Science News Explores

March 2025

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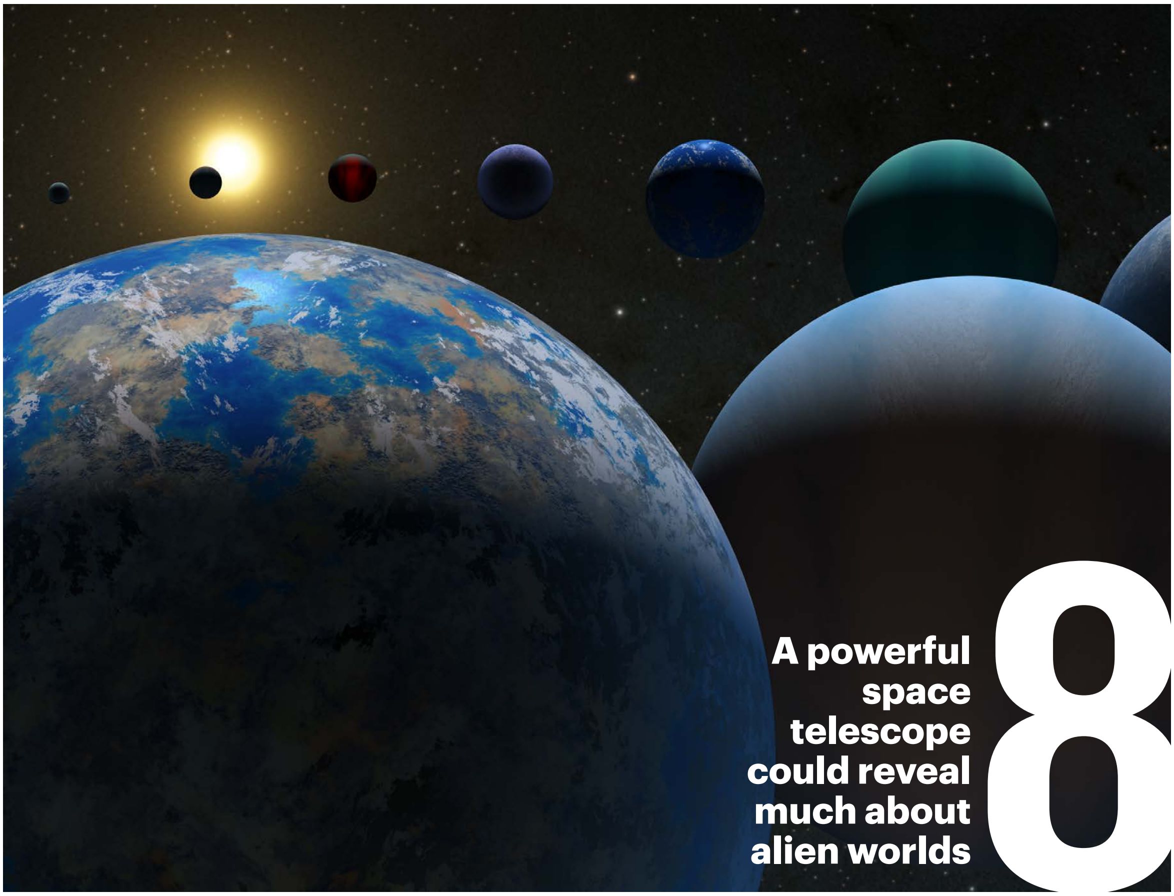

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Q Who's the community that built the pyramids?
— Matthew H.

A People all over the world have built pyramids throughout history. Perhaps the most famous pyramids are those that ancient Egyptians built as tombs for their kings, starting around 2700 B.C. But people in the Kingdom of Kush, in what is now Sudan, also constructed pyramids as royal burial sites between about 700 and 300 B.C. Residents of the ancient city of Teotihuacán (shown here), near modern-day Mexico City, built their Pyramids of the Sun and the Moon and Temple of Quetzalcóatl (Feathered Serpent) pyramid within the first few hundred years A.D. Not much is known about these people, but their pyramids appear to have been the sites of rituals, burials and sacrifices. And people in the ancient Maya city of Tikal, a thriving urban center until around 900 A.D., built several pyramid temples. One of these, in modern-day Guatemala, may have been inspired by the Temple of Quetzalcóatl at Teotihuacan. More pyramids have been found elsewhere in Africa, Europe, Asia and South America.

Q How does the HPV vaccine prevent certain cancers?
— Angela G.

A HPV vaccines work against human papillomaviruses (HPV). These viruses infect the skin and are spread mostly through sexual contact. HPV infects about 13 million Americans each year. Most infections don't cause symptoms. Some strains, though, cause genital warts. Others can change how cells divide and communicate, leading to genital, throat, anal and cervical cancers later in life. Each year, HPV causes about 36,000 cases of cancer in the United States alone. The HPV vaccine works by causing our immune systems to produce antibodies. These bind to the virus, preventing it from infecting cells. But HPV vaccines can only prevent infections, not cure them. This means the vaccine works best when given to people before they are sexually active, often at ages 11 or 12.

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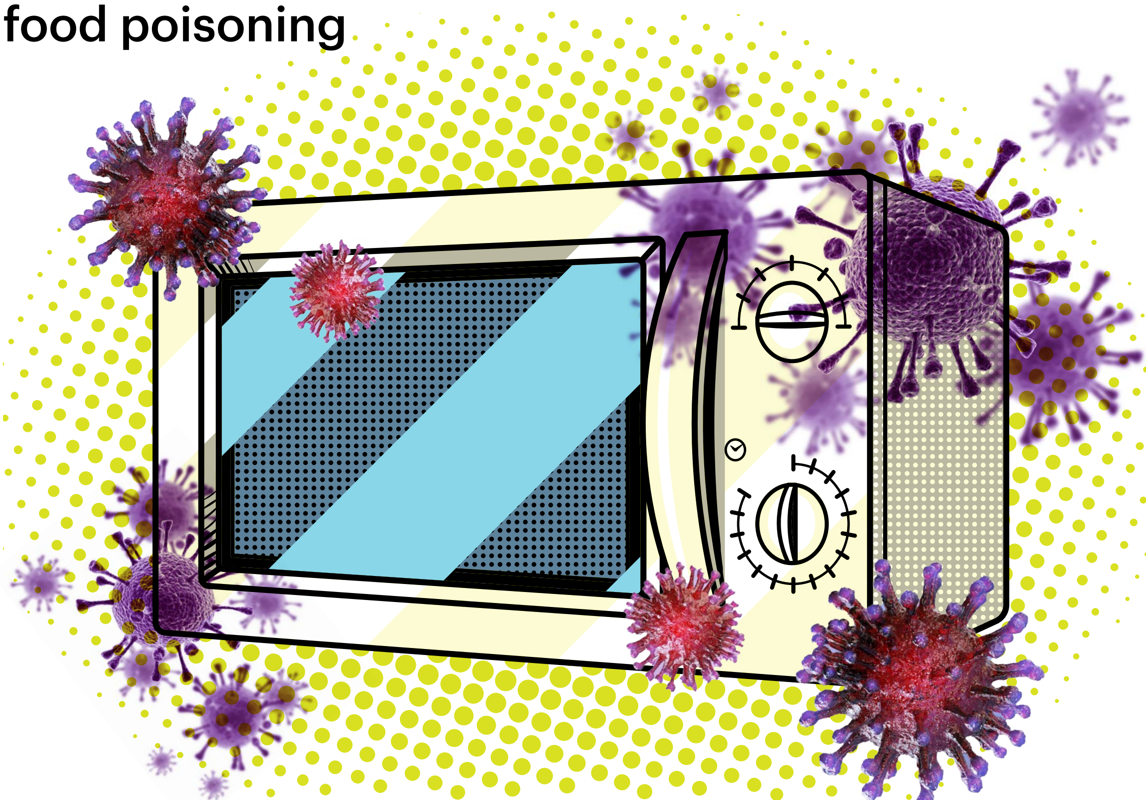
Sarah Zielinski
Editor, *Science News Explores*

ESKYSTUDIO/SHUTTERSTOCK

MICROBES

More than 100 types of bacteria found living in microwave ovens

These microbes included ones that can cause food poisoning



Even microwave ovens aren't safe from bacteria. The microwave radiation bouncing around inside them might seem threatening to microbes. After all, a microwave oven cooks food and boils water. But scientists have just found over 100 strains of bacteria living inside these common appliances.

Alba Iglesias works at the University of Valencia in Spain. Her team shared the findings in *Frontiers in Microbiology*. This is the first time that research has shown communities of germs living in microwave ovens.

The microbiologists swabbed the insides of 30 microwave ovens. Some came from home kitchens and labs. Others were being used in shared spaces, such as cafeterias. Each swab was transferred to lab dishes, allowing the bacteria to reproduce.

Iglesias's group then analyzed the microbes' DNA. These analyses showed that most microbes were kinds commonly found on human skin and surfaces that people frequently touch. The microwave ovens in kitchens also hosted *Klebsiella* and *Brevundimonas*. These bacteria can cause food poisoning.

It's unclear how these microbes survive being bombarded by microwaves, the team says. More work is needed to understand how the microbes have adapted to the ovens' high temps and radiation.

The microbes in home microwave ovens were the same as those found on countertops and other kitchen surfaces, notes Manuel Porcar. He's another member of the Valencia team. Some can even make you sick, he says. "One must clean the microwave as much as any other kitchen surface."

Still, he sees no reason to worry about microwave ovens as long as they're kept clean. They're no worse, he says, than "any other part of a kitchen in contact with food."

— *Abdullahi Tsanni*

A microwave oven can cook your food, but it won't cook all microbes. Scientists have found more than 100 strains of bacteria that can survive being microwaved.

ALEXANDER_P, AKR11_SS, CORONA BOREALIS STUDIO/SHUTTERSTOCK

SPACE

Microscopic black holes may be flying through our solar system

Massive but atom-sized, they could jostle planets and satellites

Microscopic black holes could be careening through the solar system unnoticed. But their days of stealth may be numbered. Two research teams have proposed ways to spot such baby black holes — if they truly exist.

These black holes would pack the mass of an asteroid into a space about the size of a hydrogen atom. Scientists suspect that objects like this could have formed in the very early universe. For that reason, they are known as *primordial* black holes. (Primordial means "existing from the beginning.")

One way to find primordial black holes is to look for the effects of their gravity on planets. Another is to look for their gravitational pull on satellites. Researchers shared these ideas in *Physical Review D*.

Finding primordial black holes could help solve the mystery of dark matter. This invisible stuff makes up 85 percent of the matter in our universe. Scientists know it exists because its gravity pulls on things we can see. But no one knows what dark matter is made of. If tiny black holes are caught wandering the cosmos, that could explain what makes up some or all dark matter.

A teeny tiny black hole in the solar system (illustrated) could mess with planets' movements as they orbit the sun.

BENJAMIN V. LEHMANN, WITH USE OF SPACEENGINE@COSMOGRAPHIC SOFTWARE LLC

SMALL OBJECTS, BIG GRAVITY

Black holes typically form when a dying star collapses. Some scientists think smaller black holes might have formed in the early universe. Back then, bits of space might have collapsed on their own.

Such primordial black holes might whiz through the inner solar system about once a decade, researchers estimate. That means there's no need to worry about a tiny black hole crashing into you. That's less likely than a peanut thrown at random hitting a specific blade of grass in a lawn the size of a trillion football fields!

When a tiny black hole passes near a planet, though, it could have noticeable effects. Its incredibly strong gravity could make a world like Mars wobble in its orbit around the sun, explains Sarah Geller. This cosmologist at the University of California, Santa Cruz, worked on the planetary wobble study.

A primordial black hole could also jostle satellites. Imagine a black hole with the mass of an asteroid coming within the moon's distance from Earth. It could change the altitudes of satellites a small but detectable amount.

Plain old asteroids could mimic the gravitational effects of the tiny black holes. But the black holes would have speeds of roughly 200 kilometers per second (about 125 miles per second). And they would come soaring in from outside the solar system. That's rare for space rocks.

Other celestial effects could also tweak planetary orbits. Those would need to be ruled out before blaming a tiny black hole, says Andreas Burkert. He's an astrophysicist who did not take part in either study. He works at Ludwig-Maximilians-University Munich in Germany.

Confirming that changes to satellite motions are due to black holes will be challenging. Right now, Burkert says, "I don't think it's realistic." But he remains "optimistic that it might be possible at some point."
— *Emily Conover*

ANIMALS

To stay clean, these tadpoles don't poop for weeks

The baby tree frogs live in tiny pools instead of ponds

Some tadpoles seem to have a unique way to keep their watery cribs clean: They don't poop for weeks!

These baby Eiffinger's tree frogs live in Taiwan and on the Japanese islands of Ishigaki and Iriomote. Even as adults, they're tiny — just 3 to 4 centimeters (1 to 1.5 inch) long. These frogs lay their eggs in puny pools. Often, these small pools are nestled in plant stems, tree hollows or bamboo stumps.

On hatching, the tadpoles spend their early lives in these pools. But in such small pools of water, there's not a lot of liquid to dilute ammonia. These animals release that toxic chemical in their pee and poop. So why don't the pools quickly turn poisonous?

The tadpoles' secret to keeping their pools clean is constipation. Baby Eiffinger's tree frogs store their poop in their gut. And they don't release it until they start to turn into full-fledged frogs.

Bun Ito and Yasukazu Okada are biologists at Nagoya University in Japan. They shared their findings in *Ecology*.

The pair raised tadpoles from four different frog species in makeshift nurseries: Eiffinger's tree frogs, Japanese tree frogs, Montane brown frogs and forest green tree frogs.

Once their experiment began, Ito and Okada moved the tadpoles to smaller cribs. These were plastic cases, each holding a little more than a tablespoon (15 cubic centimeters) of water.

The team measured and compared how much ammonia each frog species released. They also measured how much of the chemical each species had stored in their guts.

Eiffinger's tree frog tadpoles released less than half as much ammonia, on average, than the forest green tree frog — the species that released the most. Baby Eiffinger's tree frogs also kept more ammonia in their guts.

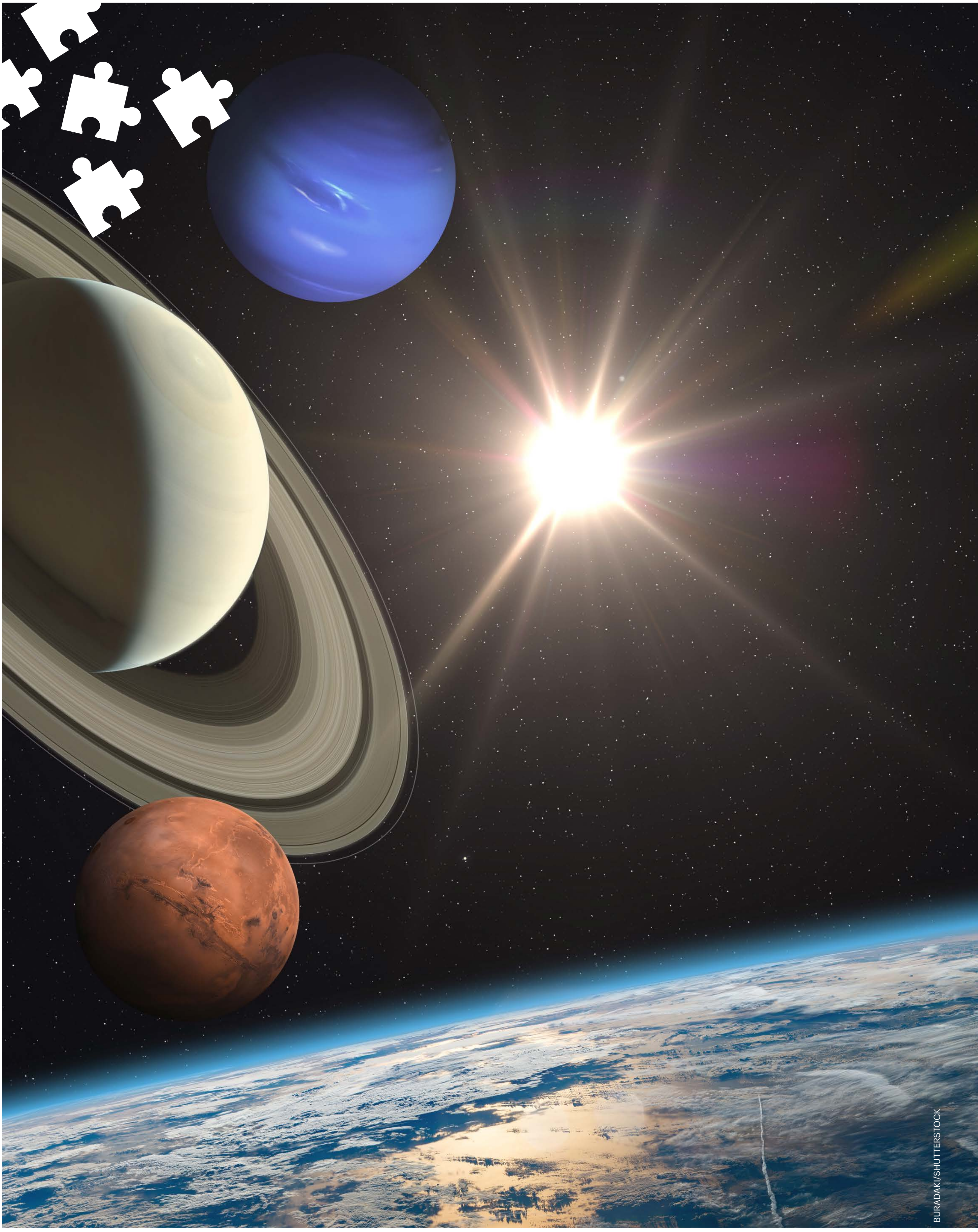
Unlike the Eiffinger's frogs, the other three species typically lay their eggs in open ponds. There, ammonia would be easily diluted. That may explain why they don't hold their ammonia in, as Eiffinger's tree frogs do.

— *Andrea Tamayo*

HANK ASIA/SHUTTERSTOCK

Eiffinger's tree frogs don't start pooping until they transform into adults. As tadpoles, they store their waste in their guts to keep their home puddles clean.

Think you know what you're seeing? Find out on page 32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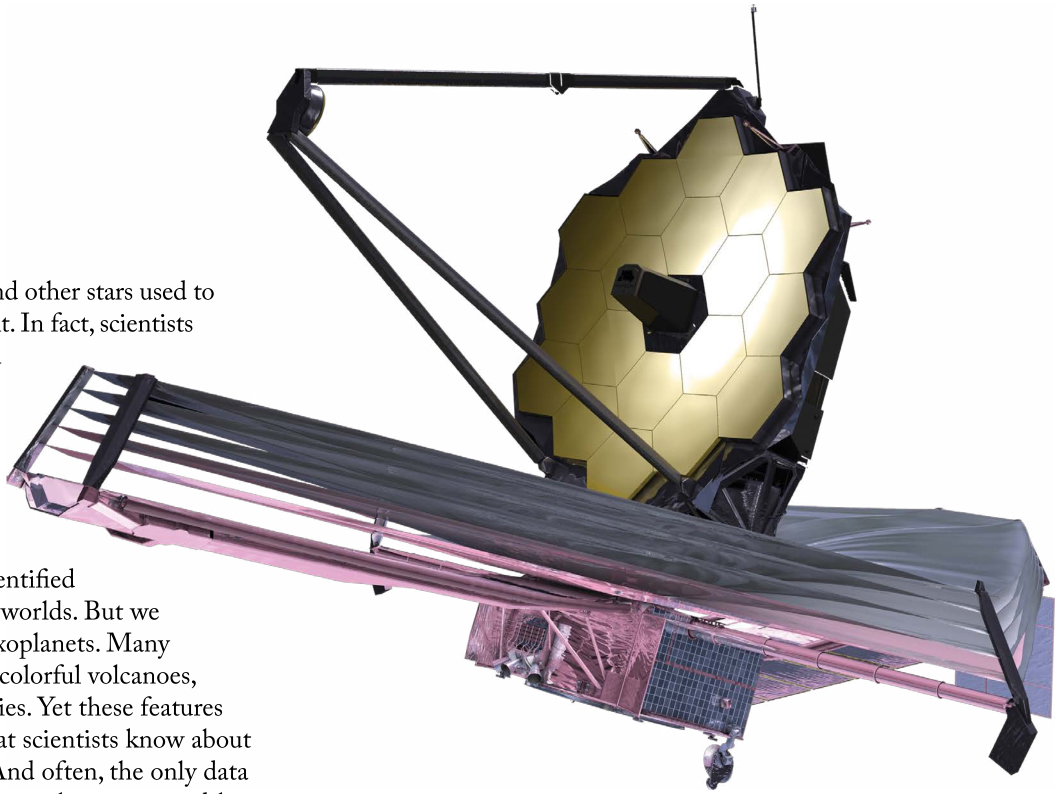
By **Elise Cutts**

PUZZLING PLANETS

The James Webb telescope could help solve these five exoplanet mysteries



Finding planets around other stars used to be extremely difficult. In fact, scientists found the first black hole and countless distant galaxies before spotting any worlds beyond our solar system. Those first exoplanets awaited discovery until 1992.

Now, astronomers have identified well more than 5,000 distant worlds. But we still know little about these exoplanets. Many illustrations show them with colorful volcanoes, oceans and cloud-streaked skies. Yet these features are only guesses based on what scientists know about the worlds they're studying. And often, the only data scientists have on those planets is their mass, width and distance from their star.

NASA's James Webb Space Telescope, or JWST, is now unveiling dazzling new details about these exoplanets. By collecting light from distant solar systems, JWST can pick out some of the specific gases in planets' atmospheres. That includes water vapor, carbon dioxide, methane and other molecules.

Since JWST launched in 2021, it has peered at the atmospheres of hundreds of such worlds. Its targets range from gas giants to rocky orbs about the size of Earth.

"There's a lot of excitement about finding signatures of alien life," says Laura Kreidberg. She's an astronomer at the Max Planck Institute for Astronomy. That's in Heidelberg, Germany. But, she adds, scientists have a lot to learn about planets before they can detect life on other worlds with confidence. JWST could help with that.

Most of what we know about planets today comes from the eight in our solar system. Over the next decade, JWST could collect data on a whole zoo of planets across the galaxy. These could include rocky worlds and gas giants like those in our solar system.

They might also include strange lava worlds or water worlds. Planets like these don't exist in our solar system at all.

This wealth of new data could answer key questions about what exoplanets are made of and how they form. It might also tell us whether our solar system is like many others or an oddball.

Here are five big planetary puzzles that JWST could help solve.

Which rocky exoplanets have atmospheres?

Small, rocky planets — like Earth — are prime targets in the hunt for alien life. But if a rocky planet is going to host life, it needs an atmosphere. And scientists still aren't sure what determines whether a rocky body can hold onto a blanket of gas.

In our solar system, there is a known divide between worlds with and without atmospheres. That divide can be imagined as a line that scientists call the "cosmic shoreline." On one side of the line, there are worlds that get blasted with too much radiation from the sun and do not have strong enough gravity to hold onto an atmosphere. On the other side are worlds that get less solar radiation and have enough gravity for an atmosphere.

But does this type of "cosmic shoreline" exist for planets throughout the galaxy? To find out, scientists need to know which exoplanets have atmospheres and which don't. This question may sound basic. But it's only just now becoming possible to answer, thanks to JWST.

Astronomers recently detected an atmosphere shrouding a rocky exoplanet for the first time. This planet, 55 Cancri e, is a bit bigger than Earth but much smaller than Neptune. That makes it a type of planet called a super-Earth. It orbits a sunlike star some 40 light-years away. JWST data suggest that 55 Cancri e has an atmosphere of carbon monoxide, carbon dioxide or a mix of the two with nitrogen.

The outlook is not as good for finding atmospheres on the other rocky worlds. Specifically, those orbiting small, dim M-dwarf stars. These

Since launching in late 2021, NASA's James Webb Space Telescope (above, illustrated) has observed the atmospheres of hundreds of exoplanets. Scientists hope the telescope will help answer fundamental questions about those exoplanets.

NASA

Data from JWST suggest that 55 Cancri e (above, illustrated), an exoplanet between Earth and Neptune in size, has an atmosphere of carbon monoxide, carbon dioxide or a mix of both with nitrogen. The rocky planet LHS 3844 b (below, illustrated), in contrast, lacks an atmosphere. It could offer new insight into exoplanet geology.

stars tend to spew bursts of atmosphere-stripping radiation more often than do stars like our sun. It's also possible these worlds just have very thin atmospheres, says Elsa Ducrot. This astronomer works at the Paris Observatory in France.

As JWST identifies more rocky planets with and without atmospheres, ideas about the cosmic shoreline can be tested.

What is exoplanet terrain like?

Rocky exoplanets without atmospheres may not be suitable for life. But they will allow astronomers to study something that was impossible to probe directly before JWST. That is, what types of rocks make up the ground on exoplanets.

"I'm really excited about this," Kreidberg says. "Of course, I want to see the atmospheres. But I think there's a lot you can learn from the surface."

Kreidberg and her team plan to use JWST to look for the chemical fingerprints of specific rocks on the rocky, airless super-Earth LHS 3844 b. Learning what the planet's surface is made of would be a powerful clue about the planet's geology.

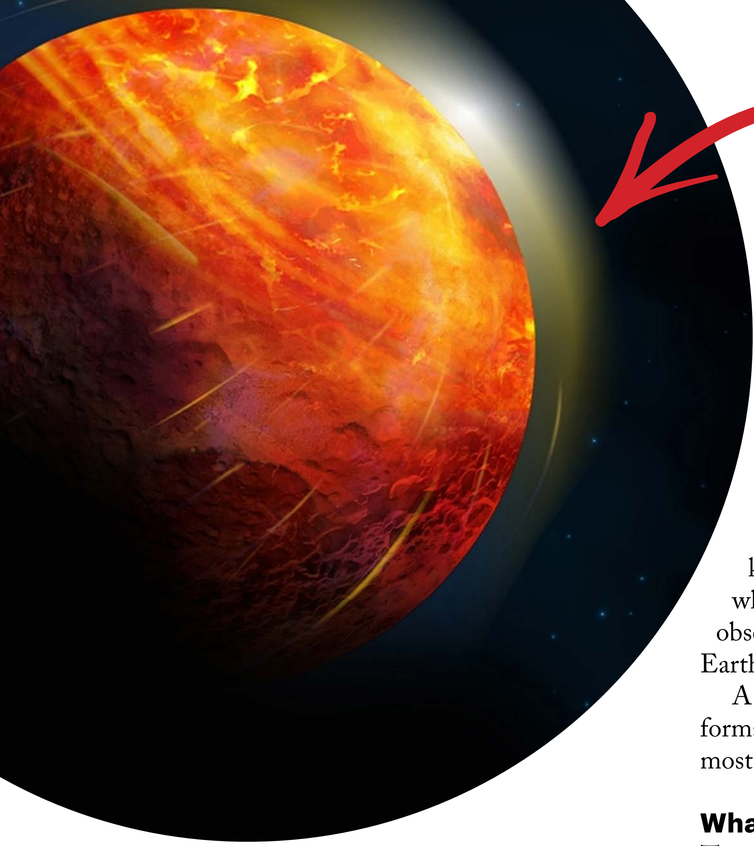
Finding signs of granite would be especially intriguing. Granite is a common rock on Earth. It forms from recycled and remelted rock. On our planet, this process depends on plate tectonics. But beyond Earth, granite appears to be extremely rare — likely because plate tectonics is too. So finding granite-like rock on an exoplanet would be a big deal.

Astronomers are also seeking rocks that are more common in space than granite. For instance, a surface covered in the black rock basalt would hint at the presence of volcanoes. And if an exoplanet were found with rocks more like those in Earth's mantle — such as peridotite — that could point to a recently frozen magma ocean. Or the planet might be home to exotic, super-hot volcanism.

JWST might even reveal the textures of rocks on exoplanet surfaces.

In our solar system, radiation from the sun wears down rocks on worlds without atmospheres. The result is a crumbly material called regolith. Worlds coated in this stuff have ragged, rough surfaces.

NASA, ESA, CSA, RALF CRAWFORD (STSCI); NASA, ESA, CSA, DANI PLAYER (STSCI)



The lava world K2-141 b (illustrated) is a super-Earth that orbits a K-type star, also called an orange dwarf.

"You might be probing really deep — which is something that I think is hard to do even on Earth," says Lisa Đặng. She's an exoplanet scientist at the University of Montreal in Canada. There, she uses JWST to study blazing hot planets.

Thanks to their magma oceans, lava planets are thought to have atmospheres. Even if part of a lava planet's atmosphere gets lost over time, gas released from magma should keep replacing it. Scientists haven't yet detected whiffs of such gases. But Đặng is trying. She's observing the lava world K2-141 b. This super-Earth is about 200 light-years away.

A "lava planet is a special case of planetary formation," Đặng says. "Oftentimes, some of the most extreme cases are the most revealing."

Kreidberg is part of a team that plans to look for regolith on LHS 3844 b. They can do this by measuring how the planet's brightness changes as it orbits its star. (Rough and smooth surfaces appear to reflect different amounts of sunlight coming in at shallow angles.)

A rough surface would suggest that regolith covers LHS 3844 b. If it's smooth, then perhaps volcanic eruptions keep coating the surface with new rock.

What are rocky exoplanets made of?

JWST might even offer a glimpse of the guts of exoplanets. How? By observing an extreme type of rocky world flooded with lava.

Such planets are hotter than Mercury. In fact, they hug their stars so closely that they can complete one orbit in mere hours. This causes the planets to become tidally locked. That means the same side of the planet always faces its sun. As a result, one side of the world freezes in endless night. The other melts into lava.

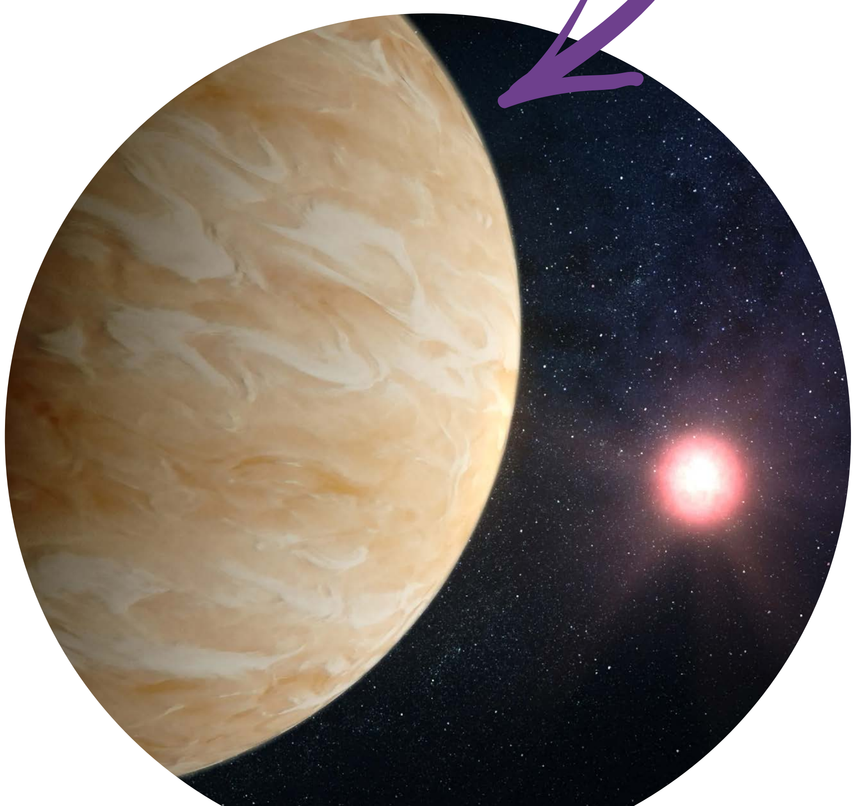
Magma oceans on the daysides of lava planets can show what's inside the planets. Gases escaping the magma might give clues to what makes up the planet's deep interior. And learning what planets are made of can tell astronomers a lot about how these bodies formed. It also can reveal whether their makeups and histories are similar to those of rocky planets in our solar system.

What are sub-Neptunes?

The most common type of planet in our galaxy isn't found in our solar system. It's known as a sub-Neptune. Yet we still know very little about them, other than that their widths are a bit smaller than Neptune's. Are they gas giants? Rocky planets? Something else entirely?

"They seem to be incredibly common," says Joshua Krissansen-Totton. He's an exoplanet scientist at the University of Washington in Seattle. "We also really have no idea what they're made of."

The exoplanet GJ 1214 b (illustrated) is a warm sub-Neptune located about 48 light-years from Earth.



Based on their masses and widths, sub-Neptunes might be mini ice giants. Such planets would be rich in ammonia, methane and water, like Neptune and Uranus. But the same masses and widths could also fit planets with very different structures. Say, rocky cores wrapped in hydrogen and helium gas. Or exotic water worlds made mostly of different forms of H_2O, not necessarily liquid.

JWST observations of sub-Neptune atmospheres could help pick out which idea is right.

If sub-Neptunes do turn out to be gas-wrapped rocks, that could solve another mystery about the variety of planets in our galaxy. Namely: Our galaxy is home to many sub-Neptunes that are just a shade smaller than Neptune. It also has many super-Earths that are just a bit bigger than Earth. But very few planets have a size in between.

Perhaps this is because sub-Neptunes and super-Earths are actually the same type of planet. Scientists may just be spotting them at different points in their lifetimes. Super-Earths could be the leftover rocky cores of sub-Neptunes that have lost their atmospheres over time.

Kreidberg's team wants to look into that possibility. The team is using JWST to study the atmosphere of WASP-47 e. Its width sits smack-dab in between Earth's and Neptune's. JWST could show what the planet is made of and if it's losing its atmosphere.

How do gas planets form?

Despite having four gas giants in our solar system, these puffy worlds are still quite mysterious.

"Essentially, it's three questions," says Ravit Helled. "How do gaseous planets form? How do they evolve? And what are they made of?" Helled is a planetary scientist. She studies gas giants at the University of Zurich in Switzerland.

Scientists want to know whether gas giants form where we find them, or if they tend to wander over time. Planets can wander due to the gravity of other objects tugging at them. Those tugs could come from the disks of gas and dust around young stars (the raw materials for planets). Or wandering gas planets might wreak havoc, knocking other planets out of their orbits, while flinging around comets and asteroids. That chaos can have serious impacts on the stability — and habitability — of smaller worlds.

JWST could provide a vital clue to how much gas giants wander in other solar systems. In general, planets that form farther from their stars have heavier elements in their atmospheres. JWST could observe enough gas-giant atmospheres to reveal where these planets tend to form and end up.

Some of these questions could be settled soon. Since gas giants are so big, they're much easier to study than small, rocky planets. With JWST, astronomers will soon have data on the atmospheres of enough gas giants to test ideas about how they form and evolve.

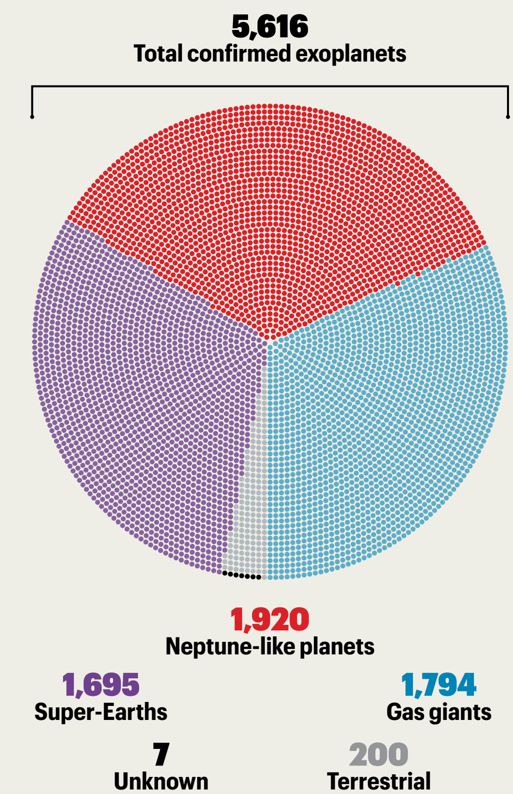
"The key is that we are going to have a large number of planets," Helled says. "Until JWST, it was a handful of objects. But once we have more and the measurements are accurate, we can start to understand trends." To her, "This is the power of JWST."

Some scientists have suggested that super-Earths and sub-Neptunes might be the same type of planet, just at different points in their planetary lives.

IMAGE BY JULIE ROUSSY, MCGILL GRAPHIC DESIGN AND GETTY IMAGES; NASA, ESA, CSA, AND D. PLAYER (STSCI); T. TIBBITTS, SOURCE: NASA

Inventory of exoplanets

Astronomers have discovered more than **5,600 exoplanets**. Most are Neptune-like (including the slightly smaller sub-Neptunes), gas giants or super-Earths (larger than Earth but smaller than Neptune). Far fewer small terrestrial planets like Earth have been found.



Jane Rigby helped make the James Webb telescope a superstar

Curiosity about the universe and a love for scientific instruments drive this astronomer

One of a telescope operator's main jobs is to keep stray light out of the instrument. That unwelcome light can wash out the cosmic glimmers of distant stars and galaxies. During more than a decade of work on NASA's James Webb Space Telescope, Jane Rigby obsessed over minimizing light leaks. And she had extraordinary success.

Rigby herself, now the senior project scientist for JWST, is a source of light.

"I don't know how she does everything that she does, and does everything well," says Keren Sharon. She's an astronomer at the University of Michigan in Ann Arbor. "She gets giddy," Sharon says of Rigby. "It could be about figuring out a [technical] bug, or discovering this super-exciting thing about a galaxy. … Her face lights up."

Rigby got interested in a career in space science around age 12, after she saw Sally Ride speak at a local college. Ride was the first American woman in space.

As a college student, Rigby got her first experience using a telescope for research. She and her colleagues aimed a telescope at the McDonald Observatory in Texas at a distant quasar. The project was plagued by light leaks and ultimately yielded no data. "But it was really fun," Rigby says. "I was learning everything, trying to learn how the telescope worked."

Since then, Rigby has used many telescopes, including ones in Hawaii, in Chile and even in space. Those instruments have helped her investigate how galaxies evolve along with the supermassive black holes hiding within them.

"I will use any telescope I can get my hands on," Rigby says. All that telescope time meant she was ready to join the JWST team when the opportunity came in 2010.

To work on JWST, Rigby took a job at NASA's Goddard Space Flight Center in Greenbelt, Md. Before launch, most of her time was devoted to making sure that changes to the telescope's design wouldn't mess up the science. After the telescope launched in 2021, her job shifted to characterizing how well the telescope works — and JWST is basically a dream come true.

There's better image quality, higher sensitivity, faster response times and a longer potential mission lifetime than predicted before launch. Plus, there's practically no light leaks. "It's not an accident that the telescope works so well," Rigby says, pointing to a huge amount of work by tens of thousands of people.

With the telescope working so well, Rigby could turn her attention to scientific questions. She helps lead an observing program that looks at galaxies whose light has been magnified by foreground objects. That helps astronomers glimpse how the galaxies form stars.

Rigby has also lit a path for queer astronomers and others who are historically underrepresented in astronomy. She has been out as part of the LGBTQ+ community since 2000, and she has devoted much of her career to holding the door open for others. She has helped set up groups and meetings for making astronomy more inclusive. A current priority is making sure trans people feel safe and welcome in the field.

"I didn't grow up with any queer role models," Rigby says. "I hope I'm the last generation for which that's true."

— *Lisa Grossman*

BRITT GRISWOLD AND JAY FRIEDLANDER/NASA; ALL TELESCOPE IMAGES: NASA, ESA, CSA, STSCI, AND VEGA: S. WOLFF, K. SU, A. GÁSPÁR/UNIV. OF ARIZONA; PILLARS: JOSEPH DEPASQUALE, ALYSSA PAGAN/STSCI; NEBULA: TEA TEMIM/PRINCETON UNIV.

Jane Rigby originally wanted to be an astronaut. Now, she explores deep space as the senior project scientist for the James Webb Space Telescope. The telescope's images (from left: glowing dust surrounding the star Vega, the Pillars of Creation and the Crab Nebula) continue to amaze and inspire scientists and the public.

HAZARD ZONE

As Yellowstone's supervolcano slumbers, another big danger lurks underground >>

MOONBANDIT, LANE V. ERICKSON/SHUTTERSTOCK

By **Douglas Fox**

Yellowstone National Park is known for its bubbling hot springs and steaming geysers. These hydrothermal wonders are powered by a massive cauldron of partly melted rock deep underground. It holds enough seething magma to build more than 100 Mount Everests.

Yellowstone's volcano last erupted 70,000 years ago. If it did so again, it could bury a vast area under lava.

Most scientists consider this unlikely, at least for the next several thousand years. But another serious hazard lurks — one more sudden and treacherous than lava. To understand its destructive power, it helps to know what happened a decade ago at Japan's Mount Ontake.

September 27, 2014, was a sunny day with a gentle wind. At 11:52 a.m., more than 100 hikers stood atop the mountain, snacking and taking photos.

Then trouble struck. It came with little warning. Windows in a nearby hut suddenly shook. They were rattled by a powerful shock wave, one too low-pitched for human ears to hear. Then a massive gray cloud billowed up from the mountain's southwestern slope.

It swept over the summit, blinding people in swirling dust. They couldn't see as a million tons of rock and dust, blasted from the mountain, rained down on them. More than 60 people died. Most were killed by falling debris.

But this volcano's sudden explosion was not driven by lava or fire. It was powered by water.

A pool of underground water was heated suddenly, likely by volcanic gases or magma rising up from below. The water boiled to steam almost instantly and expanded to hundreds of times its original volume. This shattered the mountain's slope, shooting rocks into the air.

This kind of steam blast is called a phreatic explosion. It's triggered by a sudden pulse of heat within an active volcano. But similar steam explosions, called hydrothermal explosions, also can erupt far from active volcanoes.

Yellowstone is pockmarked with craters left by these explosions. There have likely been thousands over the past 14,000 years. These include one terrifying blast in 2024; it tossed out rocks and sent tourists fleeing.

In the past century, there've been "only small ones," says Paul Bedrosian. He's a geophysicist with the U.S. Geologic Survey (USGS) in Lakewood, Colo. "But we know [Yellowstone] is capable of creating whoppers," he says — ones much bigger even than Ontake's.

To learn what triggers them, researchers have explored the depths of Yellowstone Lake, on the park's east side. Hundreds of hot-water vents dot the lake's floor. That floor also hosts some of the world's largest hydrothermal-explosion craters. And rising from the lake bottom are hard, brittle domes that might one day explode.

"Hydrothermal explosions are very, very dangerous," says Lisa Morgan. She's a volcanologist with the USGS in Denver, Colo. And another, she says, "could very well happen today."

A marshy disaster

Scientists have studied Yellowstone's hot springs and geysers since the late 1800s. But it wasn't until 1966 that they realized the area had been the site of violent steam explosions.

That summer, Patrick Muffler made his first visit to Pocket Basin, near the western edge of Yellowstone. He was a young scientist with USGS. He traveled with his boss, Donald White, a USGS scientist who studied hot springs and geysers.

Pocket Basin is a broad, bowl-shaped meadow. A rocky ridge surrounds it on three sides. Hydrothermal pools and springs are scattered across the meadow. They scent the air with the sour smell of hydrochloric acid. That acid constantly seeps out of hot water burbling up from below.

As the two scientists explored this area, White recognized something he had seen before. In 1951, a once-peaceful group of hot springs in Lake City, Calif., had exploded. That blast flung 300,000 tons of mud and rock onto nearby fields. The rocks were made of gravel and sand. These had been cemented together with minerals — whitish zeolite and opal.

White knew that these materials form when hot water full of dissolved minerals comes close to the surface. As the rising water cools, the dissolved minerals crystalize into solids, forming these rocks.

Underground water had suddenly flashed into steam, White concluded. Its instant expansion had flung out those rocks.

As White and Muffler walked up the ridge surrounding Pocket Basin in Yellowstone, their boots crunched over similar rocks. This meadow, White realized, was the crater left by a hydrothermal explosion. It spanned an area larger than 40 football fields! And that surrounding ridge? It was made of rocks blasted out by the explosion.

Yellowstone's water under pressure

Water that fuels such explosions starts as snow and rain. That moisture trickles underground through cracks. Eventually, several kilometers (miles) below Yellowstone, it nears the magma chamber.

THE ASAHI SHIMBUN VIA GETTY IMAGES; 2009 UNAVCO EARTHSCOPE FIELD TRIP PARTICIPANTS/USGS

The phreatic steam explosion at Mount Ontake in Japan in 2014 (left) shot a million tons of rock and old volcanic ash into the air. A small hydrothermal explosion occurred in 2009 at Wall Pool in Yellowstone's Biscuit Basin (right). A larger explosion occurred in this same basin on July 23, 2024. Nearby tourists ran away quickly enough to avoid injury.

Here, the water becomes heated to more than 250° Celsius (482° Fahrenheit). That's way hotter than water's normal boiling point, 100 °C (212 °F). This water stays liquid because the immense pressure underground keeps it from expanding into steam.

This superheated water can spurt back up through cracks in the bedrock. Mostly, the rock is strong enough to withstand the hot water's pressure. Near the surface, it feeds Yellowstone's hot springs and geysers.

But sometimes the water's pressure suddenly exceeds the rocks' strength. This can happen when the water quickly gets much hotter, boosting its pressure. That causes a steam explosion, as happened at Mount Ontake.

But something different triggered the explosion at Pocket Basin, White and Muffler believed. The underground water didn't get hotter. Instead, the rocks weakened due to a sudden change at the surface.

Pocket Basin likely exploded at the end of the Ice Age, around 14,000 years ago. A lake would have covered the region back then, held in place by a dam of ice. But at some point the ice melted. This broke the dam, allowing the lake to spill out.

"If you can get rid of that [lake] water instantly," says Muffler, "that depressurizes the system — and bang, it goes off." With less weight above it, the hot water below explodes into steam.

Muffler and White found nine more large hydrothermal-explosion craters scattered across Yellowstone. They published their results in 1971. Several years later, scientists found Mary Bay crater, in the north end of Yellowstone Lake. At 2.6 kilometers (1.6 miles) across, it is the largest known hydrothermal-explosion crater on Earth.

Morgan has studied what may have caused some of these big explosions. What she's found suggests they could happen again — at any time.

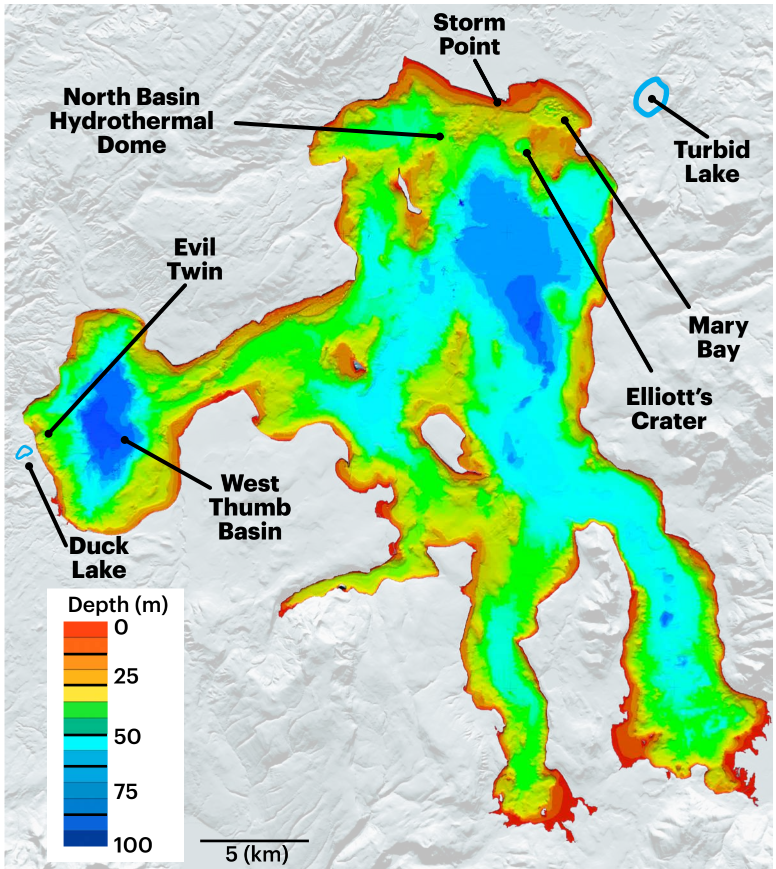
Hidden hot zone

Starting in September 1999, Morgan teamed up with Pat Shanks to explore the northern part of Yellowstone Lake, near Mary Bay. Shanks is a geochemist with USGS.

Workers spent days zigzagging across the lake in a boat. Using sonar, they mapped the lake's bumpy floor. And they used seismic sensing to show the layers of mud and rock underlying the lake bed.

Each evening, Morgan and Shanks watched as new maps of the lake floor printed out. It "was an incredible eye-opener," says Shanks.

This mapping uncovered a huge crater, now called Elliot's crater. It also turned up many smaller explosion craters on the lake floor along with more than 250 hot-water vents. "We found it to be a far more hydrothermally and tectonically active lake than anyone had ever expected," says Morgan.



In this map of Yellowstone Lake, colors indicate the water's depth. Hidden on the lake floor are several huge hydrothermal explosion craters. These include Elliott's Crater, Mary Bay and Evil Twin. Domes — such as the North Basin Hydrothermal Dome — mark spots where explosions could occur in the future.

L.A. MORGAN *ET AL*/USGS, ADAPTED BY B. PRICE

Here and there, rounded domes rise above the lake's floor. These mark where hot water seeps out. Minerals from that water slowly cement sand and mud into a crust. Eventually, hot water can get trapped beneath that crust. That's when a bulge forms.

As this continues, "you're going to have a pressure cooker," says Bedrosian of USGS. These domes could explode one day.

Many are smaller than an umbrella. But the North Basin Hydrothermal Dome is 750 meters (nearly a half mile) across. It currently rises a full seven stories above the lake floor!

Hot water still burbles out through its crust. "But over time that's going to change," says Morgan. "Those open spaces will seal." Once that happens, "it's a perfect candidate for a potential hydrothermal explosion."

In 2016, scientists took a coring platform out onto Yellowstone Lake to collect sediments from the lake bottom and learn more about what triggered past explosions.

Little catastrophes

The history of Yellowstone Lake might help reveal what set off big explosions in the past — and when they happened. So in 2016, Morgan and Shanks led a team of workers who extracted eight cores of sediment from the muddy lake floor.

Interspersed in the dark mud were layers of whitish gravel. That gravel was debris from hydrothermal explosions. Those layers revealed the lake's violent past. Morgan and Shanks found debris layers from Mary Bay, Elliott's crater and up to 14 smaller previously unknown blasts. The most recent happened around 165 years ago.

Mary Bay exploded around 13,000 years ago, the cores showed. Morgan thinks an earthquake triggered this blast indirectly. She and her colleagues found geologic evidence that the quake triggered a massive wave, called a lake tsunami. The wave may have broken through a natural dam of rocks and dirt on the lake's north end. That would have allowed much of the lake's water to drain out.

"The lake dropped suddenly 14 meters [46 feet]," she says. "That's huge!"

As downward pressure on the lake floor decreased, superheated water below would have expanded into steam. The resulting blast created the largest hydrothermal crater on Earth.

Earthquakes and tsunamis can occur without warning, Morgan points out. There's no reason they couldn't trigger a giant explosion at Yellowstone today.

Big, big boom

A Yellowstone explosion today could be far worse than the 2014 blast at Mount Ontake. Morgan estimates that the Mary Bay explosion ejected a quarter of a cubic kilometer (0.06 cubic mile) of sediment and rock out of its crater. That is 100 to 400 times the volume ejected by Mount Ontake in 2014.

The Mary Bay blast tossed refrigerator-sized boulders out of the lake. A wave of boiling mud surged onto the lakeshore. It left a pile that is four to eight stories tall in some places.

This sounds scary. But it's no reason to stay away from Yellowstone. After all, most people don't avoid visiting Los Angeles, Calif., just because they are worried about earthquakes. The chances that a massive quake or hydrothermal explosion will happen on any given day are quite low.

Still, it would be useful to predict when big hydrothermal explosions might occur.

Today, no one knows how. But Lauren Harrison has discovered that the risk might change over time. She's a geologist at Colorado State University in Fort Collins. And she's studied how rain and snowfall levels have affected Yellowstone's hot springs and geysers over thousands of years.

She's looked at how the layers of minerals that form as hot water reaches the surface have changed over time in Yellowstone National Park. Its hydrothermal system cooled down when Yellowstone's climate was wetter than today, with more rain and snow.

"There was enough water from the surface coming in to cool it down," says Harrison. Those cooler waters might have lessened the risk of hydrothermal explosions in some areas.

Her colleague Shaul Hurwitz found that dry spells, in contrast, supercharged Yellowstone's Steamboat Geyser. Hurwitz is a hydrologist with USGS in Moffett Field, Calif. During dry periods over the last 600 years, he found, this geyser sprayed more violently, killing trees and crusting their wood with minerals.

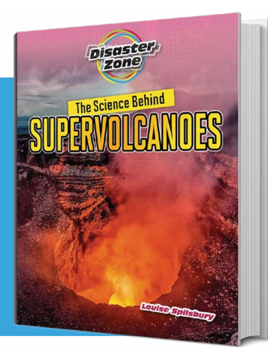
As Earth warms over the next century, Yellowstone is expected to have more severe dry spells. As things get drier, "you tend to have more explosions," says Harrison. But learning exactly how the climate will affect explosion risk will require a lot more study. For now, she says: "It's too soon to know."

READ MORE

The Science Behind Supervolcanoes

By Louise Spilsbury

Steam explosions are just one way volcanoes can have a blast — no lava needed. Check out this book to learn more about magma flows, gas clouds and other features of supervolcanoes, like the one at Yellowstone.



L. MORGAN/USGS; CHERITON CHILDREN'S BOOKS

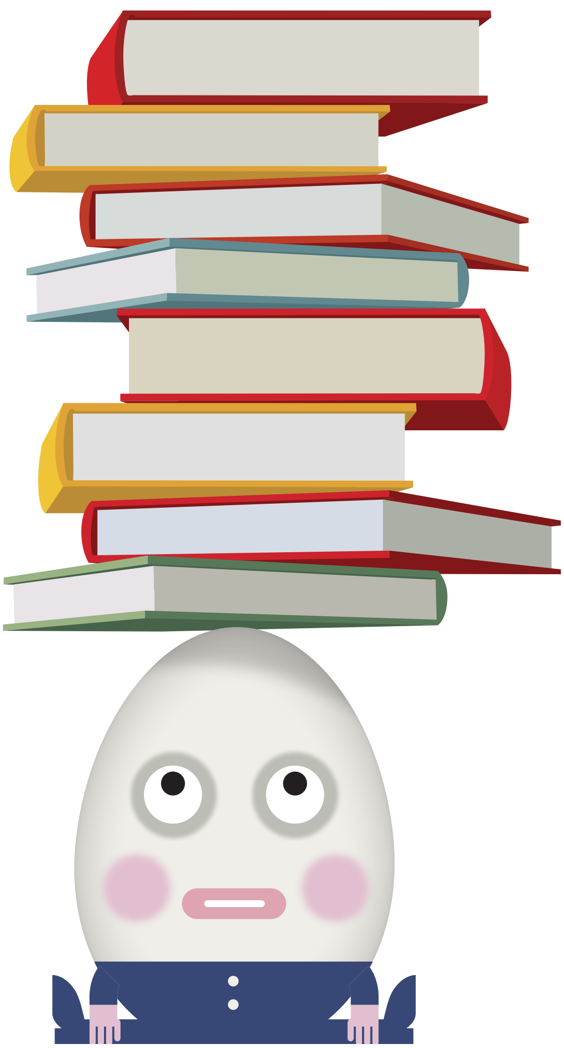
MATERIALS

Eggshell stress test

Let’s test the strength of a natural archway — an eggshell!

By Science Buddies

Archways have been used in architecture for millennia. Think about the arches in ancient Roman aqueducts. Or modern arched windows, doorways and bridges. In this experiment, let’s examine how much weight some natural archways — eggshells — can hold.



Eggshells may seem fragile, but their strength may surprise you.

OBJECTIVE

To measure how much mass eggshells can support

EXPERIMENTAL PROCEDURE

1. Draw a line around one egg that divides the egg halfway between its pointy ends.

2. Make a small hole in the eggshell at one pointy end and drain the contents. Rinse out the eggshell with water.

3. Use a triangular file to score the eggshell along the drawn line.

4. Carefully break or cut the eggshell back to the scored line.

5. Repeat Steps 1–4 until you have three eggshells of the same height.

6. Place the prepared eggshells on a flat surface, open end down, arranged in an equilateral triangle.

7. Lay a book atop the eggshells.

8. Stack magazines atop the book one at a time. Stop when the eggshells break.

9. Measure the combined mass of the book and magazines that the eggshells supported before breaking. Write the result in a notebook.

10. Repeat Steps 1–9 at least twice, so that you’ve done your experiment with at least three sets of eggshells.

11. Calculate the average mass supported, per eggshell, for each set of eggshells.

12. How much mass could each eggshell usually support? Did you see much variation between your three eggshell sets? Do your results surprise you?

Find the full activity, including how to analyze your data, at snexplores.org/eggshells. This activity is brought to you in partnership with Science Buddies.

SCIENCE BUDDIES

ILLUSTRATION BY STEVE MCCRACKEN

These words are hiding in this issue. Can you find them?

The words below came from the stories in this magazine. Find them all in the word search, then search for them throughout the pages. Some words may appear more than once. Can you find them all?

Check your work by following the QR code at the bottom of the page.

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ELECTRIC FIELDS
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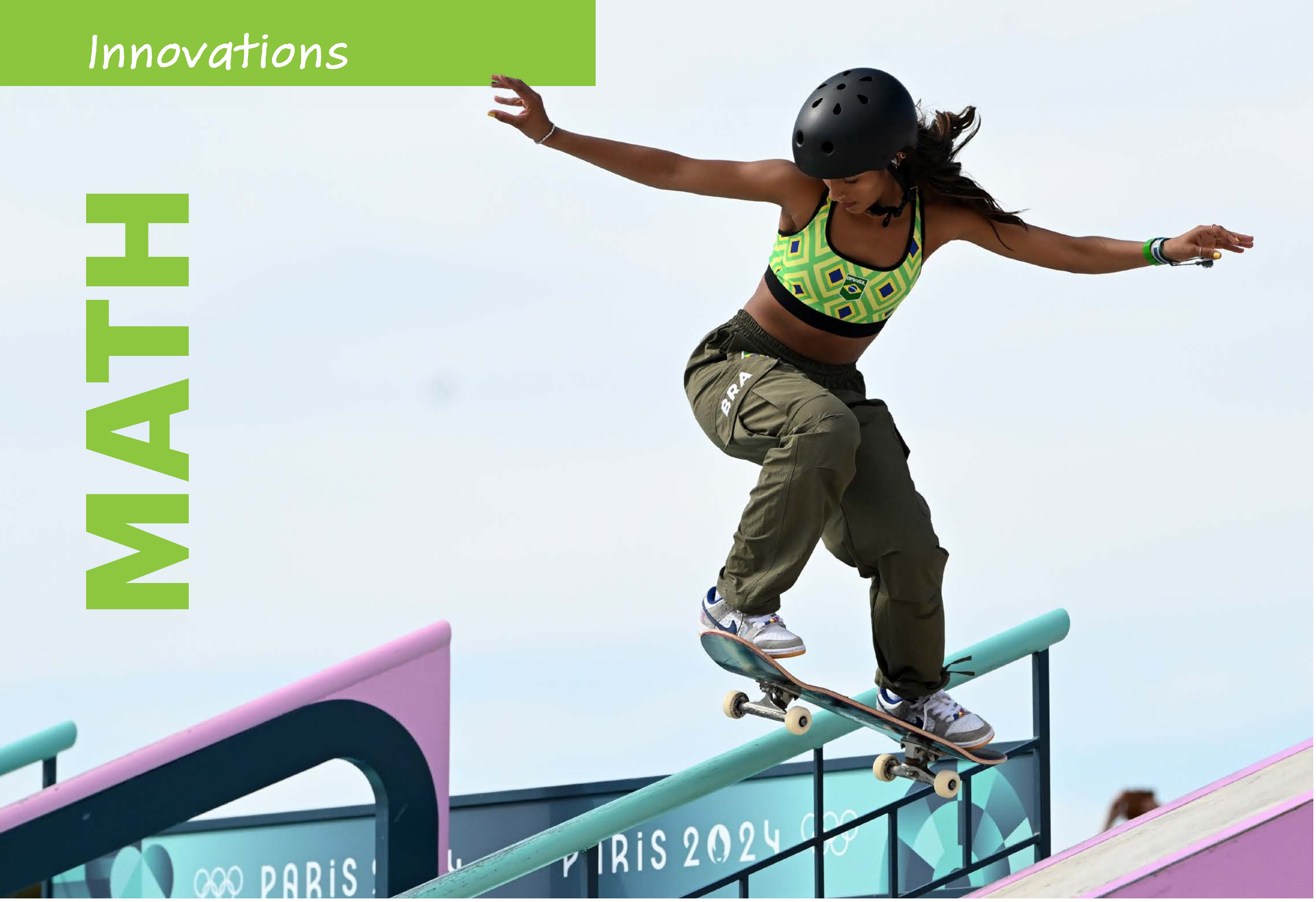
PATPITCHAYA/SHUTTERSTOCK

MATH



Rayssa Leal, 17, won a bronze medal in skateboarding at the 2024 Summer Olympics in Paris, France. She set the record as the youngest Brazilian to compete at an Olympics at the Tokyo 2020 Summer Olympics in Japan.

A. RICARDO/SHUTTERSTOCK

How skateboarders can ramp up their half-pipe skills

Crouching at key spots helps gain speed and height

The latest tips for skateboarders looking to up their half-pipe game might come from an unexpected source: math.

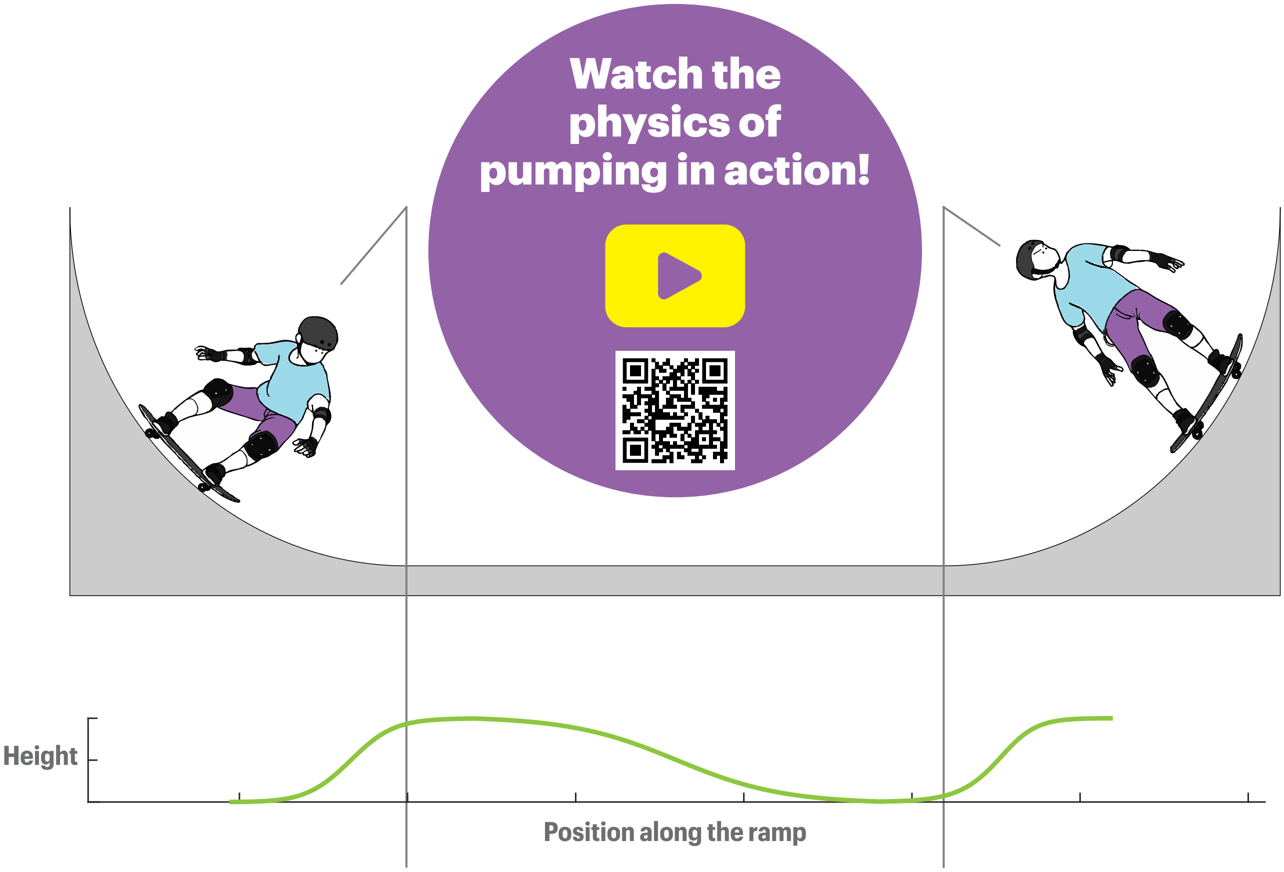
Tricks like kickflips and ollies require speed. As skateboarders roll along a U-shaped ramp called a half-pipe, they build speed and climb higher by pumping. To pump, they alternate between crouching and standing.

Pumping on a half-pipe is a lot like pumping on a swing, says Florian Kogelbauer. A mathematician, he works at ETH Zurich in Switzerland. On a swing, you stretch your legs while leaning backward and bend your knees while leaning forward. This motion changes how your body mass is distributed. Syncing your pumps with the back-and-forth motion of swinging gives you an energy boost that makes you go higher. Pumping on a half-pipe does something similar for skateboarders.

Where should skateboarders change positions to get the biggest boost? Some say it's about practice and feeling the rhythm. Kogelbauer and his colleagues turned to math for an answer.

They used a theoretical study. For this type of study, you first take a real-world problem and translate it into equations, Kogelbauer says. Then you solve the equations and translate the solution back to the real world.

The researchers started with the equations for a simple case: a rider going back and forth on a swing. The forces, motion and energy of swinging are well understood. The team modified those equations to better match the skateboard scenario. They used them to create a mathematical model. How far up the ramp a skater can go depends on how their body position changes along the half-pipe. The model captured that relationship.



To build as much speed as possible, a skateboarder on a half-pipe crouches while going downhill (left) and stands while going uphill (right). This graph shows what a mathematical model says is a skater's ideal height (from crouching to standing) along the ramp.

KOGELBAUER *ET AL*/APS 2024

Then they programmed their simple model into a computer. They included real-world details, such as the sizes of the half-pipe and the skateboarder. Then the computer calculated a skater's ideal body position as they move along the ramp's length.

Skateboarders should crouch as they go downhill and stand just before they hit the flat area, the model suggests. Then they should crouch again until they hit the uphill. Once standing, they should stay standing until they start to roll back downhill.

SIMPLE MODELS OF REAL-WORLD MOTION

The next step was to compare the model's output against how real skateboarders move. The researchers recruited two skaters to tackle a half-pipe. The scientists instructed them to reach a certain ramp height as quickly as possible. Then the team analyzed videos of the skaters' motion to see where they crouched and stood.

The more experienced skater naturally pumped just like the team's model suggested — and hit the goal height faster. The less experienced skateboarder had to pump more times to reach the same height. And their body position didn't match the model very well.

That means the model likely captures the most efficient way to pump, says Kogelbauer. If you want to get better at skating half-pipes, try to crouch and stand how the model shows, he says. The researchers shared their results in *Physical Review Research*.

This research could also benefit robotics. Human bodies can make a huge variety of movements, says Sorina Lupu. An engineer, she studies ways to help robots walk at the California Institute of Technology in Pasadena. Robots' lack of muscles limits their range of motion, she says. That makes it harder to program complex movements, such as walking.

Some groups analyze human motion with high-tech equipment. Then they use artificial intelligence and machine learning to help robots copy that motion. It can pay off, but the model for the robots' motion can get complicated. And if something goes wrong, it can be hard to figure out what happened and why, Lupu says.

But the skateboard study used a simple model to predict how someone should move. It worked even though it didn't include all the complicated forces involved. That approach might work for robotics, too.

"There's a lot of value in the work that they have done," says Lupu. She especially likes that the team checked its model's result against an experienced skateboarder's motion.

The agreement shows that simple models can tell us about real-world motion, says Kogelbauer. And it suggests that such models could help athletes and robots improve their performance.

— *Kendra Redmond*

TECHNOLOGY

Iron Man's suit would be hard to build

But other types of exoskeletons are very real

Inventor Tony Stark has just been alerted to a crime spree sweeping the streets of New York City. In his lab, robotic arms place pieces of armor over his body. He soon emerges in his iconic red-and-gold power suit as Iron Man. Suited up, he can fly toward danger, punch with superhuman strength and blast lasers.

The Iron Man suit is an example of an exoskeleton. It's a wearable device that helps someone move around and accomplish tasks. Engineers aren't likely to re-create Iron Man's armor in real life — both due to tech limitations and because the suit is, in some ways, impractical. But other exoskeletons do exist. They help people stay safe at work and do everyday tasks. Someday, similar wearable robots might even help astronauts walk the moon.

MORE LIKE TITANIUM MAN

In the movies, Iron Man's suit runs on power from the arc reactor attached to his chest. This ring-shaped power source is said to produce 3 gigawatts.

No palm-sized power source like the arc reactor exists. Instead, a real Iron Man suit would probably have to use batteries, says Erik Ballesteros. He's an aerospace engineer at the Massachusetts Institute of Technology in Cambridge.

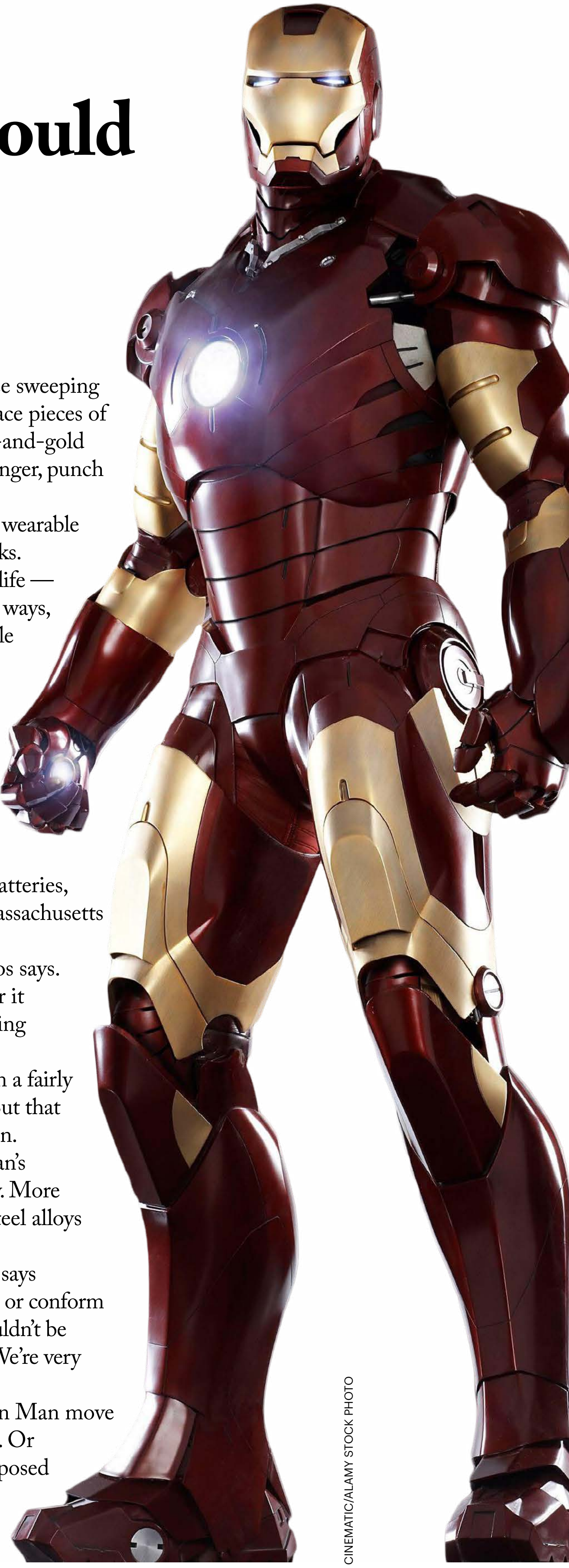
Keeping the suit's battery small would be key, Ballesteros says. "The larger the battery, the heavier the suit," and the slower it would move. Plus, larger batteries are more prone to breaking down and exploding.

Wireless charging tech might allow a Stark suit to run on a fairly small battery that needs to be recharged after each outing. But that would limit how far the armor could fly on any given mission.

Battery life wouldn't be the only thing limiting Iron Man's movement. Such head-to-toe metal casing would be heavy. More lightweight metals than iron, such as titanium, as well as steel alloys could help lighten up the suit.

Still, a superhero "can't have everything be purely metal," says Ballesteros. Unlike clothes, a stiff metal suit wouldn't stretch or conform to movement. That would hinder a hero's agility. Plus, it wouldn't be too comfortable. Humans "are very soft," says Ballesteros. "We're very sensitive. We've got nerves all over our skin."

Armor built with special kinds of metals could help Iron Man move better. These might look like metal fabrics, says Ballesteros. Or shape-memory alloys. These metals change shape when exposed to zaps of electricity. By molding to the shape of a wearer's body, these alloys could move with their joints for increased flexibility.



CINEMATIC/ALAMY STOCK PHOTO

Iron Man's iconic Mark series powersuits (right) are perfect for fighting crime in movies. But a real-life version of this armor could seriously injure anyone looking to use it. Researchers are designing wearable devices (opposite) that may one day improve how astronauts walk on the Moon.

EXOSKELETONS GET REAL

A real-world version of Stark's famous suit may not be possible — or even desirable. But engineers have built other exoskeletons, often to support specific vulnerable body parts, says Steve Collins. At Stanford University in California, Collins designs devices that help people walk.

Most exoskeletons use rigid materials to provide support and stability, says Collins. "Kind of like your bones, but on the outside of your body."

Manufacturing and warehouse workers have begun using simple exoskeletons that attach to the arms, shoulders and waist. These workers spend lots of time with their hands over their heads. "They might have to hold a heavy thing in place while they fasten it," says Collins. "It's really hard on people's shoulders, doing that all day."

An exoskeleton's rigid parts help provide the support needed to lift heavy tools or materials. Meanwhile, the device's moveable joints allow workers to hold positions needed to drill, sand or seal. Many exoskeletons do this without any powered parts, says Collins. They rely on springs or shock-absorbing components called dampers to control movements and offset weight.

Researchers are now working to create wearable devices that help with an even wider variety of jobs. Say, space exploration.

During the Apollo missions, NASA's astronauts struggled to recover from falls. Many used too much force to push themselves upright, says Ballesteros. In the moon's weaker gravity, they pushed themselves off balance.

Ballesteros and his team built a prototype of a wearable robot that might one day help astronauts recover from tumbles. Nicknamed "SuperLimbs," the device will use extra arms to supply the needed force to lift a fallen astronaut up.

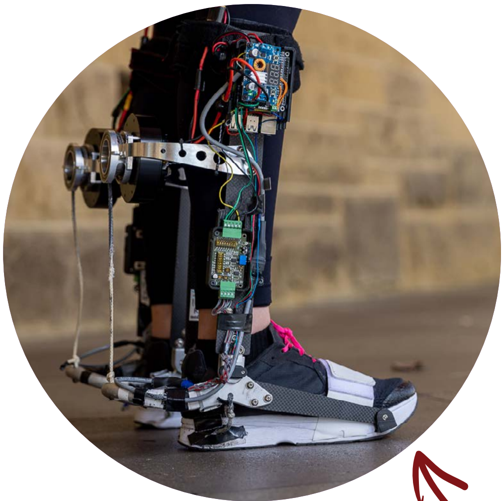
Others are looking at how wearable devices might help people closer to home. That could be older people facing mobility issues or even hikers looking to go further.

Collins' team has designed a "robotic boot" that works with calf muscles to give walkers extra speed. A motor offers a boost right before a person's toes lift off the ground during a step. Compared with normal shoes, the boots helped people walk about 10 percent faster and use 20 percent less energy.

Those who could benefit the most from exoskeletons include people with cerebral palsy or other conditions that make movement difficult, says Collins. Such tech isn't widely available yet. But meeting this need is far more pressing than making a real-life Iron Man suit, says Collins. With an exoskeleton, "you don't have to be going faster than a fighter jet. You can just be walking [at] a normal pace comfortably. And that's a win."

— *Aaron Tremper*

Engineer Erik Ballesteros designed this suit to better understand the challenges astronauts might face while recovering from falls in space.



These "robotic boots" use motors to give walkers an extra boost right before their toes leave the ground.

BOOTS: KALIND CARPENTER, PRESTON ROGERS, MIRZA SAMNANI; SUIT: E. BALLESTEROS, SANG-YOEP LEE

TONY PULSONE

HUMANS

How human ears work

There's far more to them than what you can see

ZDAN IVAN/SHUTTERSTOCK

Most people use their ears to magnify incoming waves of sound and transform them into signals the brain can interpret. The result allows people to hear a cat's purr, a parent talking and their favorite songs.

Sound travels through the air in waves that compress, stretch and then repeat. The compression exerts a push on objects, including ear tissue. As a wave stretches back out, it pulls on the tissue. These aspects of the wave cause vibrations.

Sound waves first hit the outer ear. That's a part often visible on the head, also known as the pinna or auricle. The outer ear's shape helps collect sound and direct it inside the head. The shape of the ear also amplifies the sound, increasing its volume.

From the outer ear, sound waves travel through the ear canal. In people, this tiny tube is about 2.5 centimeters (1 inch) long. Inside the head is the eardrum, or tympanic membrane. This tight membrane stretches across the end of the ear canal. As sound waves slam into this eardrum, they vibrate its membrane. This triggers pressure waves that swell into the middle ear.

Inside the middle ear is a small cavity with three tiny bones: the malleus, incus and stapes. These three bones (ossicles) are the smallest bones in the body. They work together to transmit sound waves to the inner ear.

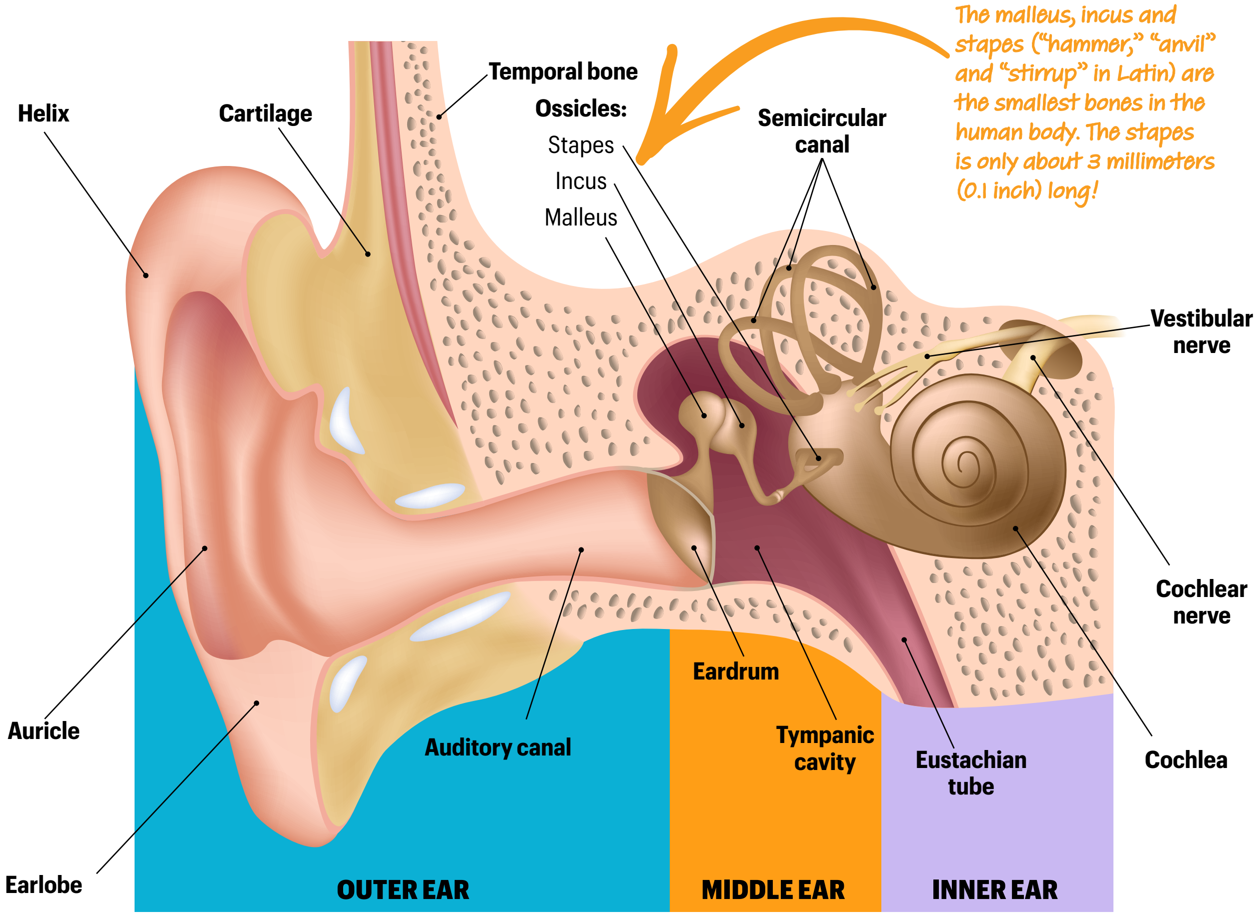
Inside the inner ear is a fluid-filled, snail-shaped structure called the cochlea. It holds ranks of microscopic "hair" cells. They contain bundles of tiny, hairlike strands embedded in a gel-like membrane. When sound vibrations enter the cochlea, they make the membrane — and its hair cells — sway to and fro. Their movements send messages to the brain. The brain interprets those messages as different pitches.

Hair cells are fragile. When one dies, it's gone forever. So over time, as these disappear, people begin to lose the ability to detect certain sounds. Hair cells that respond to high-pitched sounds tend to die off first.

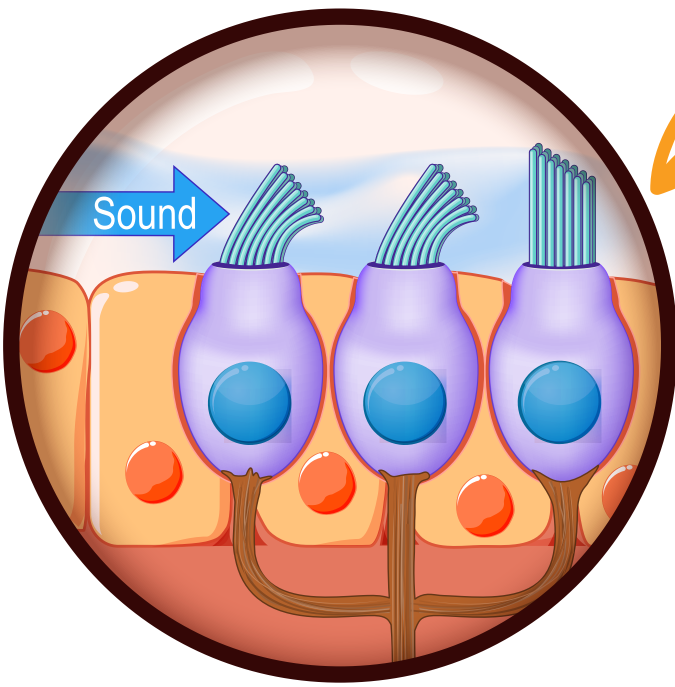
— Bethany Brookshire and Janet Raloff

Ears may look fairly simple on the outside, but they are far more complex on the inside. And that complex system of delicate parts is easily damaged by loud noises. Turn down the volume in your headphones to protect your hearing.

Anatomy of the Ear



The malleus, incus and stapes ("hammer," "anvil" and "stirrup" in Latin) are the smallest bones in the human body. The stapes is only about 3 millimeters (0.1 inch) long!



Tiny bundles of hair cells respond to vibrations. Their movements convey the sound information to the cochlear nerve, which relays it to the brain. The brain processes the sound data.

ALILA MEDICAL MEDIA, DESIGNUA/SHUTTERSTOCK

ECOSYSTEMS

Movies often give wetlands a bad rap

In film, these ecosystems are often linked to danger, death and strange things

In *The Lord of the Rings: The Two Towers*, Frodo Baggins travels through the Dead Marshes on his way to destroy a powerful ring. As Frodo plods along, he stares into pools of murky water. The faces of the dead, killed in a long-past battle, gaze back. Frodo falls in and the ghostly specters reach to claim him.

The Two Towers is hardly an outlier in its negative portrayal of wetlands, a new study finds. Many movies make wetlands into obstacles filled with danger and death. That mirrors how many people in Europe and North America used to think about wetlands.

"Wetlands used to be considered these nasty places that were difficult to control," says Jack Zinnen, a plant ecologist at the University of Illinois Urbana-Champaign. The Dead Marshes is an "excellent example," he says, of how these historic tropes show up on-screen.

Zinnen and his colleagues searched movie plot summaries for terms related to wetlands, finding 163 films from 1980 and later. The researchers watched the films, taking note of themes, imagery, biodiversity and the wetlands' role in the stories. They shared their results in the journal *Wetlands*.

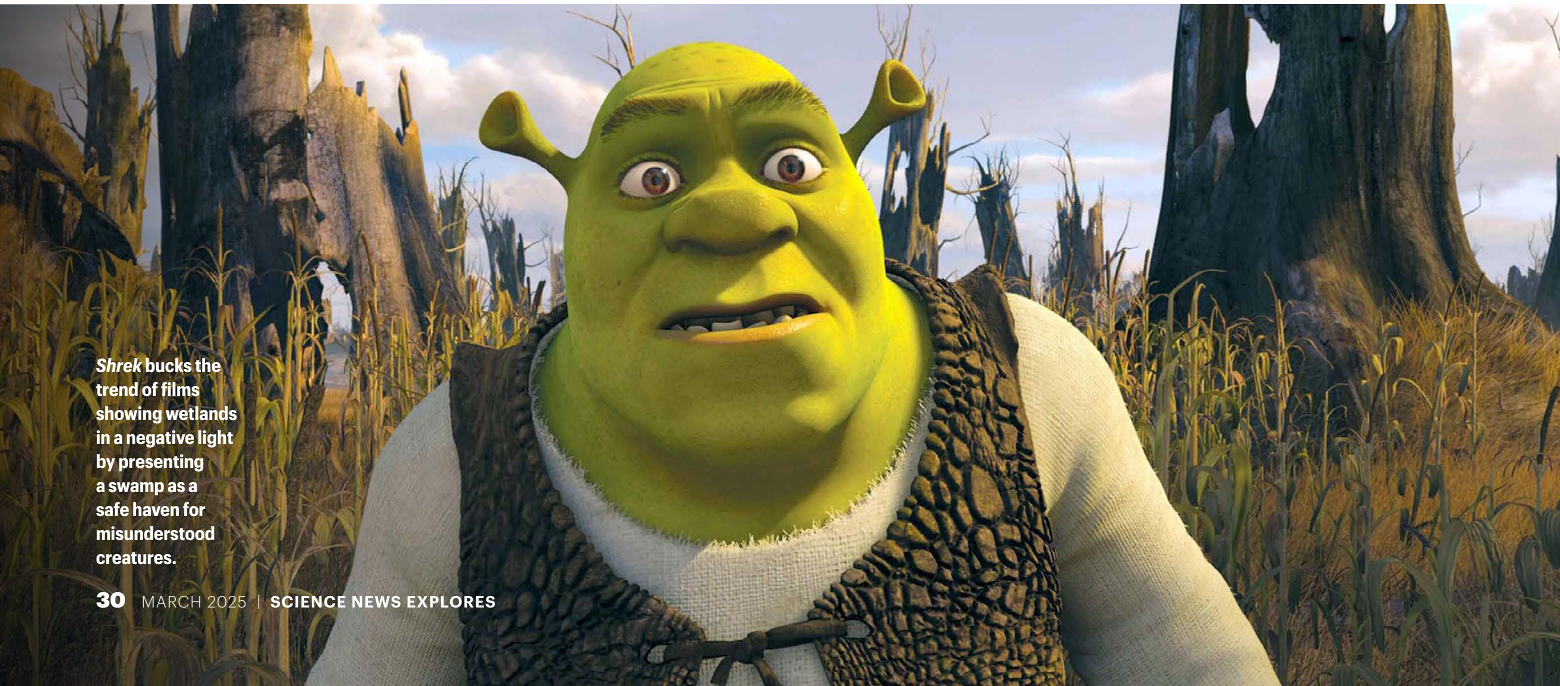
Wetlands tend to present a trial for the film's main character. "They are something that is literally pulling them down and trying to kill them," Zinnen says. For example, in *The NeverEnding Story*, the Swamps of Sadness swallow anyone who succumbs to despair.

These ecosystems also tend to be associated with strange things or people. In the *Star Wars* film *The Empire Strikes Back*, Luke Skywalker crash lands in a bog on the planet Dagobah. There, he meets odd little creatures and the mysterious, exiled Yoda.

Most films portrayed wetlands negatively, Zinnen's team found. At the same time, many films highlighted the biodiversity of wetlands. Movies often showed animals and vegetation and depicted how these places provided resources such as food to characters.

But not all movies dunk on wetlands. In *Shrek*, the movie's namesake ogre lives in a swamp. "*Shrek* leans into a lot of these stereotypes and tropes about wetlands," Zinnen says. But over time, viewers see how the swamp provides refuge from a society that doesn't accept Shrek. And (spoiler alert!), eventually the swamp becomes a home and haven for Fiona and Donkey too.

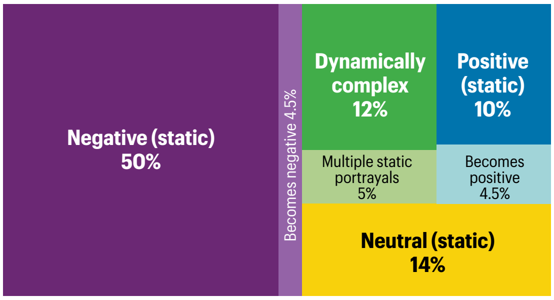
— *Carolyn Wilke*



Shrek **bucks the trend of films showing wetlands in a negative light by presenting a swamp as a safe haven for misunderstood creatures.**

WETLANDS ON THE BIG SCREEN

Researchers analyzed how films since 1980 depicted wetlands. Some presented a static view, meaning that the portrayal didn't change during the film. Others showed wetlands in a shifting, or dynamic, portrayal. Still others' depiction changed predominantly toward negative or positive during the film's story.



This treemap shows attitudes of wetland portrayals in 163 films. Treemaps are similar to pie charts but in the shape of a rectangle. Here, similar colors group similar data. For example, films that depicted wetlands in a negative light throughout the movie are shown in dark purple. Those in which the depiction became negative over time are shown in light purple.

SWAMP SCENES

Researchers cataloged the themes related to wetlands and their frequency in films. The themes fell into five categories. The first, extremes of the human experience, includes many intense situations, from adventure to war. The group of strange or supernatural themes includes boundary state, in which wetlands brought together two very different aspects, such as life and death. Some themes focused on relationships between people. Another set grouped themes about self-reflection and looking inward. This category also included aspects of the hero's journey, a common story format in which a character goes on a quest and is transformed by their experiences. Lastly, some themes related to society. This table shows the number and percentage of films, out of the 163 movies analyzed, in which themes occur.

SUBHEADING	THEME	FREQ. (%)
Extremes of the human experience	Adventure	16 (10%)
	Comedy/levity	6 (4%)
	Death	**93 (57%)**
	Survival/rebuilding a new life	24 (15%)
	Trauma	24 (15%)
	Violence/cruelty	26 (16%)
	War	14 (9%)
The strange or supernatural	Boundary state	22 (13%)
	Supernatural/magic (black magic/dark creatures)	**34 (21%)**
	Supernatural/magic (positive/allied magic)	19 (12%)
Interpersonal relationships	Camaraderie/friendship/community	28 (17%)
	Familial relationships/bonds	14 (9%)
	Justice/revenge	**34 (21%)**
	Mercy	4 (2%)
	Romantic love	23 (14%)
Introspection or hero's journey	Destiny	7 (4%)
	Identity	13 (8%)
	Obsession	5 (3%)
	Rebirth/coming-of-age/heroic self-actualization	**42 (26%)**
	Revelation/memory/storytelling/truth/knowledge	14 (9%)
	Temptation	6 (4%)
Societal relationships/social commentary	Class/social status	23 (14%)
	Corruption/damnation/lost paradise	11 (7%)
	Environmentalism	16 (10%)
	Freedom	10 (6%)
	Future of society	3 (2%)
	Modernity/development	7 (4%)
	Ostracism/outcasts	**43 (26%)**
	Racism	7 (4%)
	Refuge from hostile/separate society	**54 (33%)**

SOURCE: J. ZINNEN *ET AL/WETLANDS* 2024

DATA DIVE

1. Look at the figure above. What percentage of films show wetlands as negative?

2. How does that compare with the percentage of films that show wetlands as positive?

3. Look at the table. What are some of the most common themes in wetland scenes?

4. What are some of the least common themes in wetland scenes?

5. What are some examples you have seen of wetlands in other types of media, such as TV shows, books or games? How are they portrayed?

6. What other environments' portrayals might you want to study? Can you think of stereotypes about them?

CINEMATIC/ALAMY STOCK PHOTO

ANSWER

Lightning storms burst with gamma radiation

A NASA plane spotted a new type of light blast in 2023

A thunderstorm, viewed from an airplane soaring above the clouds, gives off gamma rays. That gamma-ray glow is purple in this illustration but invisible to the human eye.

Above the clouds, thunderstorms give off a type of invisible, high-energy light known as gamma rays.

Storms are known to produce gamma rays when electrons get accelerated in strong electric fields that build up inside clouds. When those electrons smash into air molecules, they throw off gamma rays.

There are two main types of storm-made gamma rays. Terrestrial gamma-ray flashes are short, intense blasts. Each one lasts less than a thousandth of a second. Gamma-ray glows are dimmer but last longer. But scientists still wonder: What makes a cloud emit a terrestrial gamma-ray flash versus a gamma-ray glow? And how are these different types of gamma-ray outbursts related?

Discovering a middle ground between those two extremes could help answer those questions. New data have unveiled a never-before-seen type of blast. It's called a flickering gamma-ray flash. Researchers described these findings in *Nature.*

Many of the flickering gamma-ray flashes were followed by lightning. The flickering gamma-ray flashes may help kickstart those bolts.

NASA's ER-2 aircraft captured new views of this radiation shimmering above thunderstorms. The plane soared over storms in the Caribbean and Central America in July 2023. It cruised at an altitude of about 20 kilometers (12.4 miles). Up there, the aircraft had a front-row seat to storm clouds' gamma-ray fireworks. The results have scientists feeling electrified.
— *Emily Conover*

INSIDE THE MIND OF A YOUNG SCIENTIST

A Thermo Fisher Scientific Junior Innovators Challenge winner answers three questions about her science

Science competitions can be fun and rewarding. But what goes on in the mind of one of these young scientists? **Mackensey McNeal Wilson**, winner of the Second Place Science Award at the 2024 Thermo Fisher Scientific Junior Innovators Challenge, shares her experience.

Q What was your favorite part of your project?

A When one of her dogs got a rash seemingly linked to her pet food, Mackensey got curious. She homed in on a preservative called BHT and tested for its presence in dog food brands her friends and family give to their pets. She used a technique called high-performance liquid chromatography to measure how much BHT was in each food.

"It was really cool using all the instruments and learning how they worked," Mackensey says. "The other very fun part was explaining the research to the people that I got the dog food brands from."

Q What was it like going to your first science fair?

A "It was very nerve-wracking," Mackensey says. "I had never done anything like that before." All in all, she enjoyed the fair experience. "Meeting so many people with different ideas. … You can really learn more about science just from being in a science fair, not even winning anything, but just going there and experiencing it."

Q What was the most challenging part of the project?

A "[H]aving to come in on weekends [and] having to wake up so early," Mackensey says. She had to balance her science fair project with schoolwork and extracurricular activities. "I had nationals for field hockey during one of the weekends. So I had to go in right before leaving for Pennsylvania [so I could] practice my whole science presentation."

Thermo Fisher JIC Science Award, Second Place

Mackensey "Macky" McNeal Wilson

Mackensey, 15, found preservatives in dog food that irritated her furry friend's skin. Several brands contained about 0.1 percent BHT, but none listed it on their nutrition labels. Mackensey is in the ninth grade at Greenwich High School in Connecticut.

EXPLORE
OUR SOCIAL MEDIA

What are three reasons lightning bugs glow?
Why are giraffe tongues blue?
Why do we knead bread?