mole was fair game for the hungry bass. MacKinney, though, didn't keep his odd catch. He snapped a photo of the fish and mole and released the bass back into the water. "It was alive and kicking with a good meal," he says.

*—Kathryn Free*

DIY CHALLENGE

# DESIGN A SCIENCE SET



**In "LEGO Creator" (p. 18), you read about Maia Weinstock, who designed the new "Women of NASA" LEGO set. Follow the design process below to come up with your own STEM-focused mini-figure set. Then enter your idea in our contest!**

## 1 STATE YOUR OBJECTIVE

What is the theme of your set? Which real-life scientists would it feature, and why? Why do you think kids will be interested in building this set? Research your idea to find out as much as you can. Write an explanation of your idea and the scientists, objects, and settings. Include information about the constraints.

## 2 BRAINSTORM SOLUTIONS

Think about how you could turn your idea from step 1 into a reality. What parts—such as mini-figures, vehicles, props, and settings—will you need to build the set? Come up with several different designs. Write a detailed description of how each would look. You could also draw sketches or diagrams to help you envision your plan.

## 3 PLAN AND IMPROVE IT

Pick your best idea from step 2. Then pair up with a classmate and discuss your designs. Offer each other ideas on elements that might need to be tweaked or added to improve your sets.

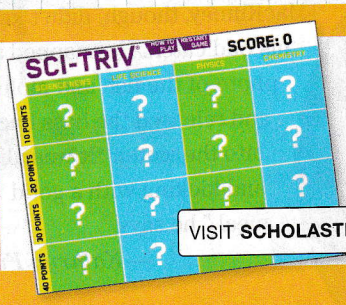
## 4 OPTIMIZE YOUR DESIGN

Based on the feedback you received in step 3, make adjustments to your original design. Keep going back to the drawing board until you're satisfied. Then enter your finished set's design plan in our contest (*below*).


**ENTER TO WIN!**

Submit a 300-word essay about your design. One entry will win a "Women of NASA" set, autographed by Maia Weinstock. Go to **scholastic.com/scienceworld** for more details about how to enter.

**ANALYZE IT** Why might it be important for toys like LEGO's "Women of NASA" set to highlight under-represented groups in STEM jobs?

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