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TECHNOLOGY

IT'S A POKÉMON WORLD

How the technology behind Pokémon GO could revolutionize everything from medicine to education

INSIDE

SCHOLASTIC
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SCIENCE WORLD NOVEMBER 21, 2016 **VOL. 73, NO. 5 Editorial Director:** Patricia Janes **Senior Editor:** Jennifer Barone **Associate Editor:** Jacob Batchelor **Contributing Editor:** Andrew Klein **Editorial Consultant:** Cody Crane **Interns:** Jeanette Ferrara and John Hering **Education Editor:** Matt Friedman **Online Editor:** Catherine Wilshusen **Senior Art Director:** Sarah Irick **Photo Editor:** Els Rijper **Production Editor:** Allan Molho **Senior Copy Editors:** Ingrid Accardi, Suzanne Bilyeu **Copy Editor:** Troy Reynolds **Digital Imager:** Vanessa Irena **Media Editor:** Marie Morreale **Executive VP, Scholastic:** Hugh Roome **Creative Director:** Judith Christ-Lafond **Design Director:** Felix Batcup **Executive Director of Production and Operations:** Barbara Schwartz **Executive Editorial Director, Copy Desk:** Craig Moskowitz **President, Chief Exec. Officer, and Chairman of the Board of Scholastic Inc.:** Richard Robinson. **POSTAL INFORMATION:** *SCIENCE WORLD* (ISSN 1041-1410; in Canada, 2-c no. 55948) is published 12 times annually; biweekly: September, October, March; monthly: November, December, January, February, April, May; by Scholastic Inc., 2931 East McCarty St., P.O. Box 3710, Jefferson City, MO 65102-3710. Periodical postage paid at Jefferson City, MO 65102 and at additional mailing offices. POSTMASTERS: Send notice of address changes to *SCIENCE WORLD*, 2931 East McCarty St., P.O. Box 3710, Jefferson City, MO 65102-3710.

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SCIENCE NEWS

DRILLING DOWN Glaciologists collect an ice sample.

THE TOOL A drill bit slices into the glacier.

EARTH SCIENCE: CLIMATE

DEEP FREEZE

A group of scientists recently hit the slopes—but not to ski. They visited the French Alps to collect ice from the Col du Dôme *glacier*, a slowly moving river of ice. Climate change is causing this and other glaciers around the world to melt. So a new project, called Ice Memory, aims to gather samples from the dwindling glaciers before they're gone for good.

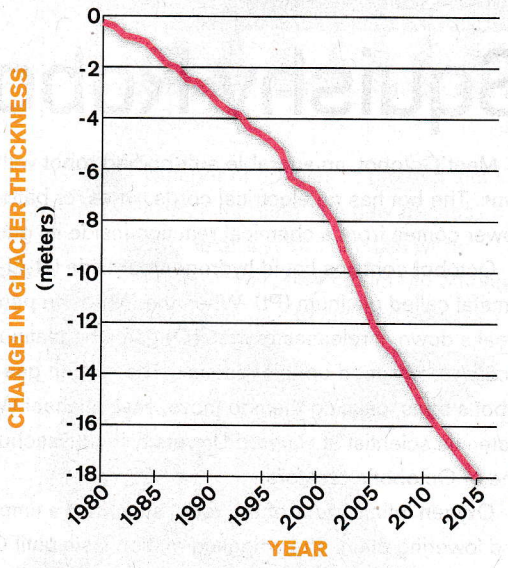
Glacial ice dates back thousands of years. It contains clues about how Earth's temperature and atmosphere have changed over time. When glaciers melt, the information they contain disappears as well.

The time to preserve glacier samples is now, says project leader and glaciologist Jérôme Chappellaz. Then they can "be studied by scientists of future generations who will have new ideas and new technologies." *—Hailee Romain*

BRUNO JOURDAIN/CNRS PHOTOTHÈQUE (DRILL BIT); COURTESY OF SARAH DEL BEN/WILD TOUCH/FOUNDATION JOA (COLLECTING SAMPLE); LUCIA SIMION (ANALYZING SAMPLE); JIM MCMAHON MAPMAN® (MAP)

TRACKING ICE LOSS

This graph shows how the average thickness of more than 100 major glaciers around the world has changed since 1980. Did these glaciers get thicker or thinner over time? How do you know by looking at the graph?



SOURCE: WORLD GLACIER MONITORING SERVICE

RISING WATERS: Rescuers help a family get to safety during flooding in Lumberton, N.C.

EARTH SCIENCE: NATURAL DISASTERS

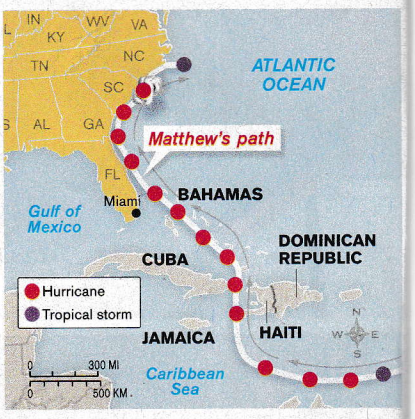
Deadly Storm

In early October, Hurricane Matthew swept across the Caribbean and then north along the U.S. coast, bringing powerful winds and violent rains. The storm was the strongest in the Atlantic Ocean since 2007.

Across the Southeast, the storm damaged roads and buildings and knocked out power to millions of homes. In North Carolina, a *levee*—a wall built to keep waterways from overflowing—broke, causing record flooding.

Emergency workers used boats and helicopters to rescue thousands of people stranded on rooftops. At least 44 people in the U.S. were killed.

In the Caribbean, Matthew devastated the nation of Haiti, causing as many as 1,000 deaths. Tens of thousands more lost their homes. Officials are concerned about food shortages and the spread of disease in the country. Recovery efforts are still under way. *—Cody Crane*



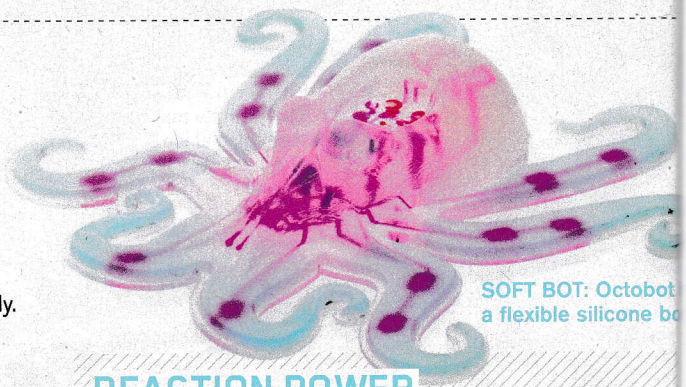
CHEMISTRY: CHEMICAL REACTIONS

Squishy Robot

Meet Octobot, an adorable soft-bodied robot with eight arms. The bot has no electrical cords, wires, or batteries. Its power comes from a chemical reaction inside its gummy body.

Octobot contains liquid hydrogen peroxide (H_2O_2) and a metal called platinum (Pt). When the hydrogen peroxide breaks down, it releases oxygen (O) gas. The platinum acts as a *catalyst* to speed up this reaction. The oxygen gas fills the robot's arms, causing them to move, says Michael Wehner, a materials scientist at Harvard University in Massachusetts and one of Octobot's creators.

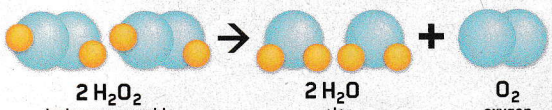
Oxygen inflates four of the robot's limbs at a time, lifting and lowering them. The wriggling motion lasts until Octobot runs out of fuel—about four to eight minutes. *—Jeanette Ferrara*



SOFT BOT: Octobot a flexible silicone bo

REACTION POWER

Inside Octobot's body, liquid hydrogen peroxide breaks down into liquid water and oxygen gas. The gas fills the bot's limbs, causing them to move.



AT RISK: A mountain yellow-legged frog

BIOLOGY: CONSERVATION

Frogs Fight Back

For the past two decades, frogs around the world have been battling a deadly infection. The disease is caused by the *chytrid fungus*. It has driven nearly 200 frog species to extinction. In the western U.S., the fungus has wiped out more than 90 percent of the mountain yellow-legged frog population. Now scientists are testing a way to help this endangered species fight back.

Conservationists in California have been collecting mountain yellow-legged tadpoles from the wild and exposing them to small amounts of chytrid fungus. The young frogs get a mild infection, which helps strengthen their disease-fighting *immune system* against the illness. When released, these frogs will be better able to fight future chytrid infections.

"The technique is new and complicated, but letting the frogs go extinct was not an option," says Jessie Bushell, the director of conservation at the San Francisco Zoo in California. Since the project began three years ago, Bushell and other scientists have seen the frogs' survival rates increase.

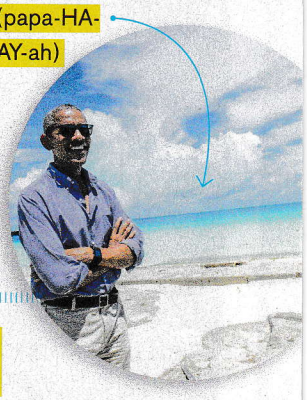
—Hailee Romain

THE VICTIM: An ecologist examines a dead frog.

NUMBERS IN THE NEWS

1.1 billion Number of stars in the most detailed map of the Milky Way ever created—400 million were previously unknown.

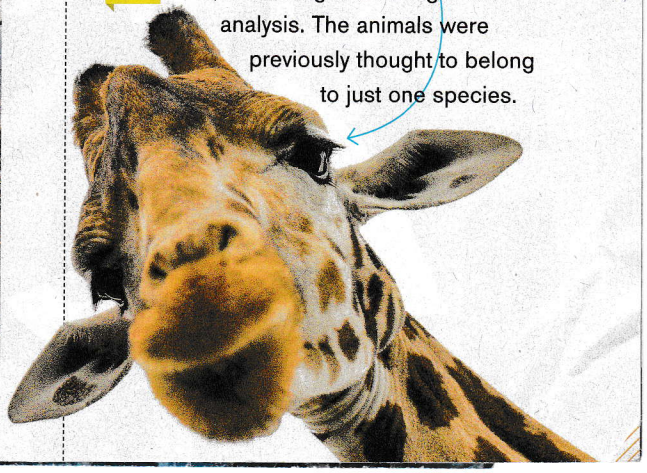
582,578 Size, in square miles, of the Papahanaumokuakea (papa-HA-now-MOH-KOO-ah-KAY-ah) Marine National Monument in the Pacific Ocean. President Obama quadrupled the size of this protected area.



40,000 Estimated weight, in pounds, of pennies that spilled onto a highway in Delaware when a truck headed for the U.S. Mint overturned. The coins were worth an estimated $70,000.

2020 The year by which France plans to ban plastic cups, food boxes, and disposable utensils to reduce plastic waste.

4 Number of species of giraffes that exist, according to a new genetic analysis. The animals were previously thought to belong to just one species.



FUNNY FACE: Researchers discovered that horses make 17 distinct facial expressions.

LOOK AT THAT FACE!

Scientists discover that horses make facial expressions, just like people

ESSENTIAL QUESTION: Why might it be important for animals to make facial expressions?

A horse named Icaro is the boss of the barnyard on the farm where he lives in East Sussex, England. According to his owner, Nicola Cramond, Icaro knows how to let his fellow horses know who's in charge: He makes a "snarky face" by pinning his ears back and narrowing his eyes.

"Horses are expressive," says Cramond, who has raised the animals for more than 20 years. A new study supports her observation. Scientists recently discovered that horses make a variety of faces. In fact, they have 17 distinct facial expressions. In comparison, people make 27—the most known of any animal.

"For a long time, we thought humans were special in the way we use facial expressions," says Jennifer Wathan, a psychology researcher at the University of Sussex. She led the study of horses' facial expressions. "There was a perception that animals didn't use their faces that much."

Wathan and her team studied 86 horses, including Icaro, to compile a manual called EquiFACS (short for Equine Facial Action Coding System). The manual allows scientists to classify the muscle movements behind a horse's apparent squint, scowl, or smile. Someday, this information could help them link emotions to those facial expressions.

WHAT'S IN A FACE?

Horses aren't the only animals whose facial expressions have been studied. In addition to studying humans, behavioral scientists have also looked at the faces made by cats, dogs, and chimpanzees. "Facial expressions have an enormous impact on social interaction," says Bridget Waller. She's a psychology researcher and the director of the Center for Comparative and Evolutionary Psychology at the University of Portsmouth in England.

Waller explains that facial expressions can tell animals what other members of their species are thinking. This helps them avoid conflicts, strengthen bonds, and show intentions to play, mate, or groom. In other words, facial expressions help animals "predict what others are going to do next and act accordingly," she says.

IDENTIFYING EXPRESSIONS

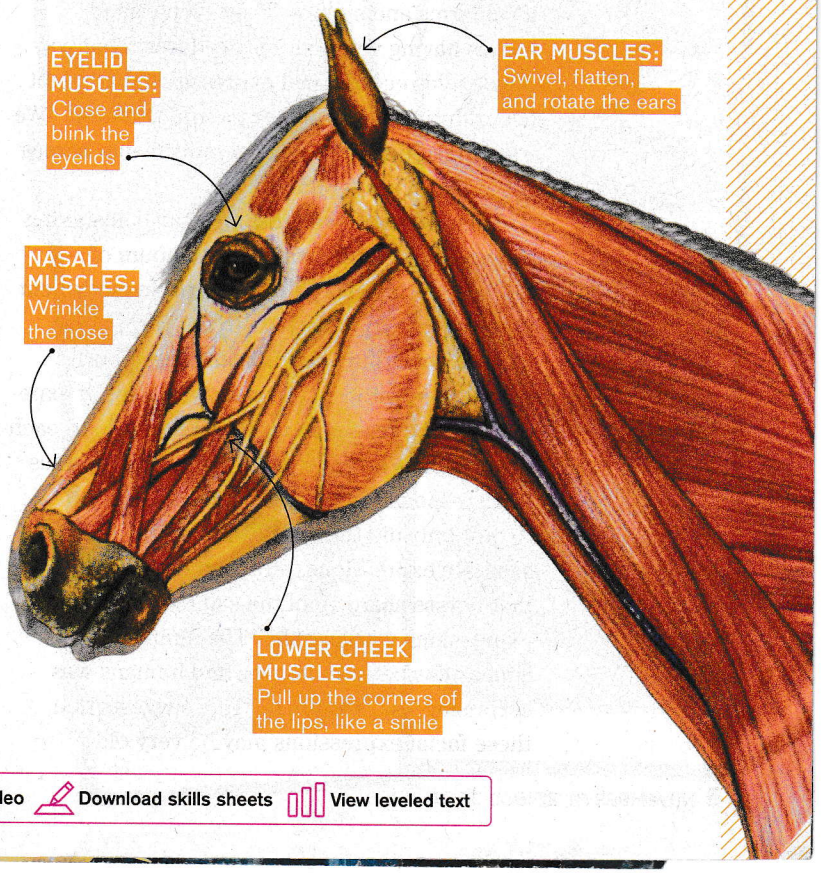
To understand whether horses made facial expressions, scientists first needed to know more about the animals' anatomy. Most muscles in the body attach to bones in order to move a body part, like an arm or a leg. But in horses and other mammals, facial muscles attach to the undersurface of skin. Previously, little was known about how these muscles work. That's because scientists had focused mostly on studying muscles essential to survival—like those used to eat—instead of those used to make facial expressions.

Wathan and her team examined the face of

Continued on the next page →

MAKING A FACE

By studying a horse's anatomy, scientists learned how the animal's facial muscles help it make expressions.



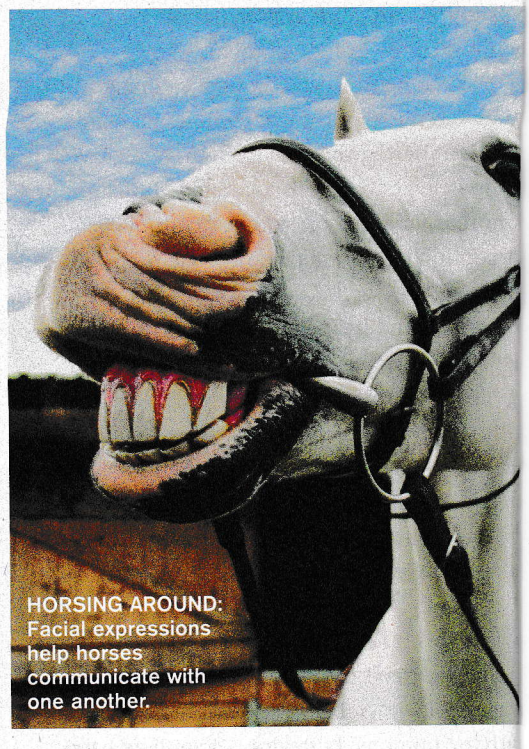
SILLY FACES: Chimpanzees can make 13 different *facial expressions.*

a dead horse. They studied the facial muscles to see how they were attached to the skin. That way they could determine how each muscle contracts and relaxes to move the skin. From this information, the researchers created a virtual map of a horse's facial muscles (*see Making a Face, p. 7*).

Next, Wathan and her team recorded videos of horses in different situations. They visited local farms and stables. They even visited horses having veterinary procedures. That way they could record facial expressions that might occur during a stressful or painful situation. "We tried to capture all the facial movements horses could make," says Wathan.

Then the team went through the painstaking process of carefully watching 15 hours of footage, noting every distinct muscle movement they observed. "Being able to interpret horse faces is something that humans aren't born with," says Wathan. "It comes with a lot of experience." The researchers assigned a code to each expression. The code identified which muscles were responsible for the movement.

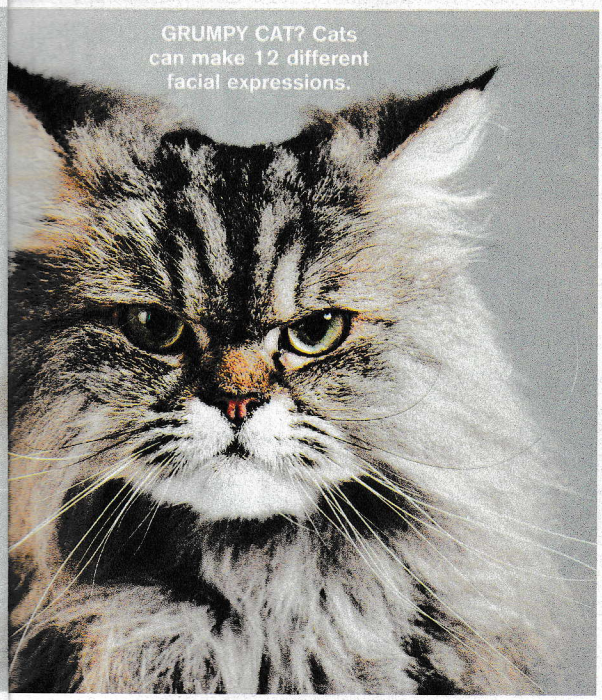
Not only did the scientists confirm 17 separate expressions, they also discovered that horses share 10 of the same facial-muscle expressions with people. "The number of similarities between horses and humans was surprising," says Wathan. "This suggests that these facial expressions may be very old behaviors that were present in our last common ancestor. Or they may have evolved in humans and horses in response to similar pressures."



HORSING AROUND: Facial expressions help horses communicate with one another.

EMOTIONAL CONNECTION

The next step in Wathan's studies is to link horses' facial movements with the emotional states that might cause them. Translating horse facial expressions could help people understand the animals' emotions—something they can't



GRUMPY CAT? Cats can make 12 different facial expressions.

tell us directly. This could be important to veterinarians when an animal becomes ill. It could also help animal owners trying to solve behavioral problems—like when Icaro acts out by "bullying" other horses.

"We need new methods that allow the animals to tell us what they're feeling," says Wathan. One way scientists hope to connect expressions with emotions is by studying which hormones the animal releases at the moment it makes a facial movement, she says. For instance, when a dog seems like it's smiling, its brain could be releasing *endorphins*. These chemicals in mammals' bodies are partly responsible for feelings of happiness.

Some studies also suggest that humans have the ability to accurately interpret some animal emotions by just looking at facial expressions (*see Decoding Doggy Emotions, right*). But to know for sure, scientists say that more research needs to be done.

Of course, for longtime horse lovers like Cramond, Icaro's owner, the discovery that horses' faces communicate how they feel comes as no surprise. "People who are around horses all the time are wondering what the fuss is about," she says.

—Andrew Klein

CORE QUESTION

What steps did scientists follow to learn about horses' distinct facial expressions?

(HORSE): DIGITAL VISION/GETTY IMAGES (CAT); COURTESY OF TINA BLOOM/BARKWOOD GALLERY (ALL DOG EXPRESSIONS)

DECODING DOGGY EMOTIONS

Researchers at Walden University in Orlando, Florida, did a study to see if people could tell what a dog is feeling just by looking at its expressions. Volunteers labeled what they perceived to be the dog's feelings in each photo. The percentages show how well people did at matching the dog's emotion to the correct photo.

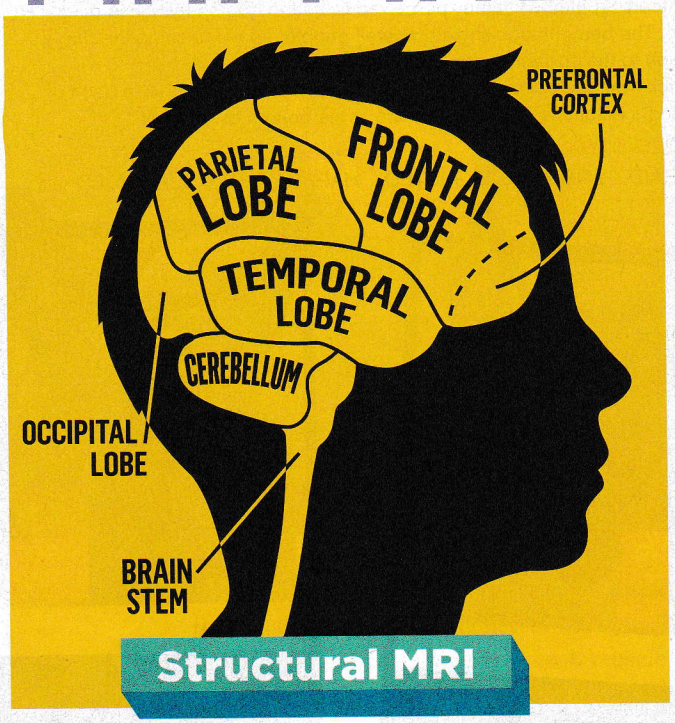
Pick from the emotions listed in the word bank below to fill in each of the dog's emotions. The answers are at the bottom of the page.

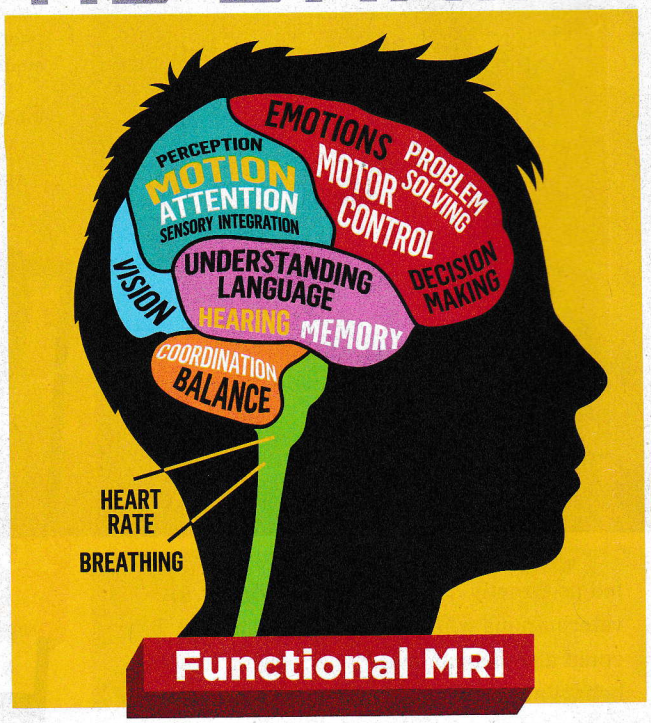
WORD BANK:

AFRAID ANGRY DISGUSTED HAPPY SAD SURPRISED

A. Surprised B. Disgusted C. Angry D. Afraid E. Sad F. Happy

MAPPING THE BRAIN





How technology is shaping what we know about the brain

Your brain has an estimated 85 billion *neurons** (nerve cells) that send signals with speeds of up to 270 miles per hour. Through neurons, your brain controls every move you make and every thought you think.

We know this, and much more, from advancements in *neuroscience*—the study of the nervous system, including the brain. Neuroscientists use brain-imaging tools—**MRI**, **fMRI**, and **PET**—to study the brain's structures and functions.

With these technologies, neuroscientists have mapped out which brain regions control different bodily functions. They've identified the brain areas that control critical thinking, movement, and breathing, as well as feelings like pleasure, sadness, and fear. They've also learned what happens to the brain as we age, as well as the effects of injury and of using drugs.

But there is still a lot to figure out. Read on to learn how these technologies work and how they are helping to teach us about ourselves, now and in the future.

*The prefix *neuro-* signals a word related to the brain, nerves, or the nervous system—such as *neuron* (a nerve cell).

The Future of Brain Research: The ABCD Study[1]

We know the brain changes a lot during adolescence. But does sleeplessness or stress affect brain development? Does playing sports? Are there lasting changes to the brain that result from vaping e-cigarettes?

To answer these questions and many more, neuroscientists will begin a study in 2016 that researches 10,000 9- to 10-year-olds for a period of 10 years. The researchers will use MRI and fMRI to track brain structure and function in the participants, as well as surveys and games to track the participants' behaviors. In the largest study of its kind, scientists will be able to look for patterns in how teens' lives affect their brains, and how teens' brains affect their lives. This information can be used to help future generations live better, healthier lives.

[1] Adolescent Brain and Cognitive Development Study

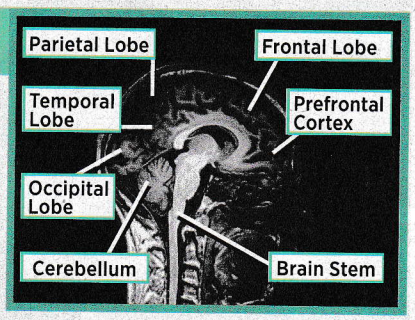
From Scholastic and the scientists of the National Institute on Drug Abuse, National Institutes of Health, U.S. Department of Health and Human Services

Structural MRI
Structural Magnetic Resonance Imaging

WHAT IT SHOWS

A detailed image of the structure (size and shape) of tissues, organs, and bones. Also shows the presence of disease.

HOW IT WORKS



A person lies still in an MRI machine, which surrounds the body with a magnetic field and emits radio waves. Hydrogen atoms in the water of tissues and bones absorb and then release the energy from the radio waves. A computer maps and measures these changes to create an image. Changes in the size of tissues (such as from diseases like cancer that cause tumors) can increase the amount of water in different parts of the body, which can be detected by MRI scans.

SOMETHING WE'VE LEARNED

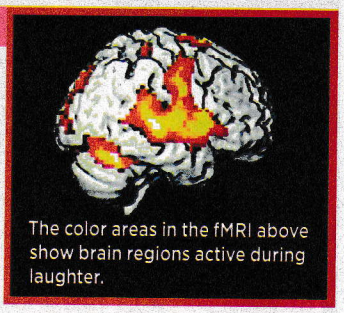
MRI scans of the brain have shown that people who have been using drugs for a long time have a smaller prefrontal cortex than people who have not been using drugs. The prefrontal cortex is the area where decision making occurs.

Functional MRI (fMRI)
Functional Magnetic Resonance Imaging

WHAT IT SHOWS

Areas of the brain that are active during a task.

HOW IT WORKS


The color areas in the fMRI above show brain regions active during laughter.

A person lies in an MRI machine while doing an activity such as looking at an image, hearing a sound, laughing at something funny, or completing a puzzle. The areas of the brain that are active during the behavior have increases in blood flow and blood oxygen levels. A computer analyzes these changes to map brain function.

SOMETHING WE'VE LEARNED

In studies where adolescents played a game to earn rewards, their brain scans showed higher activity in the area of the brain that processes motivation and pleasure (the nucleus accumbens[2]) compared with the area of the brain that guides thoughtful decision making (the prefrontal cortex). Scientists think this imbalance in activated brain regions may lead teens to focus more on the possible rewards of a decision than on any drawbacks. This could increase a person's risk for using drugs.

PET Positron Emission Tomography

WHAT IT SHOWS

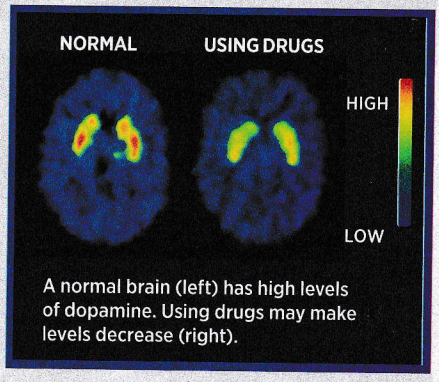
The brain and body at the cellular level.

HOW IT WORKS

PET scans use radioactive chemicals, called radiotracers, that are injected into the body. The radiotracers go to different areas depending on the chemical that is used. The PET machine detects the radiotracers and computer programs use colors to show their location.

SOMETHING WE'VE LEARNED

Dopamine is the brain chemical that helps us feel pleasure. By following radiotracers for dopamine receptors, PET scans have shown that using drugs heavily reduces the number of these receptors. Fewer receptors indicates less dopamine activity in the brain. This finding helps explain why people addicted to drugs experience less pleasure from everyday activities. They begin to crave the drug to get their dopamine activity back up to normal.



A normal brain (left) has high levels of dopamine. Using drugs may make levels decrease (right).

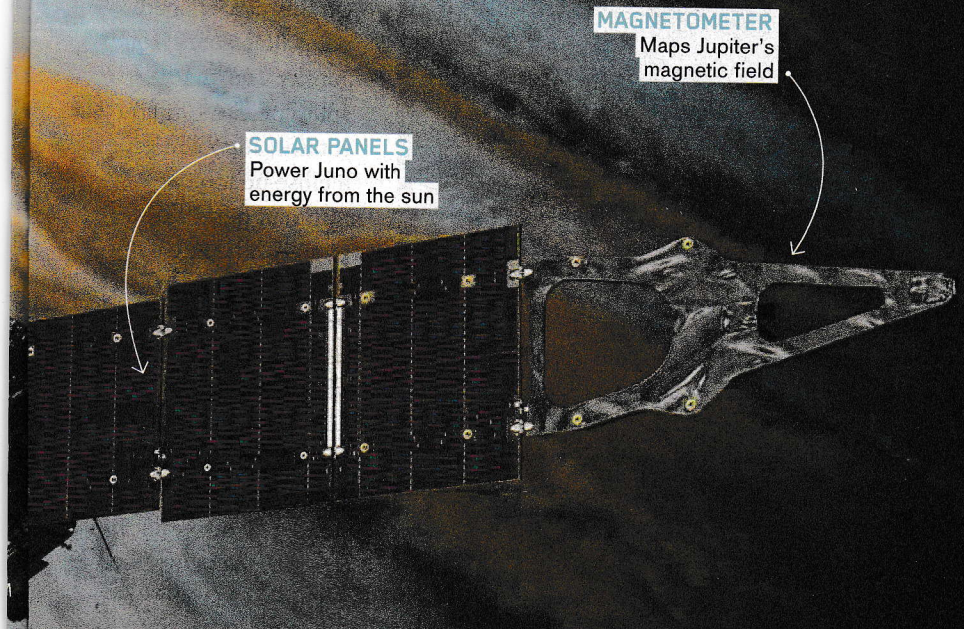
[2] The nucleus accumbens is a brain structure located at the base of the frontal lobe deep inside the brain. It does not appear on the MRI scan shown on this page.

More Info: For additional facts about the brain, visit **scholastic.com/headsup** and **teens.drugabuse.gov**.

HELLO FROM JUPITER!

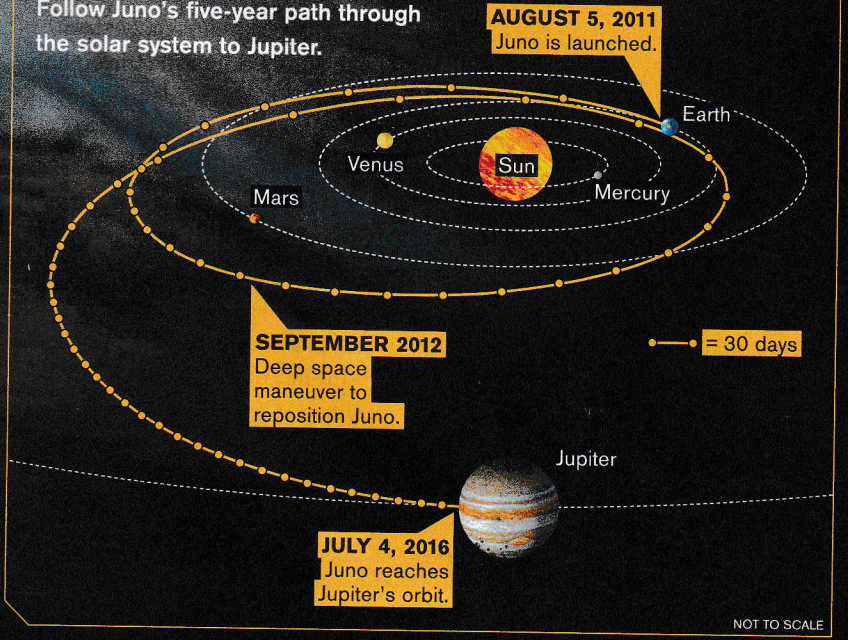
A spacecraft gets the closest-ever view of our solar system's largest planet

ESSENTIAL QUESTION: What is the largest planet in our solar system? How long do you think it would take for a spacecraft to travel there?



JUNO'S JOURNEY

Follow Juno's five-year path through the solar system to Jupiter.



On July 4, NASA scientists nervously gathered in a mission control room in Pasadena, California. They were waiting to find out if a spacecraft called Juno had reached Jupiter. At 8:53 p.m. Pacific Time, the scientists received a series of beeps. The control room erupted with cheers: The signal, broadcast by Juno, meant the spacecraft had made it.

"We only had one chance to get it right," says Steven Levin, Juno's project scientist. "So I was really relieved when Juno arrived safely."

Juno's epic trip began five years ago, when it launched from Cape Canaveral, Florida, on August 5, 2011. Since then, it has traveled 2.9 billion kilometers (1.8 billion miles). The spacecraft is now in *orbit*, or following a curved path, around Jupiter (*see Juno's Journey, left*). Juno will get closer to the planet than any other spacecraft in history. Its mission is to gather data that could answer some big questions about the massive and mysterious planet.

EXTREME PLANET

Jupiter is the fifth planet from the sun and the largest planet in our solar system. It's so big that a thousand Earths could fit inside it. Jupiter, Saturn, Neptune, and Uranus are our solar system's four *gas giants*—planets made of mostly hydrogen and helium gases.

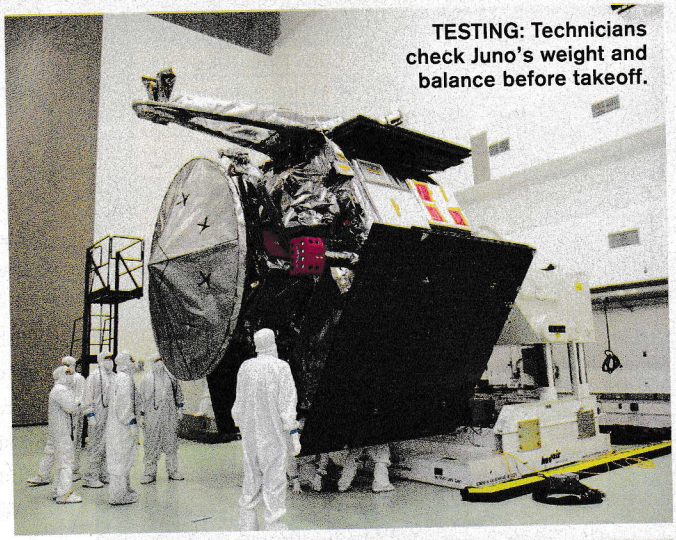
Red, brown, yellow, and white clouds cover Jupiter's surface in bands, making Jupiter look striped. Winds gust across the planet at 640 km (400 mi) per hour—twice as strong as the most powerful hurricanes on Earth. These winds

Continued on the next page →

create one of Jupiter's most famous features: its *Great Red Spot*. This giant storm is about twice the width of Earth.

"Everything about Jupiter is bigger and more extreme than other planets," says Levin. "It's surrounded by intense storms, and traveling into its clouds would be deadly."

Scientists have learned about many of Jupiter's features thanks to seven spacecraft that have flown by the planet and one that has orbited it. But Juno will get much closer than any of these past missions, which weren't designed to survive the dangerous conditions surrounding Jupiter.



TESTING: Technicians check Juno's weight and balance before takeoff.

SUCCESS! The NASA team cheers when Juno reaches Jupiter.

BUILT TO LAST

The biggest obstacle to getting close to Jupiter is the intense *radiation* around it. The radiation comes from tiny charged particles emitted by the sun and *Io*—one of Jupiter's 67 moons—and caught in Jupiter's *magnetic field*. Jupiter's field is much stronger than the similar force on Earth that moves compass needles. It accelerates the particles to incredible speeds (*see Dangerous Radiation, p. 15*).

It's some of the most powerful radiation a spacecraft has ever encountered. Even though these particles don't weigh much, they carry huge amounts of energy with them. These fast-moving particles can interfere with a spacecraft's instruments or damage them permanently.

Before Juno went into orbit, its *star tracker* was shut off to prevent interference. This device helps keep the spacecraft on course. Without it, the spacecraft was flying blind. "At that point, you just hold your breath and cross your fingers," says NASA astrophysicist Jack Connerney. Juno was so far away that it took 48 nail-biting minutes for its communications to reach scientists and let them know that the spacecraft had arrived.

Scientists still have to worry about radiation as Juno orbits Jupiter. To help protect the spacecraft, engineers designed Juno to follow an orbit that dips in and out of Jupiter's radiation belt. That way Juno can avoid the most-intense patches of charged particles and limit the damage they are expected to cause. On this oval-shaped path, Juno soars from Jupiter's north to south pole. As Jupiter rotates, Juno will get a close-up look at different parts of the planet with each flyby. There, it can snap amazingly detailed pictures and capture valuable data.

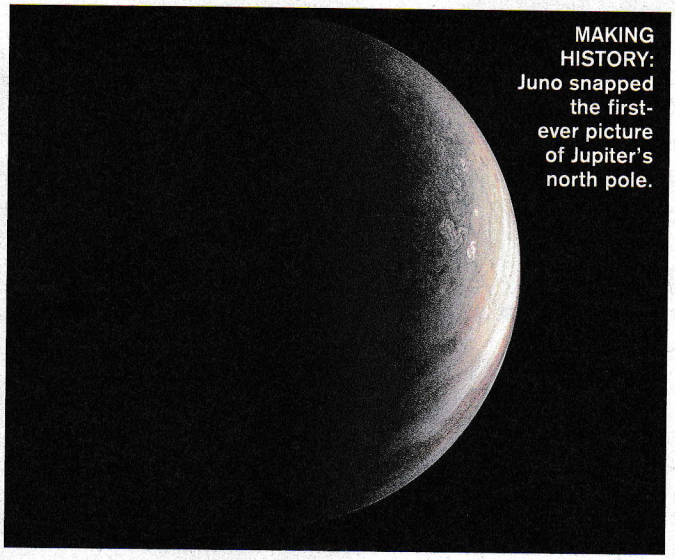
GATHERING DATA

To further protect Juno, engineers put its electronic components inside a vault about the size of an SUV's trunk. It's made of the element *titanium* (Ti), a light but extremely strong metal. Juno's onboard instruments are crucial to the mission. They will allow the spacecraft to peer below Jupiter's clouds and reveal the materials churning deep inside the planet. One instrument, for example, called a *microwave radiometer*, is measuring how much water is in Jupiter's atmosphere.

Another tool, called a *magnetometer*, will measure the magnetic field around and within Jupiter. It can help scientists learn about Jupiter's interior, where an ocean of liquid metallic hydrogen lies above the planet's core. Scientists

believe this ocean helps create Jupiter's magnetic field.

Information about Jupiter's composition could help explain how the planet—and the rest of our solar system—formed. About 4.6 billion years ago, what would become our solar system was just a spinning cloud of gas and dust. Ninety-nine percent of the material in the cloud became the sun. Jupiter was next to form, taking more than two-thirds of the leftover material. All of the other planets, including Earth, formed from what remained. Understanding how Jupiter was formed will help us understand how Earth, and everything on it, came to be, says Levin.



MAKING HISTORY: Juno snapped the first-ever picture of Jupiter's north pole.

MISSION AHEAD

Juno will orbit Jupiter at least 37 times, collecting data to relay back to Earth. Eventually, the radiation surrounding Jupiter will take its toll on the spacecraft. Experts expect that Juno will have to end its mission sometime in 2018. When that happens, the spacecraft will be sent on a controlled dive into the planet's stormy clouds and burn up like a meteor.

Until then, Juno has a lot of work to do. Its cameras, which NASA scientists powered up again once Juno was past the most intense radiation, have already snapped spectacular close-ups of Jupiter. NASA scientists eagerly await new discoveries made by the spacecraft. "We're expecting all kinds of surprises," says Levin.

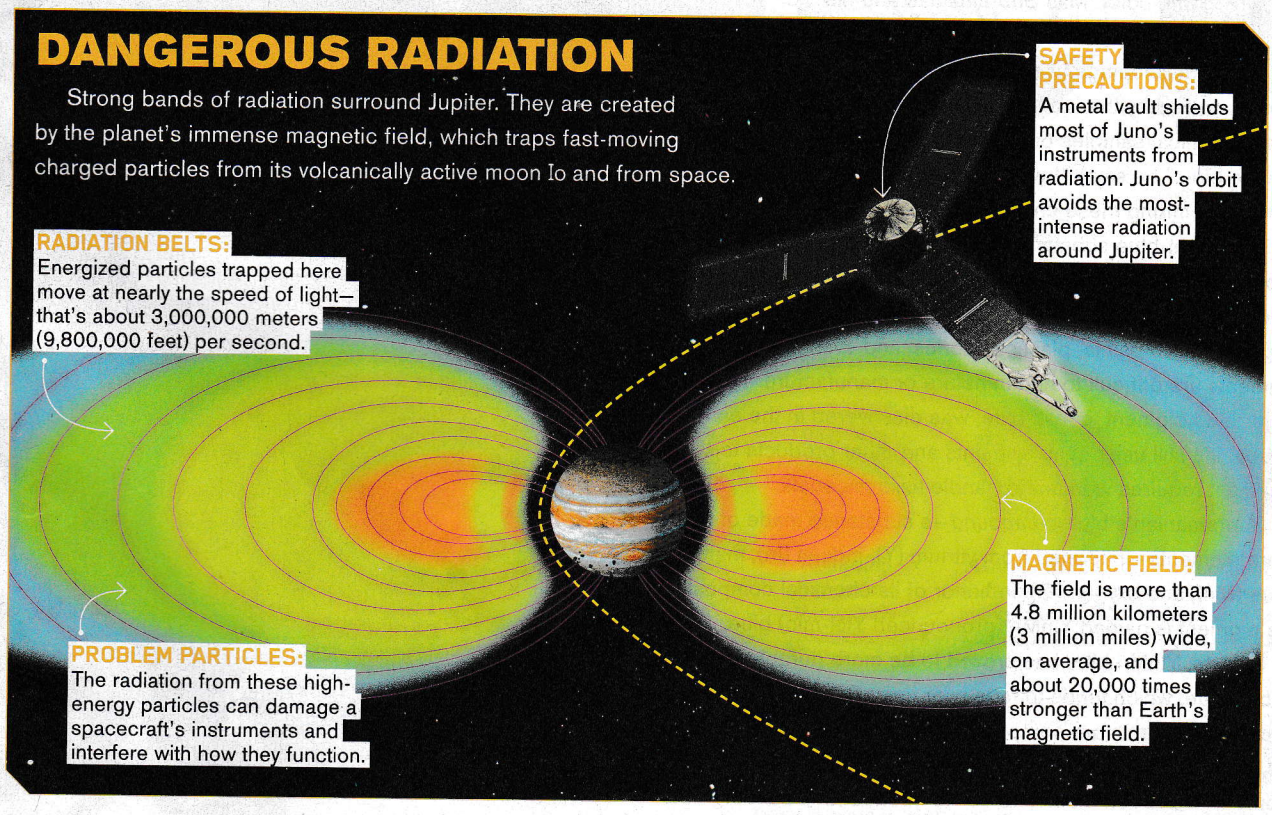
—Amy Barth

CORE QUESTION

Use evidence from the text and diagrams to explain why getting close to Jupiter is risky for spacecraft.

DANGEROUS RADIATION

Strong bands of radiation surround Jupiter. They are created by the planet's immense magnetic field, which traps fast-moving charged particles from its volcanically active moon Io and from space.



NEW BLUE

An accidental discovery leads to a new pigment

ESSENTIAL QUESTION: What are pigments, and what are they used for?

The materials scientist at Oregon State University never planned on working with color. Mas Subramanian and his research team were instead focused on developing materials for electronics. But one day, he walked by the lab just as a graduate student was pulling some chemical samples out of the furnace. "I saw this vivid, intense blue," he says. "I was shocked. I'd never seen anything like it from mixing these chemicals."

The bright-blue substance turned out to be a new pigment—a substance that absorbs and reflects different *wavelengths*, or colors, of light (*see Light and Color, right*). Pigments are used to give color to paints, plastics, fabrics, and even foods. Blue pigments are difficult to find in nature or manufacture. The last major blue pigment, cobalt blue, was discovered in the early 1800s. It's still used in many paints and other products today, but making it requires workers to handle toxic materials.

Subramanian's blue *compound*—a substance made of two or more elements—is formed from yttrium (Y), indium (In), manganese (Mn), and oxygen (O). In honor of its chemical composition, the pigment is named YInMn (pronounced YIN-min) blue.

In tests, YInMn blue has proved to be more durable than cobalt blue, which tends to fade over time. Better yet, the pigment and its ingredients are completely nontoxic. Subramanian and his colleagues patented their creation, and the Shepherd Color Company will soon make and sell it. Look for this dazzling new blue in paints and other products.

—Jennifer Barone

TOUGH STUFF
The color remains stable even when exposed to chemically damaging acids and bases that eat away at most other blue pigments.

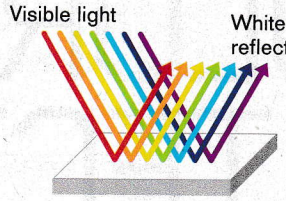
COOL COLOR
The pigment reflects *infrared light*, an invisible form of light that can transmit heat. So it can help keep objects cool.

HOW IT'S MADE
YInMn blue is created by heating manganese oxide and other substances to about 1,200°C (2,200°F).

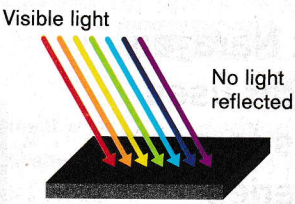
LONG LASTING
YInMn blue absorbs high-energy *ultraviolet* (UV) light without breaking down. That means paints made with YInMn should last for a long time without fading.

LIGHT AND COLOR

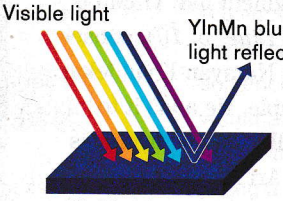
Most *visible light*—the light people can see—contains a mix of many *wavelengths* of light. Each wavelength—a measurement of the distance between a wave's peaks—corresponds to a different color. The color an object appears depends on which wavelengths of light the object absorbs and reflects.



White objects reflect all colors of light.



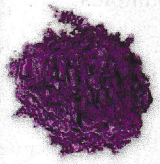
Black objects absorb all colors of light.



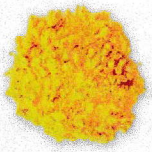
YInMn blue absorbs most reddish and greenish light and reflects primarily blue light.

THE YINMN FAMILY

By tweaking the elements used, Subramanian and his team have developed many new pigments with the same desirable properties as YInMn blue.



Adding titanium (Ti) and zinc (Zn) creates purple.



Removing manganese (Mn) yields yellow.

Green can be made by replacing manganese (Mn) with copper (Cu) and titanium (Ti).

Replacing manganese (Mn) with iron (Fe) yields orange.

CORE QUESTION

How is YInMn blue superior to cobalt blue? Cite two examples.

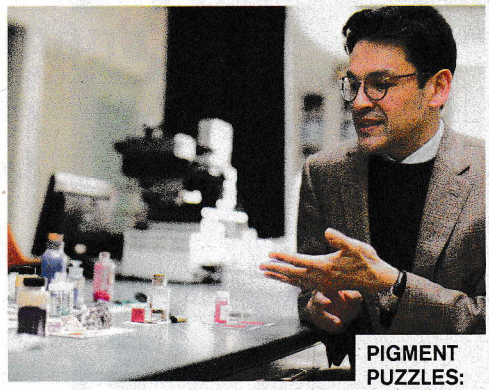
TURN THE PAGE FOR A PAIRED TEXT

ON DISPLAY: Vials of pigments

COLOR DETECTIVE

Chemist Narayan Khandekar uses pigments to solve art mysteries

When a new pigment like YInMn is made (*see New Blue, p. 16*), conservation scientist Narayan Khandekar snaps up a sample. He adds it to the pigment collection he oversees at the Harvard Art Museums in Cambridge, Massachusetts.



PIGMENT PUZZLES: Khandekar studies the composition of pigment samples.

Pigments are substances that absorb and reflect different *wavelengths*, or colors, of light. They can occur naturally in minerals or plants, or they can be created in a lab—as YInMn was. Throughout history, people have chosen pigments for their bright or unique colors. The pigment collection at the Harvard Art Museums, which was started in the 1900s, now holds about 2,500 samples from around the world.

Art experts use the pigments in the collection as *standards*, or established norms, with which other pigments can be compared. Having a vast reference library of pigments helps conservators restore and preserve aging or damaged artworks. By studying pigments' chemical compositions, they can better understand why paint on artworks has changed over time. Khandekar spoke with *Science World* about the pigment collection and how he has used it to determine whether works attributed to famous artists are authentic or forgeries.

MAUVE: This synthetic pigment was the first affordable purple.

What are some of the most interesting pigments you've come across?

In the Middle Ages, a period that lasted from the 5th to the 15th century, the deep-blue pigment *ultramarine* used to be more valuable than gold. That's because it came from crushing up a gem called lapis lazuli.

Another one, *mummy brown*, comes from the weirdest source. It was used in the 1800s and collected by scraping substances off the bandages used to wrap ancient Egyptian mummies. *Dragon's blood* has the strangest name. It's a bright-red *resin*. The sticky substance comes from the leaves of a rattan palm. It got its name from a myth that the pigment could be collected only from blood spilled on the ground when dragons and elephants fought one another.

How do you study a pigment's chemical makeup?

I first look at a sample under a microscope and identify the individual pigment particles based on their shape, color, and how they interact with light. Then I use *X-ray spectroscopy* and *X-ray fluorescence*, techniques that can reveal a pigment's chemical composition based on the way it interacts with X-rays.

What are some notable projects you've worked on?

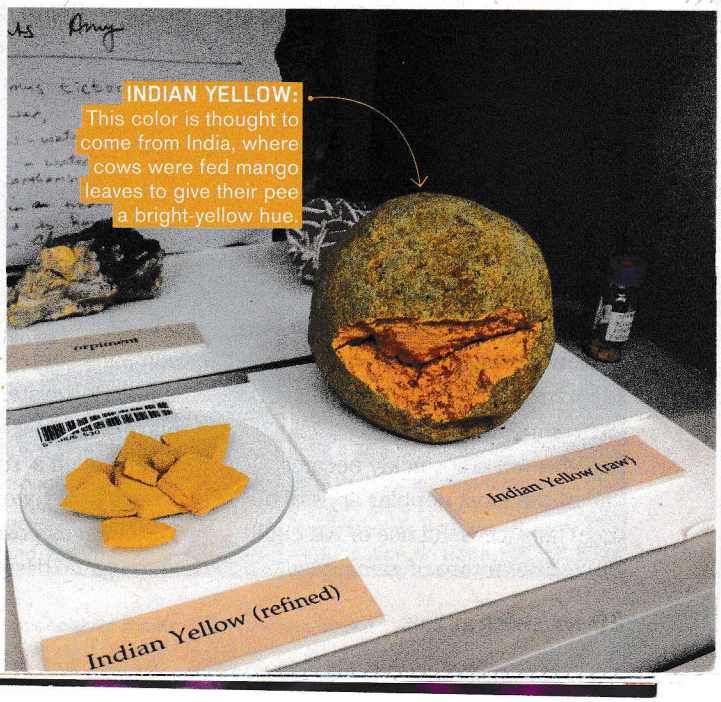
I recently worked on a series of panels by the 20th-century American artist Mark Rothko. Some of the panels had faded. My team took a sample from each painting to determine the pigments they contained and learn how and why their colors had deteriorated.

Another time, we were asked to confirm whether a newly discovered painting attributed to the American painter Jackson Pollock was authentic. We tested a sample from the painting and determined that it contained a pigment called *PR254*, which was used to give Ferrari sports cars their characteristic red color. This pigment wasn't discovered until after Pollock's death in 1956, which means he couldn't have painted the piece.

What is the most challenging part of your work?

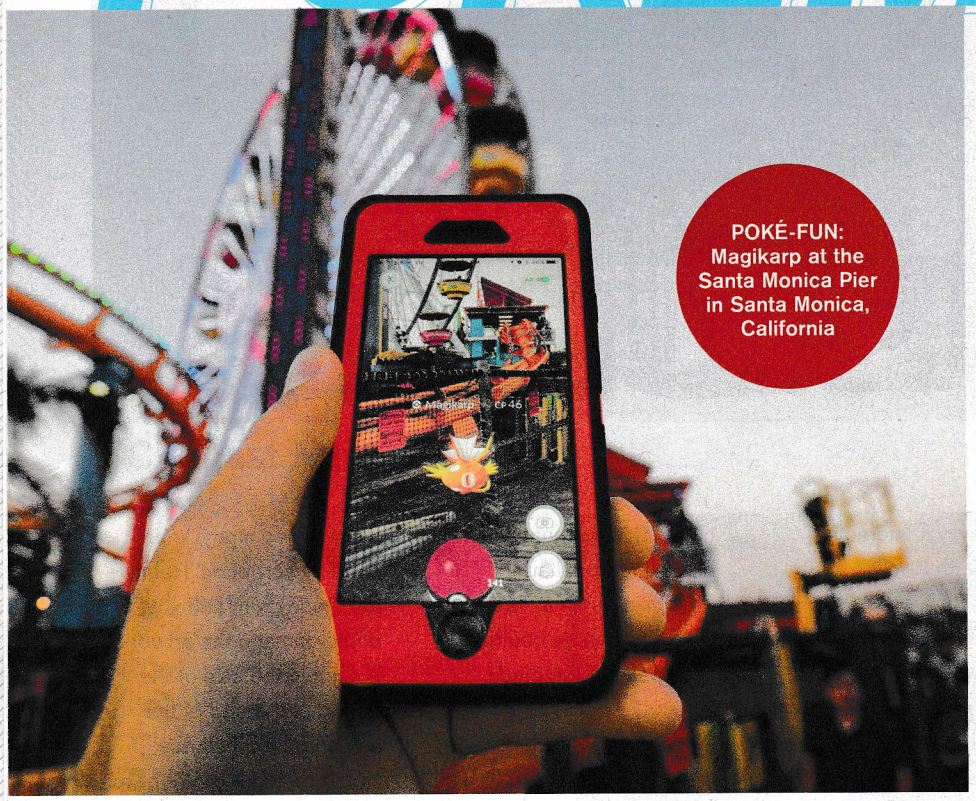
Taking pigment samples from a work of art requires a great deal of skill. We collect the samples with a *scalpel*—a sharp knife used by surgeons. Remove too much paint and you could damage the artwork. A sample the size of the period at the end of this sentence, for instance, would be too big. We have to convince curators that taking a sample is worth the risk because of how much we'll be able to learn.

—Jeanette Ferrara

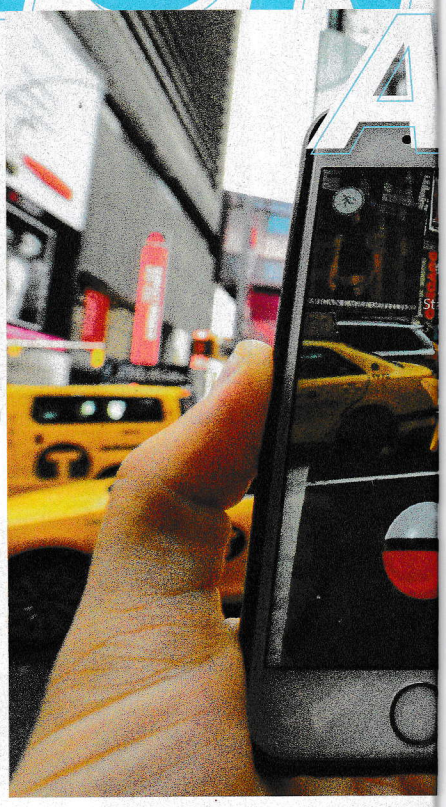


COURTESY OF PETER KNEBEL/HARVARD UNIVERSITY (NARAYAN KHANDEKAR, MAUVE, EMERALD GREEN); CASE, PINK PIGMENTS); COURTESY OF STEPHANIE MITCHELL/HARVARD UNIVERSITY (NARAYAN KHANDEKAR, MAUVE, EMERALD GREEN); COURTESY OF JENNIFER ALBIN/THE STRAUSS CENTER FOR CONSERVATION AND TECHNICAL STUDIES/HARVARD ART MUSEUM (INDIAN YELLOW)

POKÉMON



POKÉ-FUN: Magikarp at the Santa Monica Pier in Santa Monica, California



Technology from a popular app has real-world applications

ESSENTIAL QUESTION: What is augmented reality and how does it work?

Last summer, digital monsters began popping up all over cities, parks, and living rooms with the release of *Pokémon GO*. The smartphone app lets people catch and battle Pokémon in the real world. The game is based on a technology called *augmented reality* (AR) that allows people to view digital information that is *superimposed* on their physical environment.

Pokémon GO quickly became one of the most popular apps of all time. Its successful use of AR could change the future of gaming by getting players to interact with the real world. But beyond helping you "catch 'em all," AR has the potential to revolutionize how we experience many other aspects of life—from medicine to education and beyond.

HISTORY OF POKÉ-MANIA

Pokémon might walk among us now, but for more than 20 years the characters were trapped in a 2-D world. They first appeared in 1996 as part of a video game released by the company Nintendo for its portable Game Boy system. In the game, players could choose a human character, called a Trainer, and head into an imaginary world to catch as many Pokémon as possible. Japanese video game designer Satoshi Tajiri dreamed up the idea of Pokémon.

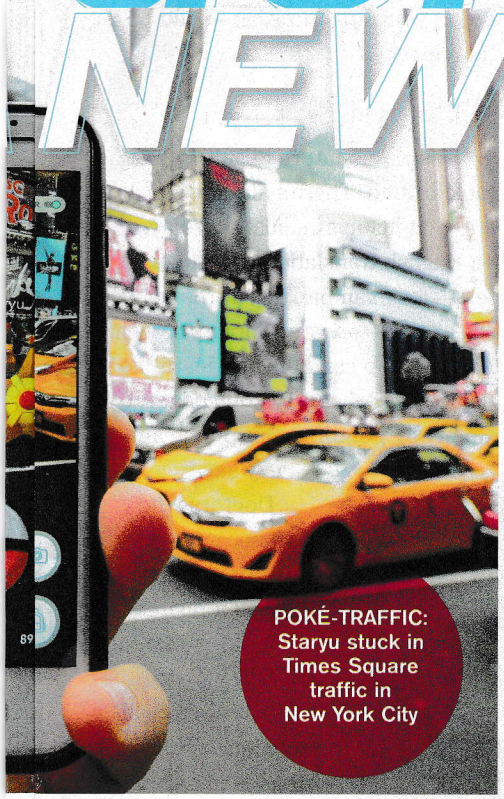
"As a child, Mr. Tajiri loved collecting insects," says J.C. Smith, a director of Japan-based The Pokémon Company. "He came up with the idea to create a game about collecting and sharing creatures."

The game's success inspired dozens of spin-offs, including more video games, trading cards, toys, and TV shows. Now, with the help of the software development company Niantic, the dream of becoming a Pokémon Trainer is closer to reality.

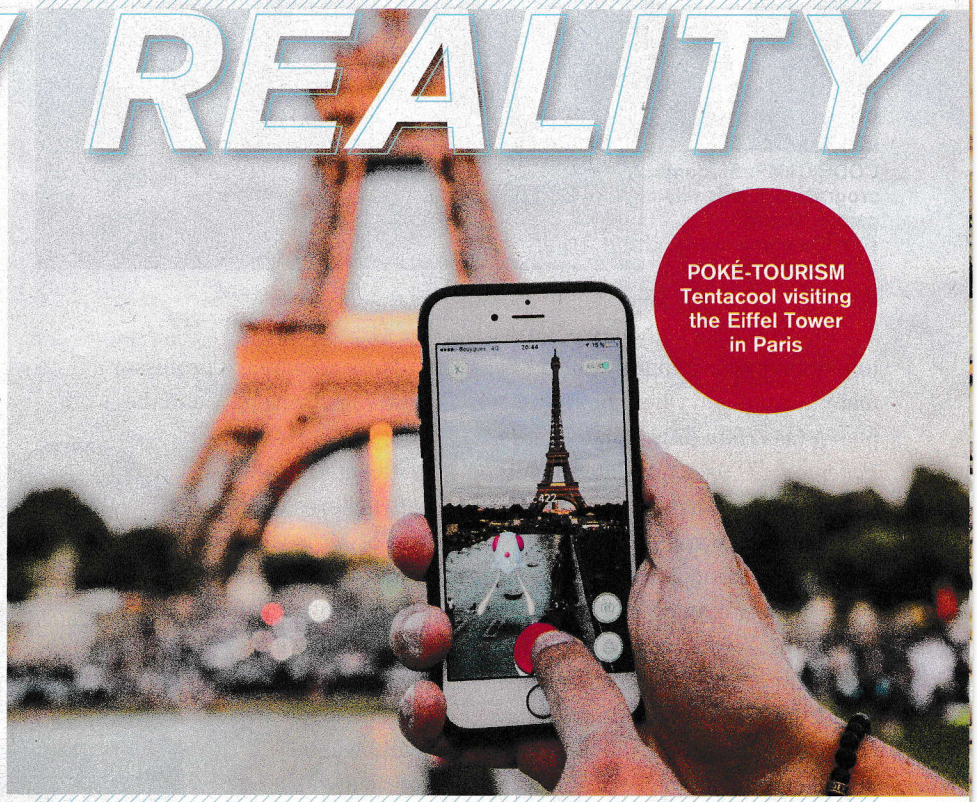
TAPPING SMARTPHONE TECH

An app like *Pokémon GO* is possible thanks to the technology already inside smartphones. The game's AR works by overlaying

GO: NEW REALITY



POKÉ-TRAFFIC: Staryu stuck in Times Square traffic in New York City



POKÉ-TOURISM Tentacool visiting the Eiffel Tower in Paris

an image of a Pokémon on top of the view from your smartphone's camera. As a result, it looks as if the creature is right in front of you.

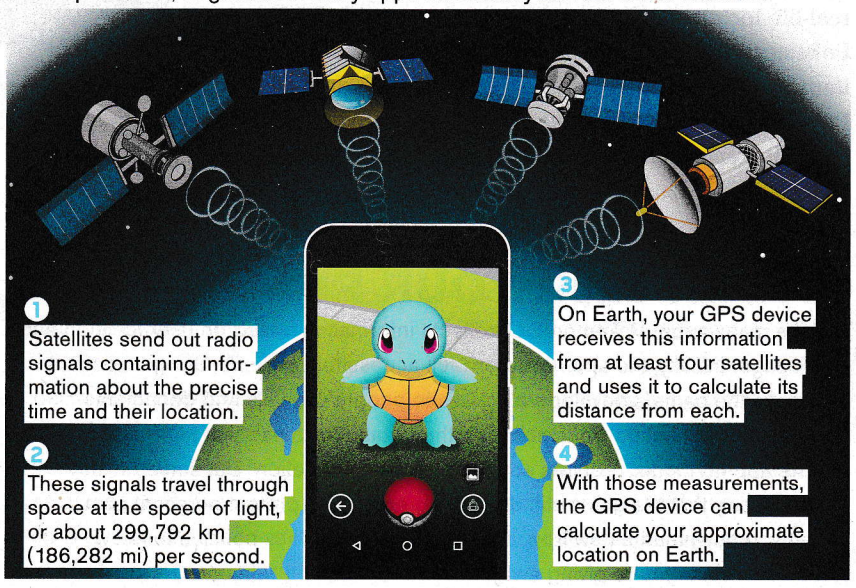
Once a Pokémon appears in the game, the app uses the compass inside your phone to determine which direction you're pointing. The app also uses your phone's *accelerometer*—which senses your phone's movements—and its *gyroscope*—which tracks when you rotate your phone. The constant stream of data from these components helps keep the Pokémon in about the same place, even if you move your phone in different directions.

Another essential technology for *Pokémon GO* is its ability to access the *global positioning system*, or GPS, through your phone. GPS uses

Continued on the next page →

HOW GPS WORKS

The global positioning system (GPS) is a group of satellites flying more than 20,000 kilometers (12,400 miles) above Earth. Each satellite orbits Earth twice a day following a different path to provide constant, worldwide coverage. With the help of GPS, augmented reality apps can track your real-world location.



CODE CAMP: Students program virtual reality games during a summer camp at the University of Maryland.

satellites orbiting high above Earth to pinpoint your phone's approximate location anywhere on the planet (*see How GPS Works, p. 21*). *Pokémon GO* uses this data to plot where you are on the game's map. In doing so, the app tracks your real-time location, a feature that has some privacy experts worried (*see Protecting Your Privacy, below*).

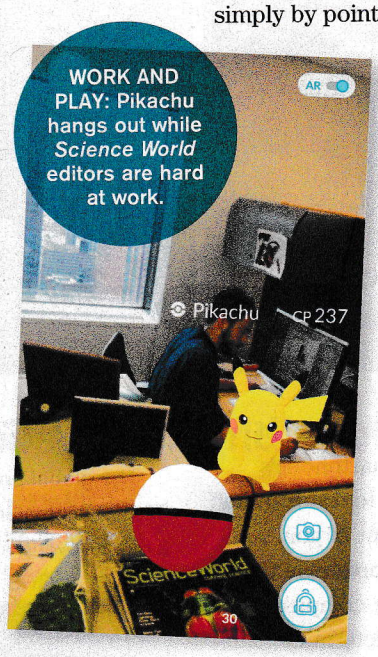
Pokémon GO developers used data from another Niantic game, *Ingress*, to help place the game's digital characters, objects, and places in the real world. In *Ingress*, users uploaded photographs of historical landmarks and cultural attractions and tagged them with geographical information. This data makes it possible to turn real-life locations into digital Pokéstops (places to collect virtual items to power up Pokémon) and Pokémon gyms (where players can battle Pokémon).

POWERFUL POTENTIAL

Mark Skwarek, a professor at New York University and the head of the NYU Mobile Augmented Reality Lab, believes the best of AR is yet to come—and that the technology's reach will extend well beyond gaming.

"The whole world will be overlaid with knowledge," says Skwarek. "You'll be able to know so much more about your surroundings than you could unaided. It'll be like having superhuman powers."

Skwarek predicts that soon we'll experience AR through wearable devices. Imagine glasses or contact lenses that display information about paintings, restaurants, or monuments as you pass by them. Map programs could show you the way home. Information would no longer be "at your fingertips," it would be "at a glance."



WORK AND PLAY: Pikachu hangs out while *Science World* editors are hard at work.

THE FUTURE IS NOW

To see this future in action, just look around. There's already an app that instantaneously overlays an English translation of foreign text—for example, the words on a street sign—on your phone's screen. Another app can help you learn the name of nearly every constellation simply by pointing your phone at a starry sky.

Doctors who live in remote locations are using AR and a related technology, *virtual reality* (VR), to learn new surgical techniques. While AR adds imaginary elements to the real world, VR completely replaces the real world with a simulated one. By wearing a special VR headset over their eyes, people can physically move around and interact with a 3-D computer-generated environment.

The possibilities these technologies provide are almost limitless. "The future of AR will be up to people with great imaginations—and people with the right skills," Skwarek says. —*Jacob Batchelor*

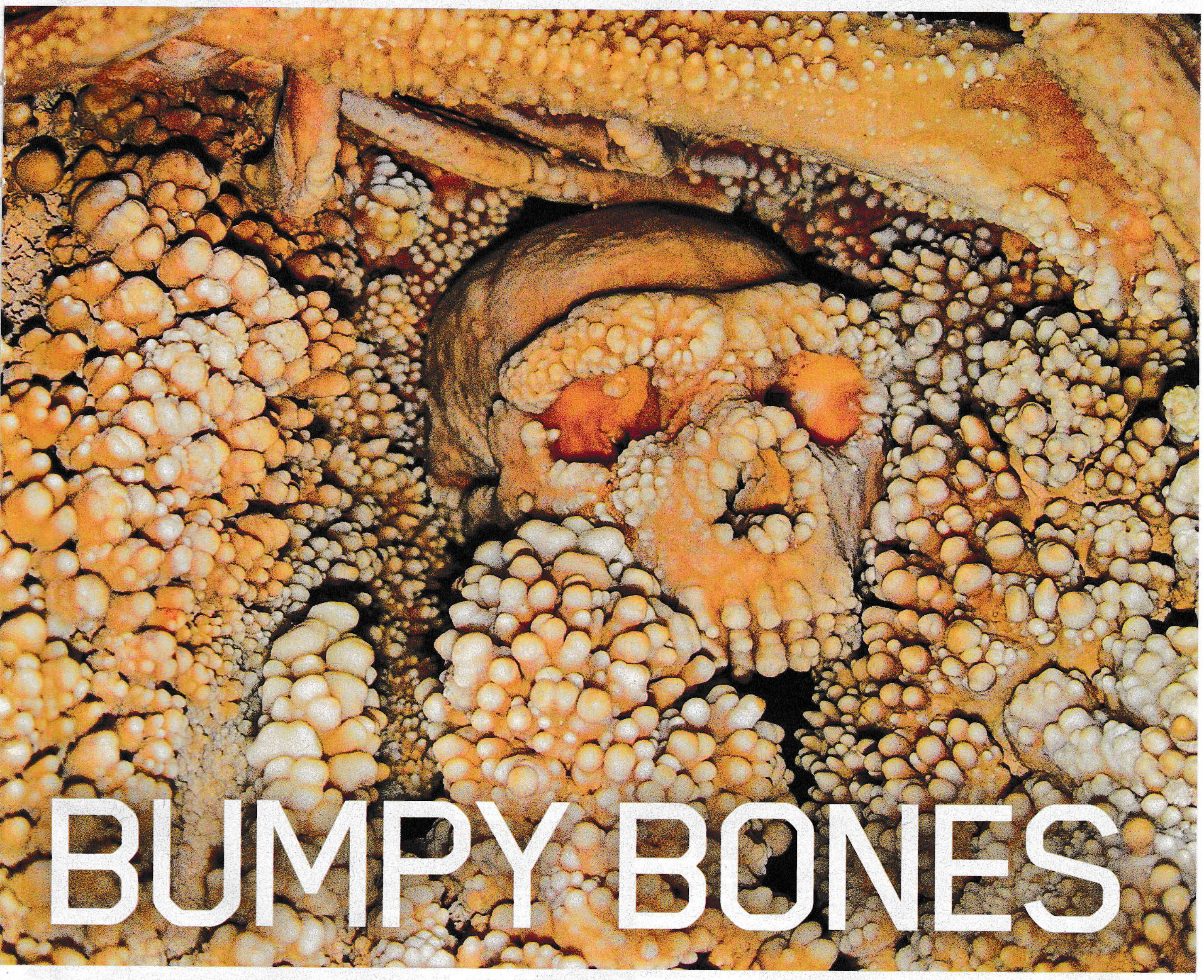
PROTECTING YOUR PRIVACY

Like many apps, *Pokémon GO* collects information based on user location and web usage. Initially, the app requested full access to a player's Google account. This gave the game's developers access to people's emails and documents. If criminals had hacked *Pokémon GO*, they would have had that information too.

The app no longer requires so much private information. But some privacy experts worry that the game still doesn't do enough to protect personal data. When you download a new app, carefully read the privacy policies to know what information you're giving away.

CORE QUESTION

Cite two examples from the text of ways people now use augmented reality and two future possibilities.



BUMPY BONES

More than two decades ago, cave explorers stumbled upon this strange, bumpy skeleton in a cave in Altamura, Italy. Only the skull and parts of a few bones were visible. The rest of the skeleton was embedded in the wall of the cave. Scientists wanted to study it, but they feared extracting the bones from the surrounding rock would damage them. So their origin has remained a mystery . . . until now.

Recently, a team of Italian researchers was able to chisel off a small chunk of bone from the skeleton's shoulder blade. By studying it, the scientists concluded that the remains belonged to a *Neanderthal*—a species of human ancestor that went extinct about 40,000 years ago.

The scientists were also able to extract *DNA*—the molecule that carries hereditary information—from the bone sample. The skeleton is between 130,000 and 170,000 years old, making its DNA the oldest genetic material from a Neanderthal ever discovered. Because the DNA is so old, though, much of it was damaged, says David Caramelli, an *anthropologist* (a scientist who studies humans) at the University of Florence in Italy.

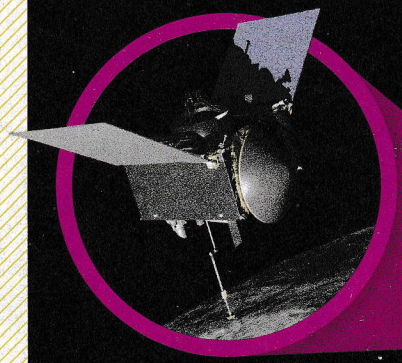
Caramelli explains that the hard bumps covering the skeleton are a mineral called *calcite*. When water seeps into the ground, it dissolves calcium (Ca) in rock. Inside the cave, this mineral-rich water *evaporated*—changed from a liquid to a gas—leaving behind hard calcite crystals. Caramelli says the skeleton is likely so well preserved because it's been shielded within a cocoon of rock for thousands of years.

—*Hanneke Weitering*

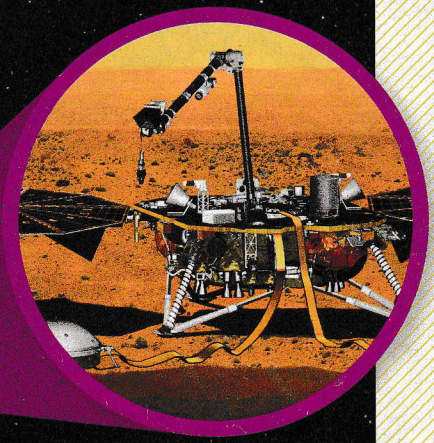
SEQUENCE OF EVENTS

FUTURE SPACE MISSIONS

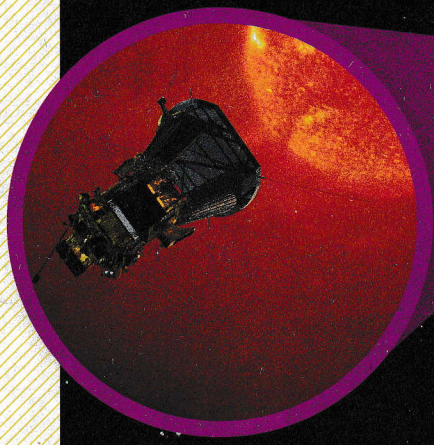
In "Hello From Jupiter!" (p. 12), you read about the Juno spacecraft's mission to Jupiter. Find out where NASA plans to explore next.



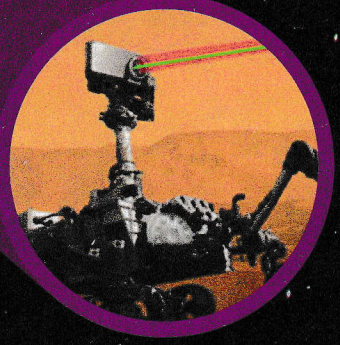
SEPTEMBER 2016: SAMPLING A SPACE ROCK
The OSIRIS-REx spacecraft, launched this fall, will travel for more than two years to reach an *asteroid* called Bennu. It will collect samples to bring back to Earth.



2018: DRILLING ON MARS
The InSight mission will send a lander to drill into Mars's interior, giving scientists a better understanding of the Red Planet's composition.

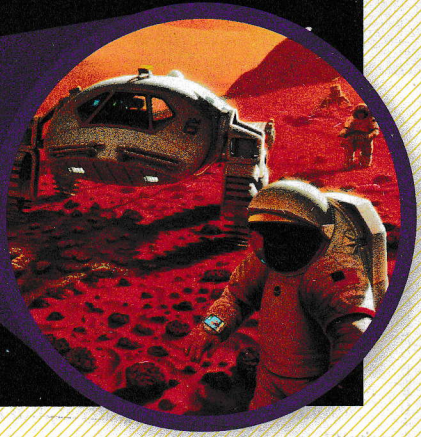


2018: STUDYING THE SUN
Solar Probe Plus will orbit the sun for nearly seven years to gather data on its outer atmosphere—called the *corona*.



2020: LOOKING FOR LIFE
The Mars 2020 rover will look for signs of past life on the Red Planet and collect rock samples. It will also test technology for future human exploration.

2025: VISITING AN ASTEROID
NASA hopes to capture an asteroid and redirect a chunk of it to orbit the moon. Astronauts aboard the *Orion* spacecraft will explore the asteroid.



2030s: SENDING HUMANS TO MARS
Orion's asteroid mission will help NASA test technology needed to send astronauts even further into the solar system—to Mars.

ANALYZE IT

How might the early events listed in the timeline help NASA send astronauts to Mars in the 2030s?

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