Science News Explores

December 2024/January 2025

ALIENS AMONG US

HOW VOLCANOES ERUPT

P28

WANT TO SPOT A DEEPFAKE? FOCUS ON THE EYES


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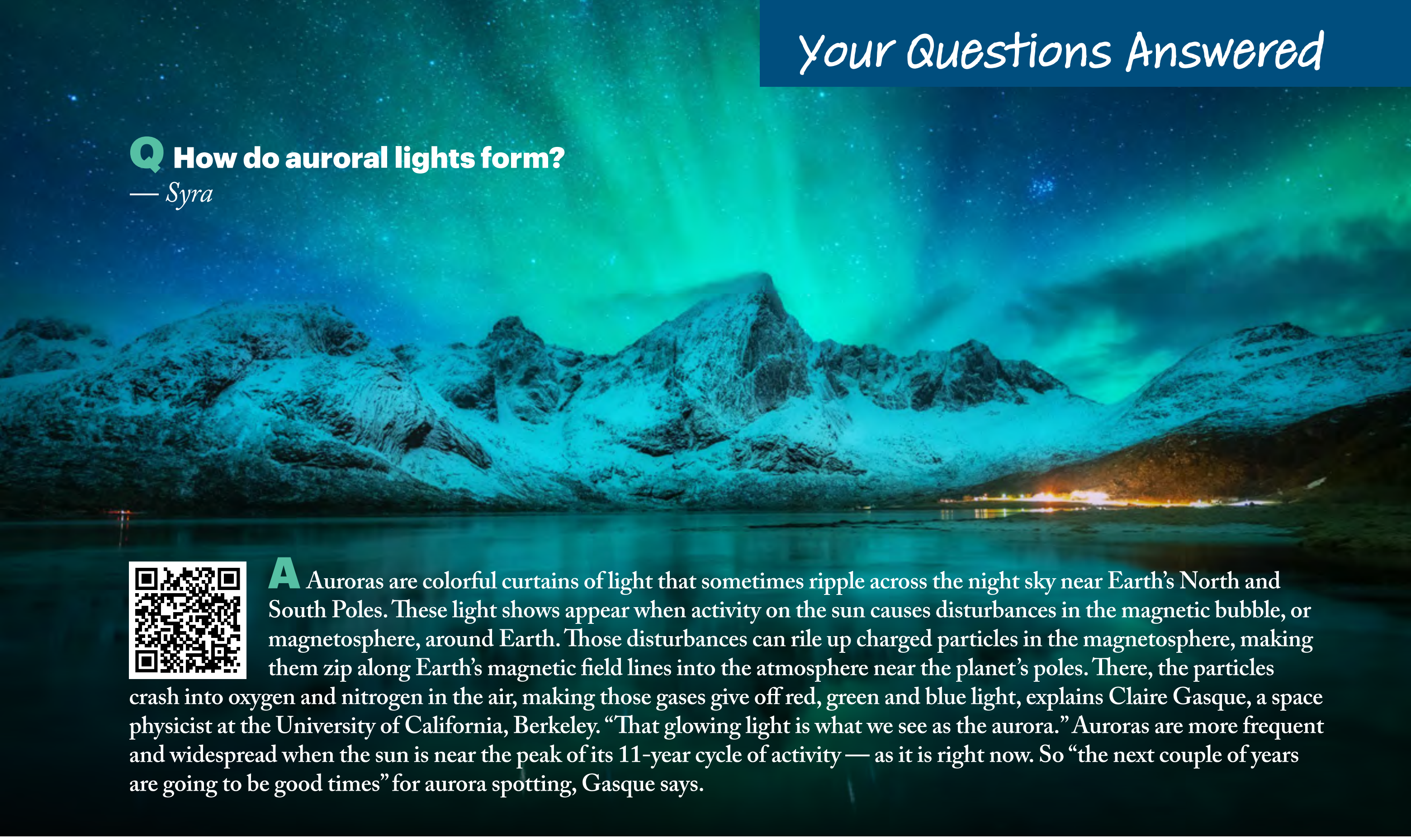

Q How do auroral lights form?

— *Syra*

A Auroras are colorful curtains of light that sometimes ripple across the night sky near Earth's North and South Poles. These light shows appear when activity on the sun causes disturbances in the magnetic bubble, or magnetosphere, around Earth. Those disturbances can rile up charged particles in the magnetosphere, making them zip along Earth's magnetic field lines into the atmosphere near the planet's poles. There, the particles crash into oxygen and nitrogen in the air, making those gases give off red, green and blue light, explains Claire Gasque, a space physicist at the University of California, Berkeley. "That glowing light is what we see as the aurora." Auroras are more frequent and widespread when the sun is near the peak of its 11-year cycle of activity — as it is right now. So "the next couple of years are going to be good times" for aurora spotting, Gasque says.

Q Why do babies drool?

— *Charen M.*

A "It is very normal and expected for infants to drool," says Laura Barrett. At George Washington University in Washington, D.C., Barrett helps children who have difficulty communicating with others. Drooling usually starts when an infant's teeth begin to emerge through the gumline. Known as teething, this often happens at around age 3 to 6 months. When babies teethe, they chew on objects as a way to explore their environment and to build motor skills. This chewing action causes the brain to prompt the salivary glands to produce more saliva. Because infants can't fully control their mouths and lack a full set of teeth, much of this drool spills out. Drooling often lasts until the second set of molars are coming in, at around 2 years old. Still, each child develops at their own pace, notes Barrett, with some continuing to drool until age 6.

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Sarah Zielinski
Editor, *Science News Explores*

DENIS BELITSKY/SHUTTERSTOCK

PHYSICS

How paper makes its painful cuts

Thickness and slicing angle determine whether paper buckles or cuts

Tiny as they are, paper cuts can cause real pain. It's common to get a minor cut while flipping through a magazine or book. But tissue paper is not likely to draw blood. Now, scientists have explained the physics behind why some paper is more likely to slice through skin.

Physicist Kaare Jensen was part of the team that studied this. He works at the Technical University of Denmark in Kongens Lyngby. His group set up experiments using a gelatin replica of human tissue. A paper thickness of around 65 micrometers (not quite 3 thousandths of an inch) was the sweet spot for paper cuts, the researchers found. (Or you might call it the sore spot!) Their findings were posted in *Physical Review E*.

A thin sheet of paper wouldn't cut; it would bend instead. Thicker paper made a dent in the gelatin but couldn't break its surface. Like a dull knife blade, it couldn't apply enough force over a small enough area of the material to pierce it.

The most treacherous paper tested was the kind used in old-fashioned dot matrix printers. Good news for fingers everywhere: That paper isn't used much anymore. Magazine paper ranked a close second in the scientists' tests. (Sorry to anyone whom this magazine has harmed.)

The slicing angle also mattered. Pressing the paper's edge straight down into the gelatin was less likely to cause a cut than if the paper's path angled across and down.

The researchers also put paper's slicing powers to use. They designed a 3-D printed tool they call the Papermachete. Loaded with a strip of printer paper, the tool becomes a single-use knife. The paper blade can cut into cucumber, pepper and apple. It can even cut chicken. The tool could be a low-cost option for prepping some foods.

Next, the researchers plan to study more realistic, finger-shaped materials, rather than flat sheets of gelatin, says Jensen.

No human fingers were harmed in the making of the study. "Ideally, you would want some test subjects," Jensen says. "But it's hard to find volunteers."

— *Emily Conover*

CHEMISTRY

The periodic table might soon have a new element

The periodic table currently lists 118 chemical elements. Each has a different number of protons in its atomic nucleus. They range from one proton (hydrogen) to 118 (oganesson). Some of these elements have been found in nature. Others have been made in labs.

A new study lays the groundwork to create an element with 120 protons. If produced, this element 120 would occupy a new row of the periodic table.

The plan to make that element involves a beam of electrically charged titanium atoms, or ions. Scientists would slam this beam into a target of californium atoms.

In theory, that smashup between titanium (element 22) and californium (element 98) should forge element 120. (It's simple math: 22 + 98 = 120.) But scientists have not used a titanium beam to create such a heavy element before.

So scientists did a test run with plutonium (element 94) to create livermorium (element 116) — and it worked as planned. Jacklyn Gates shared their success at the Nuclear Structure 2024 meeting in Lemont, Ill. Gates is a nuclear scientist at Lawrence Berkeley National Laboratory in California.

"If you want to push above what we currently know on the periodic table," Gates says, "you need to find a new way of making heavy elements."

— *Emily Conover*

VIKTORIA_M/SHUTTERSTOCK

TECHNOLOGY

Want to spot a deepfake? Focus on the eyes

Reflections in the eyes of AI-generated images don't always match up

Deepfakes are phony pictures created by artificial intelligence, or AI. They're getting harder and harder to tell apart from real photos. But a new study suggests that eye reflections may offer one way to spot deepfakes. The approach relies on a technique used by astronomers to study galaxies.

Researchers presented the work at the Royal Astronomical Society's National Astronomy Meeting in Hull, England.

In real images, light reflections in the eyes match up. For instance, both eyes will reflect the same number of windows or ceiling lights. But eye reflections in AI-made pictures often don't match.

Put simply: "The physics is actually incorrect," says Kevin Pimbblet. He's an astronomer at the University of Hull. He worked on the new research with Adejumoke Owolabi while she was a graduate student there. The team's deepfake-spotting technique relied on something called the "Gini coefficient."

Astronomers use Gini coefficients to describe how light is spread across some image of a galaxy. If one pixel has all the light, the value is 1. If the light is spread evenly across pixels, the index is 0. This measure helps astronomers sort galaxies by shape, such as spiral or elliptical.

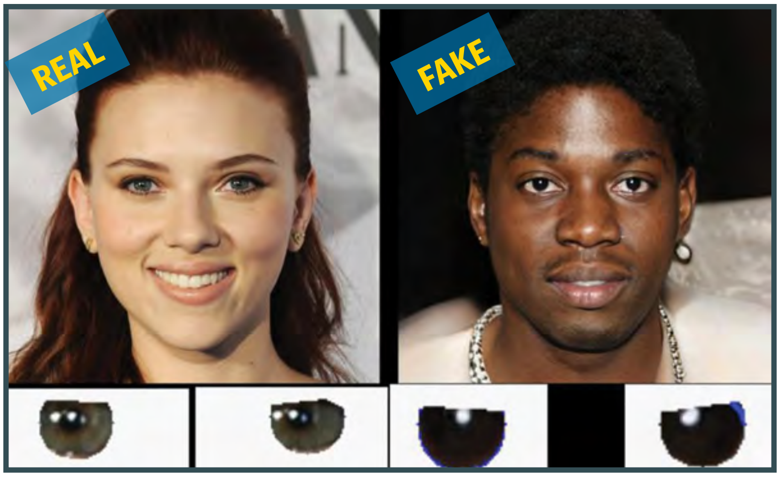
Pimbblet and Owolabi applied this idea to photos. First, they used a computer program to detect eye reflections in pictures of people. Then, they looked at pixel values in those reflections. The pixel value represents the intensity of light at a given pixel. Those values could then be used to calculate the Gini index for the reflection in each eye.

The difference between the Gini coefficient of the left and right eye can hint at whether an image is real, they found. For about seven in every 10 of the fake images examined, this difference was much greater than the difference for real images. In real images, there tended to be almost no difference between the Gini index of each eye's reflection.

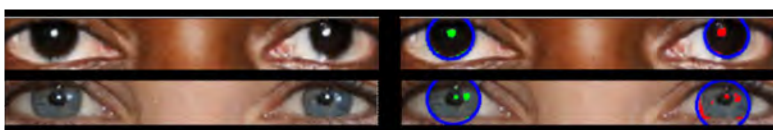
"We can't say that a particular [difference in Gini index] corresponds to fakery," Pimbblet says. "But we can say it's [a red flag] of there being an issue." In that case, he says, "perhaps a human being should have a closer look."

This technique could also work on videos, in theory. But it is no silver bullet for spotting fakes.

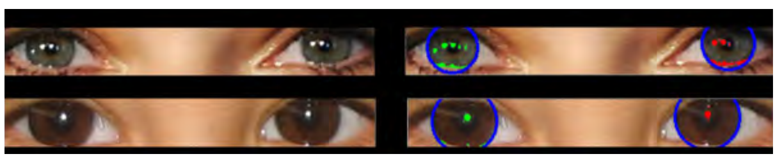
— *Ananya*



Reflections don't match = FAKE



Reflections match = REAL



A. OWOLABI

Reflections in the eyes of the images above reveal that the one on the left is a real photo (of the actress Scarlett Johansson) and the one on the right is an AI-generated deepfake. By comparing the reflections (left), it's easier for a computer program to tell which pairs of eyes are deepfakes and which are real.

EARTH

This Hawaii volcano erupted like a stomp rocket

It's a never-before-seen type of volcanic eruption

A strange eruption exploded debris high into the sky from Hawaii's Kilauea volcano in 2018. It wasn't one big ka-pow! Kilauea had already been erupting lava. Then a series of 12 strange blasts hit over more than a week. These blasts shot gas, ash and rock eight kilometers (five miles) into the air.

Those blasts were a lot like the action of a stomp rocket, scientists now say. That's a toy propelled from a launch pad as somebody stomps on a pocket of air, suddenly compressing it.

That's different from most volcanic explosions, notes Joshua Crozier. A geophysicist at Stanford University in California, he led the new study.

Most eruptions use one of two well-known processes. One is a sudden release of pressure as hot magma moves up pipe-like channels from underground. The magma contains bubbles of gas. As they expand, molten rock will blast out the top of the crater. The other happens when a rising plume of magma flash-heats water in some of the volcano's rocks. The water expands and shoots steam and rock skyward.

Neither one seems to explain what happened at Kilauea in 2018.

Kilauea has more scientific instruments than almost any other volcano. These tools pick up sound and seismic waves and ground movements. They collected data as the volcano blew its top again and again between May 17 and May 26, 2018.

Those data now suggest the strange sequence of explosions were due to something scientists had never seen before.

For one thing, the erupted material didn't contain bubbly bits of magma, as you'd expect from the first process. And rocks in the caldera were already far too hot to contain much liquid water. That eliminates the second scenario.

Instead, it seems large chunks of the crater's rock fell down into the chamber of magma below. Each drop suddenly compressed air in the magma chamber. Like stepping on the air bladder of a stomp rocket, this could have sent debris shooting skyward. A series of rock drops likely triggered burst after burst, Crozier's team wrote in *Nature Geoscience*.

Stomp-rocket-style eruptions probably happen elsewhere too, Crozier says. Their close eye on Kilauea just made it easier to spot the new phenomenon.

— *Carolyn Gramling*

Unusual explosive eruptions rocked Hawaii's Kilauea volcano repeatedly in May 2018 (including this one, on May 27). A newly described type of eruption now appears to explain the volcano's never-before-seen activity.

HAWAIIAN VOLCANO OBSERVATORY, USGS

Think you know what you're seeing? Find out on page

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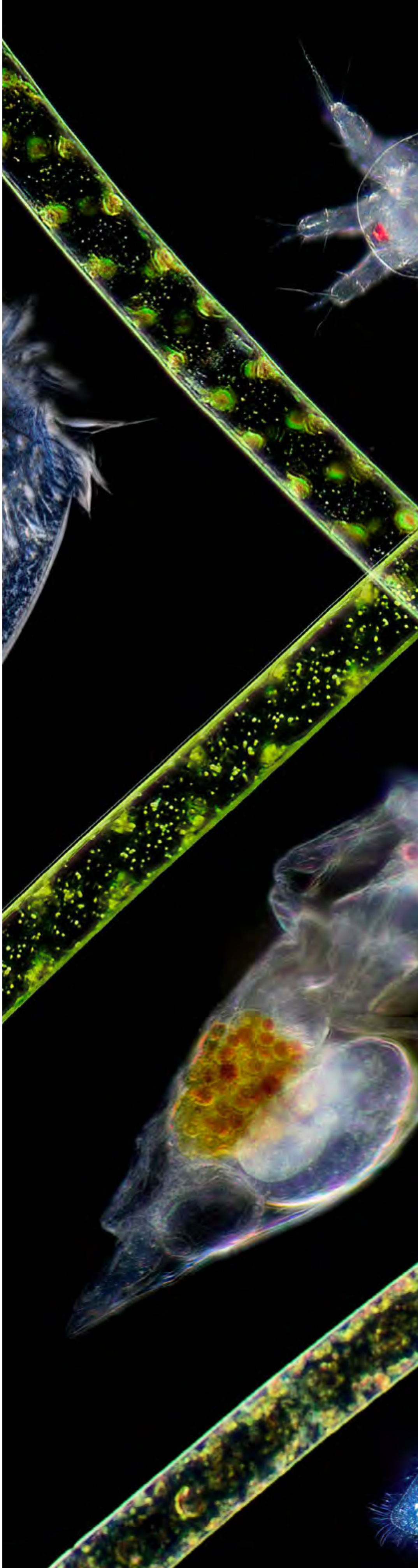
ALIENS AMONG US

The weird world of protists can teach us a lot about life on Earth

By Susan Milius



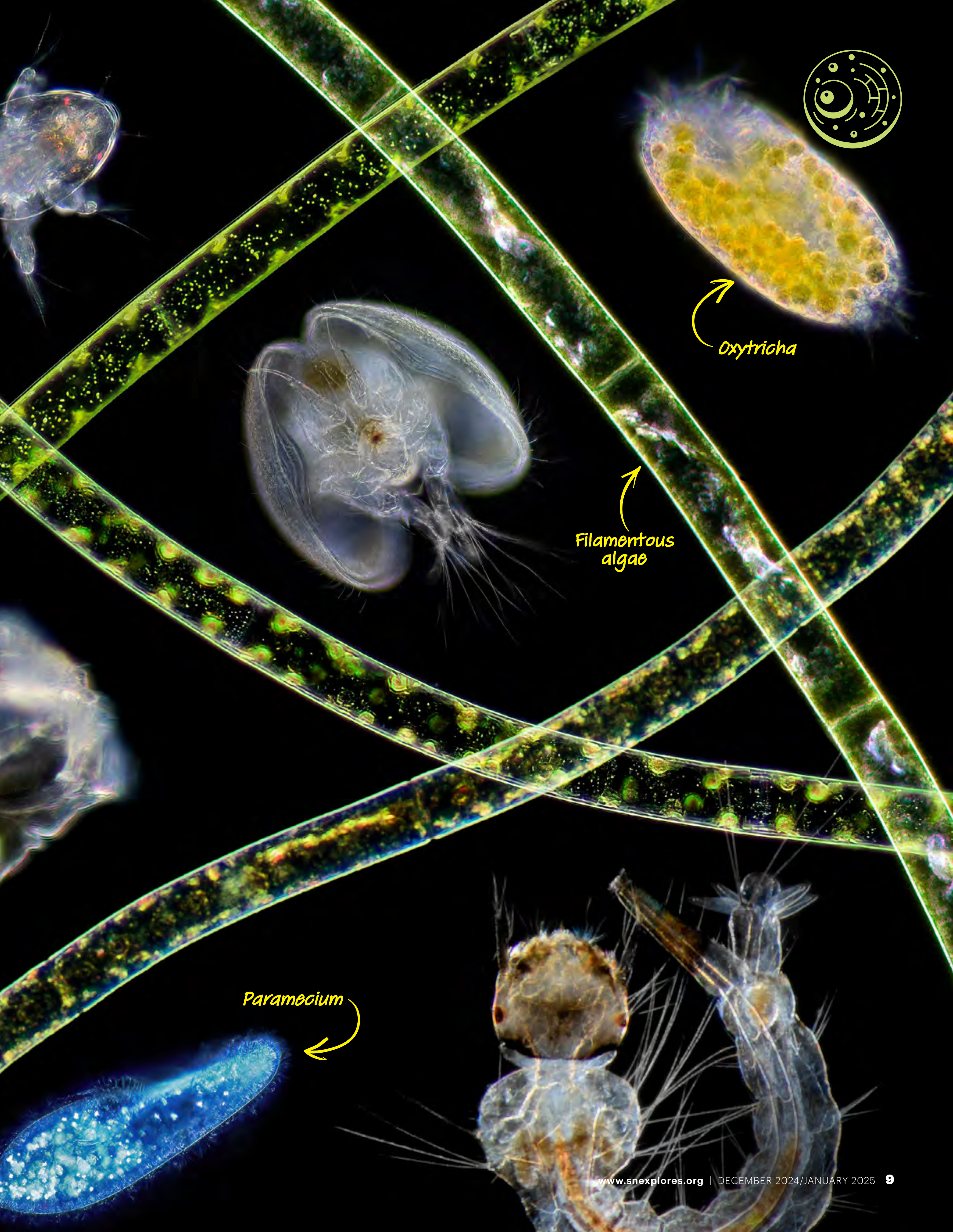
Protists can be found all around us. In this sample of pond life, protists (*Paramecium*, *Oxytricha* and filamentous algae) are found with multi-celled creatures such as an ostracod crustacean (center).

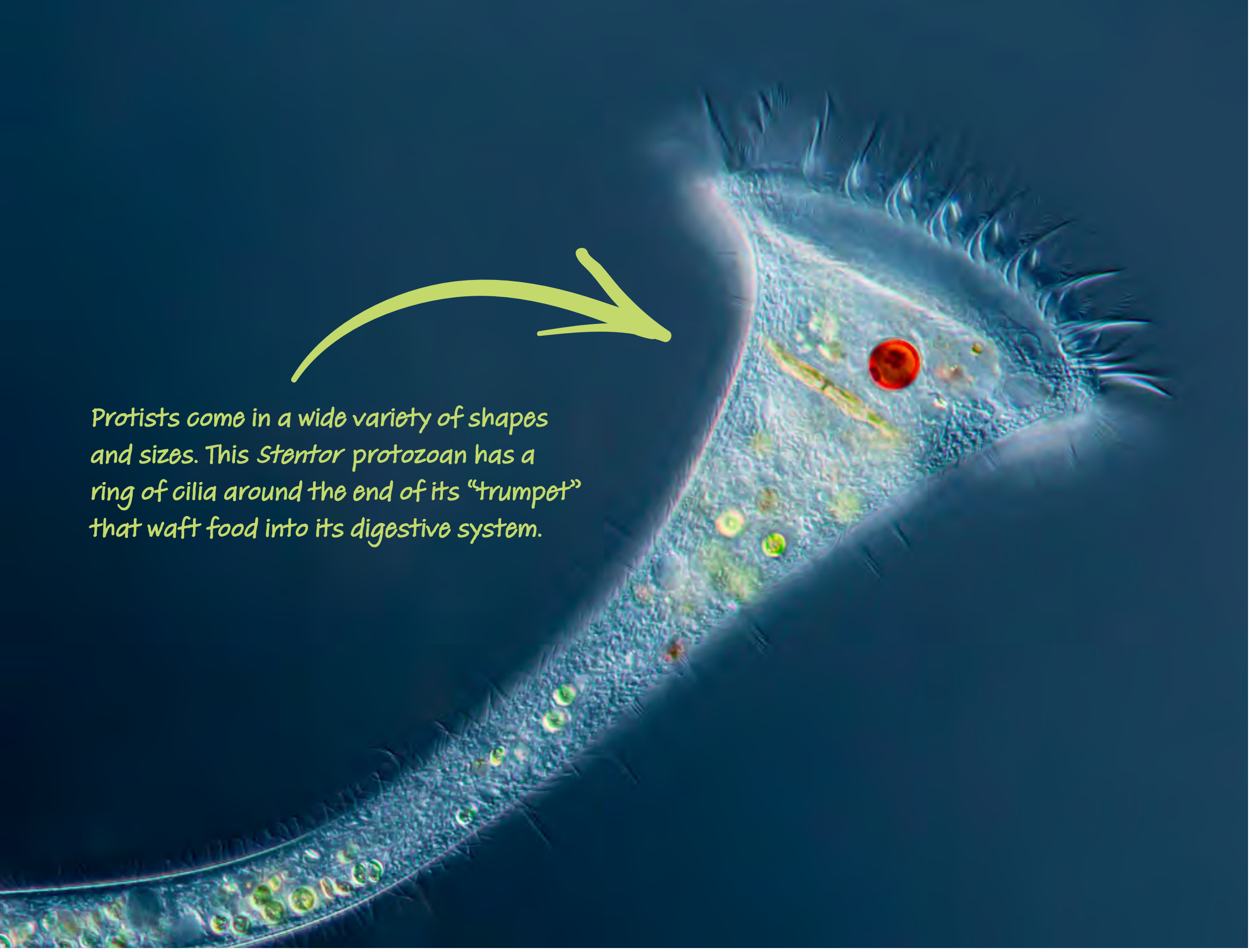
LAGUNA DESIGN/SCIENCE PHOTO LIBRARY

Gumdrop with an earring. That's what pops to mind when I look at photos of a creature Sebastian Hess found in a mossy pond in Germany. It's kind of plump and has only one cell. It's also violent.

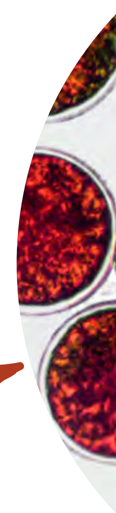
This shape-shifting, amoeba-like cell prowls for algal cells to attack. It curls a long strand called a flagellum into an earring-like loop. Holding the loop steady, the cell somehow glides. "They look basically like tiny flying saucers," Hess says.

Hess has been seeking and tending such single-celled wonders since a young age. As a teenager, he kept a zoo of microbes on his windowsill. Now, he's a biologist at Technical University of Darmstadt in Germany. But he still studies the same type of specimens that filled his zoo: the protists.


Oxytricha
Filamentous algae
Paramecium



Protists come in a wide variety of shapes and sizes. This *Stentor* protozoan has a ring of cilia around the end of its "trumpet" that waft food into its digestive system.



Algae are photosynthetic protists. Like plants, they convert sunlight into energy.

Protists are a huge, varied group of mostly one-celled organisms. On the traditional "tree of life," they comprise a whole kingdom, alongside those for animals, plants, fungi, bacteria and archaea.

Protists are among the closest microbial cousins to multi-celled life. Like animals, plants and fungi, they wrap their genetic material inside a cell nucleus. Yet they're often overlooked, drawn in many science textbooks as a lower branch beneath the crown of many-celled life.

It's becoming clear, however, that the small can be mighty. And they outnumber us — by a lot.

In fact, single-celled microbes — protists among them — dominate the planet. A 2018 comparison estimates that Earth's protists account for twice as many gigatons of carbon (an ingredient of life) as all animals put together. Add in other microbes, and together they hold 40 times the biomass of animals.

We may think that what we can see represents much of our world's life. Yet our eyes capture only a narrow — and rather odd — sliver of life's variety.

As high-tech biology meets old-fashioned boots-in-mud exploration, protists are getting a closer look. What scientists are learning challenges old notions that single cells are simple. The microscopic world is full of breathtaking complexity and diversity.

And the tiny protists are giving us a whole new view of what it means to live on Earth.

We live on a non-animal planet

Hess' flying saucers are just one of an amazing array of protists. The kingdom showcases a wide variety of looks and behaviors.

Daimonympha friedkini, a new species named in 2023, has the one-celled equivalent of a rotating head. The cell itself is roughly shaped like a globe. The top, somehow, spins steadily around without ripping or strangling itself.

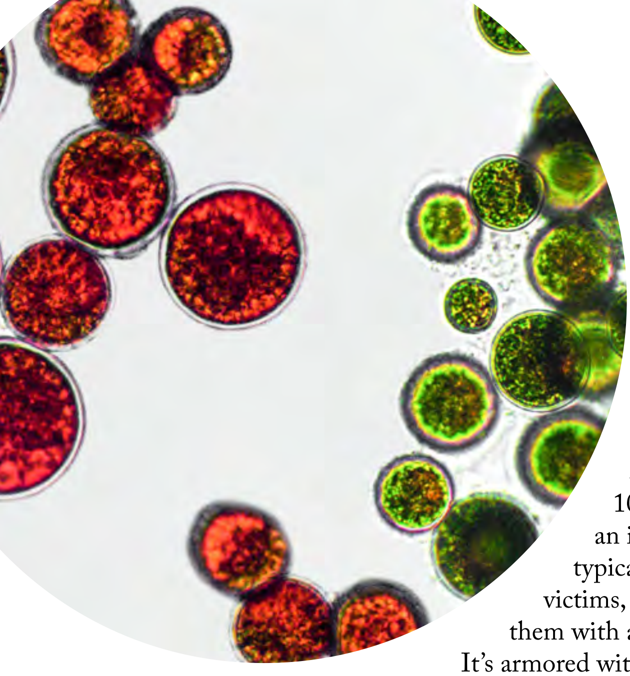
Emiliania huxleyi (now *Gephyrocapsa huxleyi*), which lives in the sea, covers its cell in what look like tiny hubcaps. Another group of water-dwellers, *Euplotes eurystomus*, grows skinny projections that look like stick-drawing legs. Even with no brain or nervous system, some of these cells can "walk" on an underwater surface. (Engineers seeking inspiration for microscale robots have been analyzing such gaits.)

"Stunning" is how Hess describes protists. "They really behave like entire organisms," he says. "But they are just cells."

Many are fierce predators. One of his favorites has a pretty teardrop shape. But don't let *Lacrymaria olor*'s mild looks deceive you. This cell chases prey by shooting out a cartoonishly long swan neck. It can stretch more than seven times the length of the original cell. That neck swerves this way and that, lithe as a snake — until a sudden pounce finally snags dinner.

Protists are a huge, varied kingdom of mostly one-celled organisms, and they dominate our planet. Now, scientists are finding that these microbes aren't nearly as simple as once believed.

TOP LEFT & BOTTOM RIGHT: FRANK FOX/SCIENCE PHOTO LIBRARY; ELIF BAYRAKTAR/SHUTTERSTOCK



Or consider five new species of tiny, voracious cells nicknamed nibblerids. When hungry, they take a sickle shape that measures just 3 micrometers (a 10-thousandth of an inch) across. They typically feast on larger victims, "biting" down on them with a special body groove. It's armored with hard, toothlike bits called denticles.

Hess' flying saucers are amoebas called *Idionectes vortex*. They use a stealthier approach. When one spots an algal meal, the gliding spaceship becomes an attack amoeba. First, it dissolves a hole through the algal cell's wall. Then it slides itself through the hole and devours its prey from the inside.

Predators play critical roles in their ecosystems, says Patrick Keeling. He's an evolutionary biologist at the University of British Columbia in Vancouver, Canada. As an example, think of animal-based food chains. "If you took all the lions and cheetahs and killed them all," he says, "the whole ecosystem would go wacky." That's likely the case with protists, too.

Just be glad that protists aren't bigger. Or that humans aren't smaller.

Microbes experience a different world

Protists' tiny size means that they inhabit a different version of the world than we do.

"We spend so much time trying to imagine alien worlds," says Keeling. "There's one right under our noses — more weird than anything we can think of."

Consider how protists' bodies experience water. Lone cells are so tiny that the properties of plain water affect them very differently than they do humans and other sizable swimmers.

Say you dive into a swimming pool. "If you're not kicking, you still go forwards for quite a while

Lepocinclis spirogyroides is a species of freshwater algae. Because protists like these are so small, they interact with their watery world very differently than larger creatures do.

until you stop, right?" Keeling asks. For a single cell, though, the viscosity of water means the cell barely glides at all. If it stops swimming, it just … stops. "It's more like you're in corn syrup," he says.

This "syrup world" changes how critters have to approach swimming.

Think about a sea scallop. Normally, it opens its shell slowly and snaps it closed to jet around. But if it were magically miniaturized, the scallop would be stuck flapping in place. Physicists predict it could move by shutting its shell, but it would slip right back upon opening it again.

On the upside, though, motions that are useless for people or scallops could propel a tiny swimmer. Physicist Geoffrey Ingram Taylor theorized one idea in 1952. Take a microbial swimmer shaped like a doughnut, he said. It should be able to move itself with a sort of inward rotation.

In fact, that rotation is more or less how *I. vortex* swims with its loop. Hess and colleagues announced that in 2019, nearly 70 years after Taylor's suggestion. The cell's long, stringy flagellum curls into a skimpy "doughnut" shape. At first, Hess couldn't see it moving at all. Then he and his colleagues put those cells in a syrupy fluid full of bits of latex. Movements of the microparticles showed the loop was rotating after all.

How protists are discovered

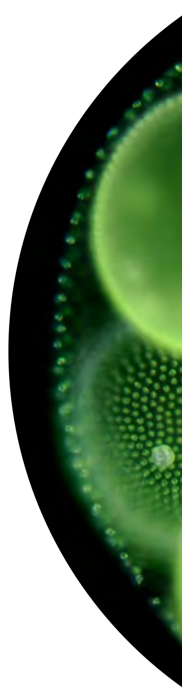
This wild world of protists really is right under our noses — and everywhere.

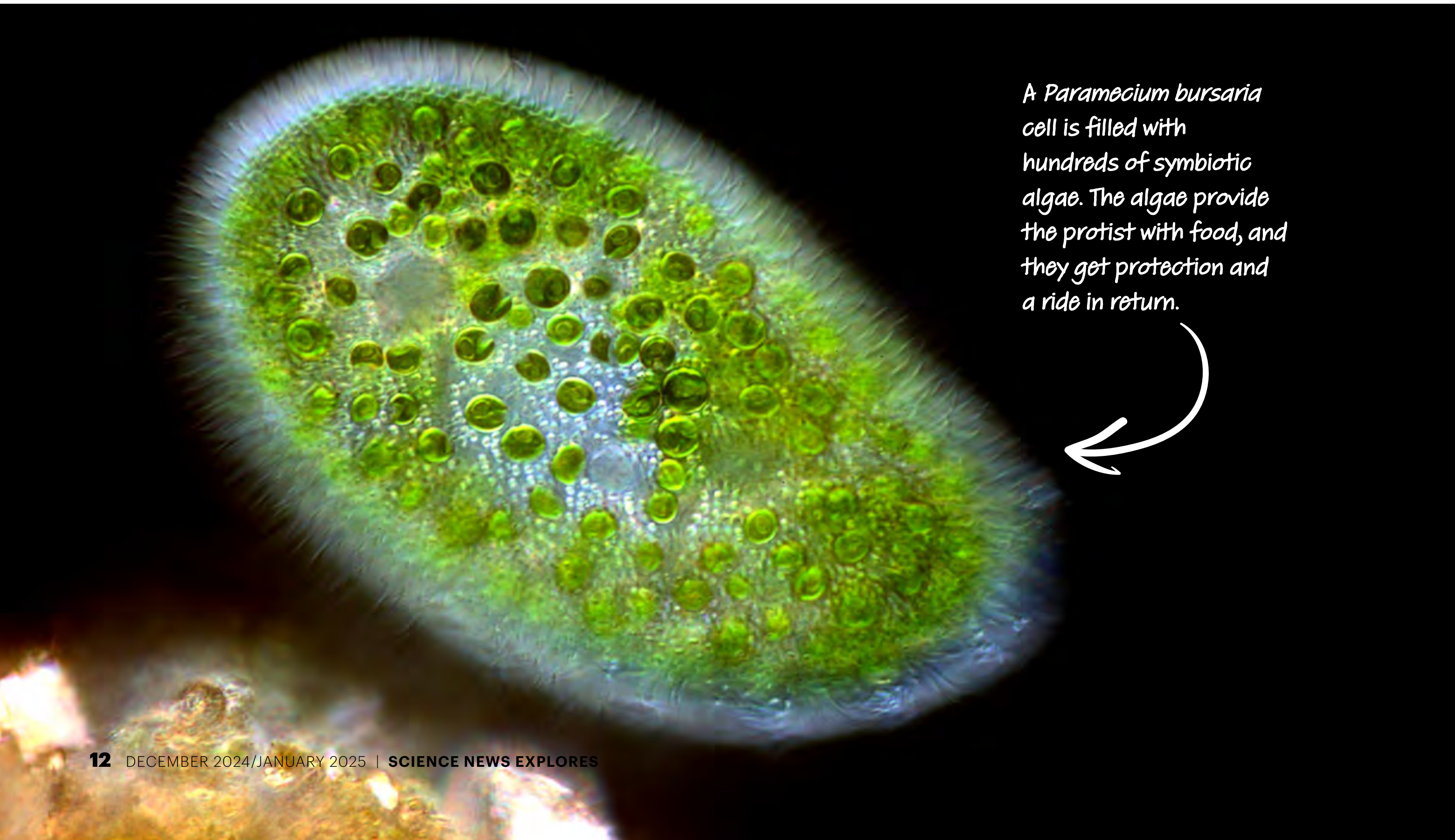
In 2016, Kiran More was an undergraduate at Dalhousie University in Halifax, Canada. That summer, his family drove through the eastern countryside of Nova Scotia. At a village on Cape Breton Island, More scooped up some sand from the shore. He had packed a set of sampling tubes just in case, hoping to search for some new species. "I just carried it from hotel room to hotel room and stuck it in the minifridge," he says.

He brought the sand back to school, where it became part of his undergraduate research project. He was looking for unknown species of marine amoebas called vampyrellids.

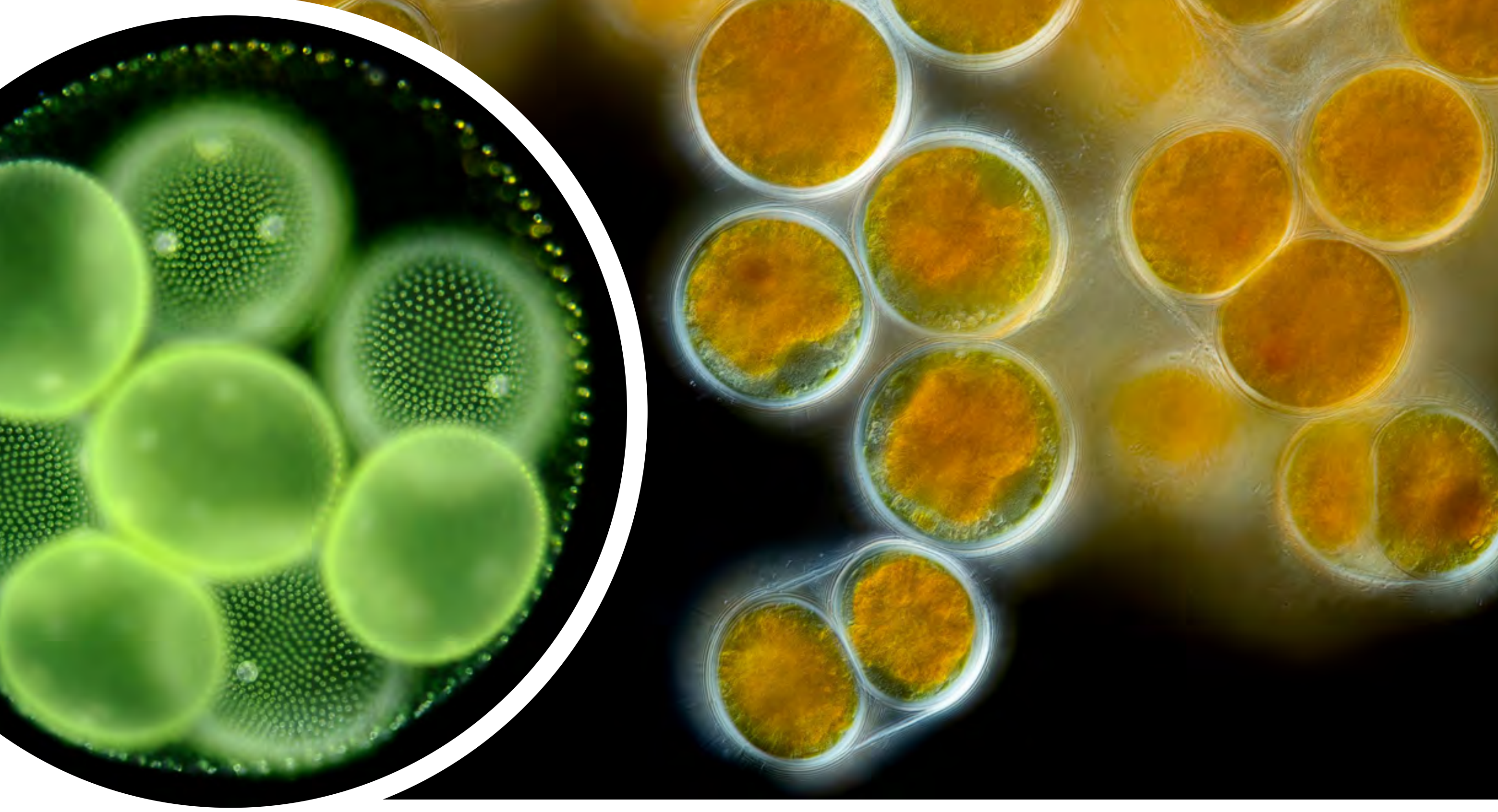
The name sounds spookier than they look. Some look a bit like fried eggs. But a vampyrellid's "egg white" is actually an attack structure. It can pierce algal cells to feast on their nutritious interior.

In his sand, More found at least seven different vampyrellid amoebas. Two fried-egg types turned out to be new species. Now named *Placopus melkoniani* and *P. pusillus*, they hunt by rolling forward. Their outer membranes move "like a conveyor belt," More says — or maybe the treads on a tank. "You can see all their cell contents inside also rotating as the outer membrane rotates, which is almost beautiful," he says.





A *Paramecium bursaria* cell is filled with hundreds of symbiotic algae. The algae provide the protist with food, and they get protection and a ride in return.



Scientists named ***Nottbeckia ochracea*** **a new species in 2018 after finding it in a rockpool in Finland and discovering that it had unique structures. While it may look similar on this page, *Volvox globator* (inset), is a very different species — one that you can see without the help of a microscope.**

In 2021, he described a third new species from that same vacation sand. More was then a graduate student at the University of Alberta in Edmonton, Canada. He was part of a team that named this species *Sericomyxa perlucida*. This means “transparent silken slime.” It looks like a road-killed badminton shuttlecock but with exquisitely delicate tufts. And it was not just a new species in a new genus but also a whole new family of protists.

Microbes dominate Earth

Protists may seem weird. But in many ways, we are actually weirder, says Maureen O’Malley. As multicellular beings, she says, “we’re an aberration.” She’s a philosopher of microbiology at the University of Sydney in Australia.

Earth housed only microbes for more than half its existence — 2.5 billion years or more, O’Malley points out. Multicellular life was able to evolve due to microbial innovations. One example: the oxygen we breathe. It was produced by cyanobacteria via photosynthesis, starting 2.7 billion years ago.

Even today, an estimated half of the oxygen we breathe comes from microbes, not plants. And plants got their own oxygen-making ability from microbes, too. Plant chloroplasts, where photosynthesis takes place, arose from microbes once engulfed by plant ancestors.

Protists help plants and animals in countless other ways every day. Termites “eat” wood thanks to the protists packed into their guts. Tomato plants grow better with more predatory protists in the soil around their roots. The list goes on and on. Protists and other microbes shaped the world and keep us alive in it.

O’Malley sums up microbes as “the dominant life-forms not only in today’s world, but also in all past eras of the living Earth.”

With a few quirky exceptions — including us — to be an earthling is to be microscopic.

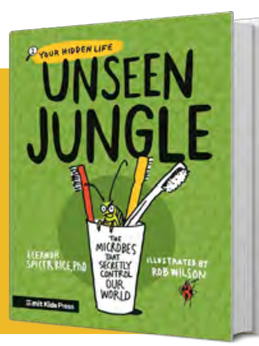
LEFT: FRANK FOX/SCIENCE PHOTO LIBRARY; RIGHT: WIM VAN EGMOND, FRANK FOX/SCIENCE PHOTO LIBRARY; MIT KIDS PRESS

READ MORE

Unseen Jungle:
The Microbes That Secretly Control Our World

By Eleanor Spicer Rice
Illustrated by Rob Wilson

Protists are the microscopic powerhouses of our planet. From world-saving termite farts to parasites controlling mice minds, learn more in this book about the small-but-mighty microbes all around us!



Under the microscope, this biologist sees a tiny jungle

Sally Warring studies life forms called protists — and captures them on camera

To Sally Warring, protists are an absolutely underrated type of wildlife.

"Protists are very charismatic and interesting," says Warring, who studies these creatures at the Earlham Institute in Norwich, England. Among this richly diverse group of mostly single-celled eukaryotes (creatures whose DNA is packed in a nucleus), some are hunters and others prey. Some live in colonies, others alone. Some even have mating rituals or build themselves tiny structures to live in.

"There's all this stuff going on that we usually associate with more complex animals," Warring says. "It's just not as well-studied because it's harder to study."

Warring's research investigates the genetic blueprints, or genomes, of protists. "From the genomes, we can get information about what these organisms are and how they live — what they need to eat … if they secrete things into the environment, that kind of information," Warring says. That could not only help explore the largely uncharted biodiversity of protists. It could put more familiar types of life into better context.

"Protists make up most of eukaryotic diversity," Warring says. "So if we want to understand how different eukaryotic groups evolved — including animals, plants, fungi and important parasites — then we need to understand what's going on in protists."

In this interview, Warring shares reflections on her experiences with *Science News Explores*. (This interview has been edited for content and readability.) — *Maria Temming*

Q What sparked your interest in protists?

A During my undergrad, I randomly took a course on protists, and I just was blown away. We got to look at different protists through the microscopes, and I got to see organisms such as *Volvox* and *Paramecium* and amoebas. I couldn't believe how much complexity and behavior and lifestyle was exhibited by organisms that were only one-cell big. Or, in the case of *Volvox*, a colony of cells.

Q What's your favorite protist?

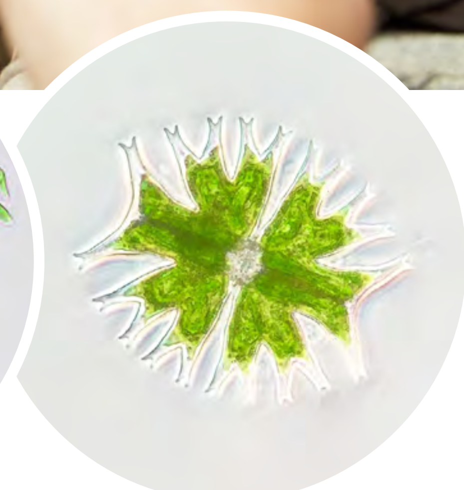
A I do like *Volvox*, mainly because it's one of the ones I first saw and is just really beautiful. It's big enough that you can see it with the naked eye, because it's a colony. If you find it blooming in a pond, you can just hold that water up to the light, and you'll be able to see them all moving around.

I now work on a group of protists called the Euglenozoa. They come in a range of colors and sizes, and they do all sorts of different things. One of my favorites is called *Phacus*. It looks like a falling leaf when it moves around. It's really beautiful.

Q What advice do you wish you'd been given when you were younger?

A Sometimes when I tell people I'm a scientist, they react like it might be boring. But I think people underestimate the level of creativity that's important

Sally Warring is fascinated by the tiny life forms that live in pond water. In samples that she has gathered (top and bottom left inset), Warring has photographed organisms such as Euglenozoa (bottom middle inset) and green algae (bottom right inset).

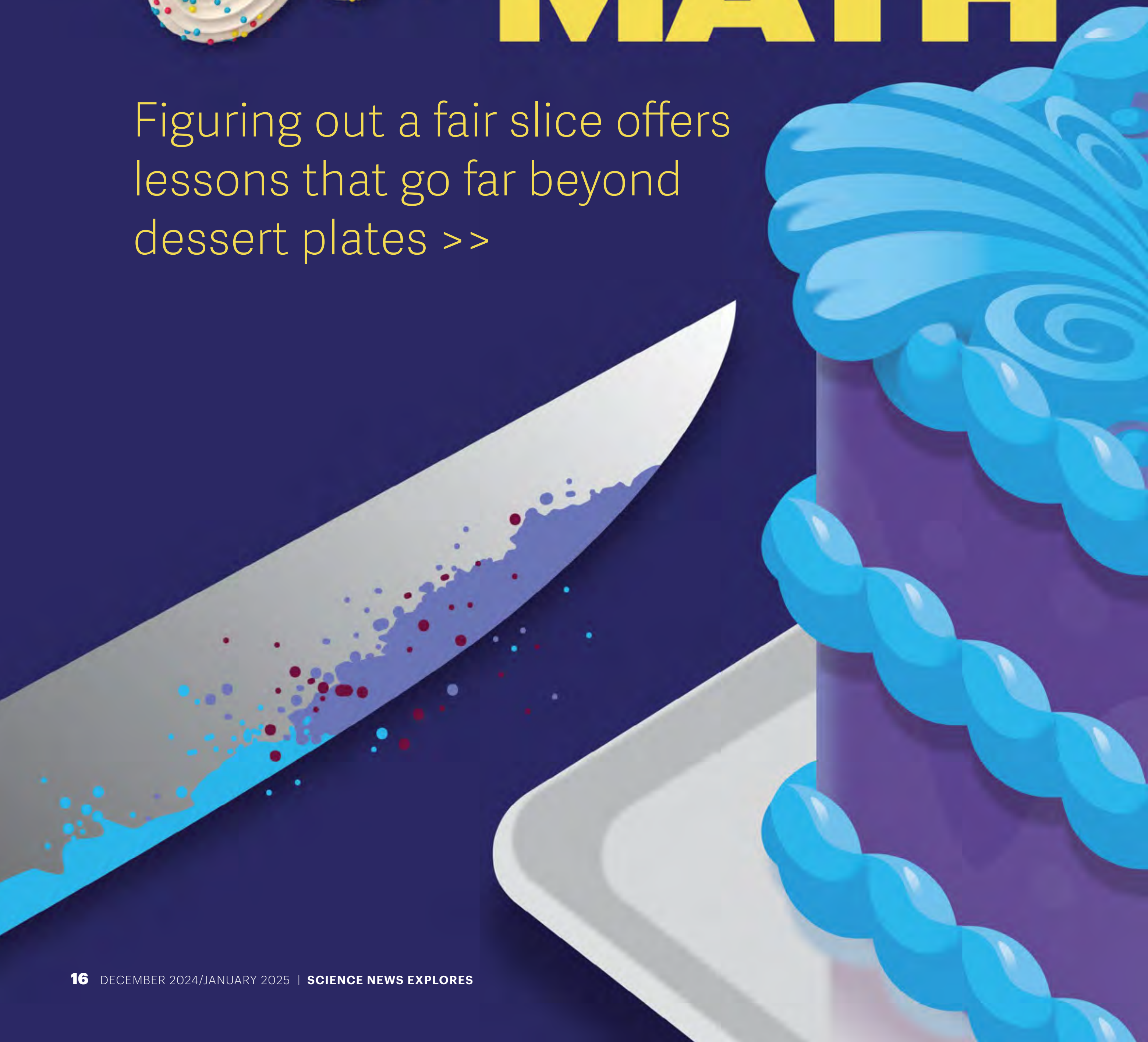


SHAWN SIMPSON; SABRINA IMBLER; S. WARRING

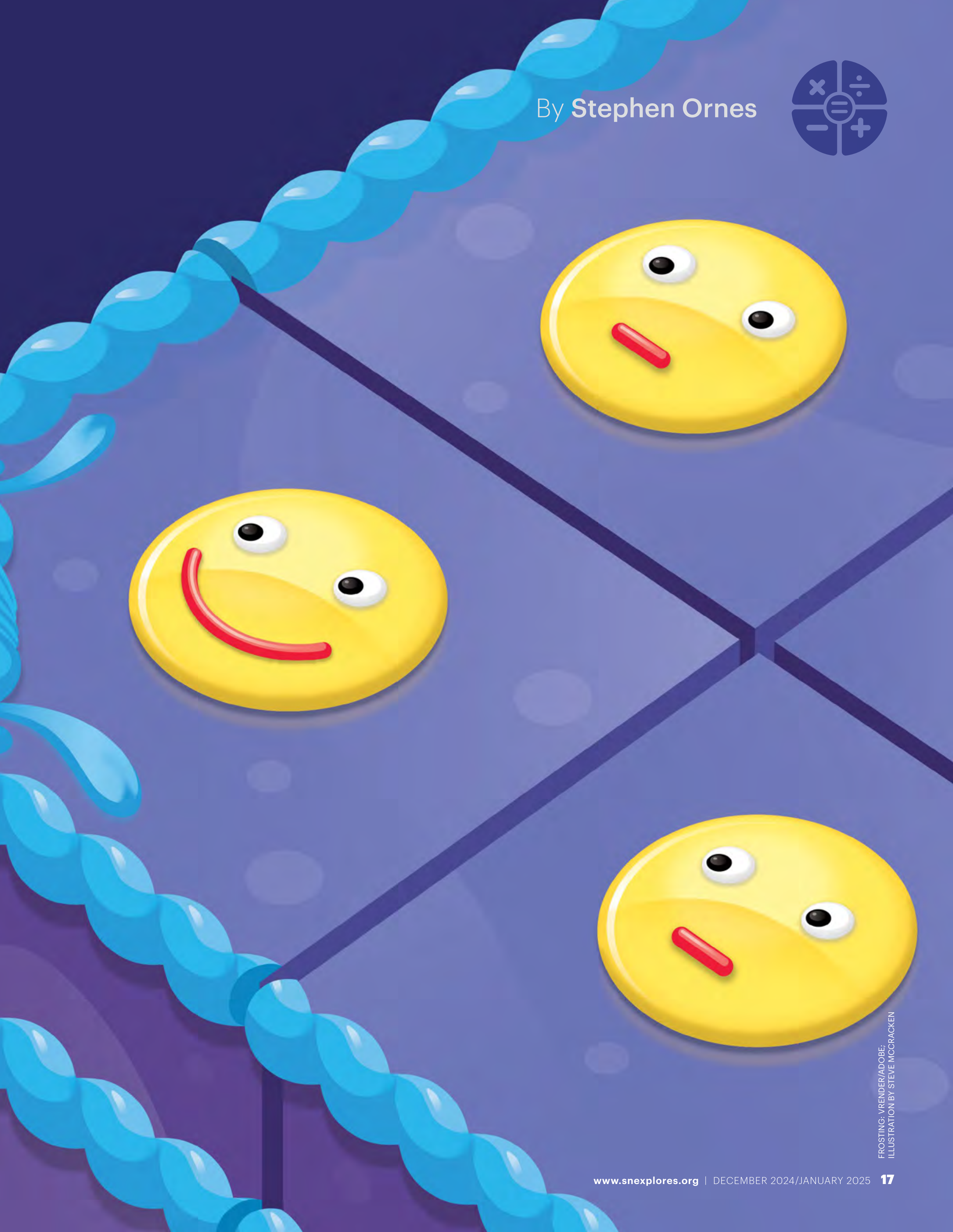
in science. I underestimated that, too. But it really is. That's probably my favorite bit about what I do, is that I get to think about problems and come up with the best way to interrogate them. I would like to tell even myself a few years ago, don't feel like you always have to follow the rules. Try to be more creative in how you think about tools and solving problems and even thinking of hypotheses.

cake MATH

Figuring out a fair slice offers lessons that go far beyond dessert plates >>



By **Stephen Ornes**



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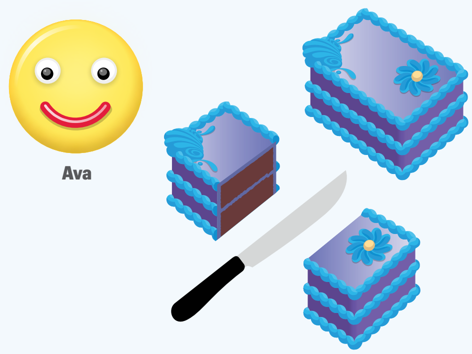
Ariel Procaccia has thought a lot about how to cut cake over the past 15 years. That's partly because he has three children. As a group, they've celebrated more than two dozen birthdays. So Procaccia knows what it's like to stand with a knife before a tempting dessert. Sweet layers of cake. Buttercream frosting and chocolate curls. And a crowd of small, eager partygoers who will instantly spot if someone else gets a better slice.

But Procaccia is also a computer scientist at Harvard University in Cambridge, Mass. There, he studies the mathematical rules for dividing stuff up. And dessert is a handy way to think about that. It comes down to a deceptively simple question about fairness: How can you cut a cake to make sure everyone at the party is happy with what they get?

HOW TO SHARE CAKE BETWEEN TWO PEOPLE

You probably already know how to fairly share cake between two people. Sometimes called "I cut, you choose," it's the simplest approach to fairly cutting cake.



First, one person, in this case Ava, cuts the cake into what she thinks are two fair slices.

The second person, Ben, chooses his preferred slice. Ava gets the remaining slice. Ava is happy because she liked both pieces equally; Ben is happy because he chose his favorite piece.

The answers reach far beyond birthday parties. For more than 75 years, mathematicians have puzzled over how to fairly divide resources. Such questions have real-world uses. How can food be divvied up between hungry communities, for example? How should roommates split up rent or chores? How can communities draw boundaries for fair voting districts?

These questions include more than math, too. They must consider what people prefer and other issues. So they become interesting to scientists, economists and legal experts.

Cake works as a stand-in for anything that can be divided, says Steven Brams. He's a game theorist and political scientist at New York University (NYU) in New York City. Cake-cutting ideas can easily be applied to splitting up land, time or other limited resources.

Recipes for fair cake-cutting

Experts have come up with many rules, called algorithms, for how to cut a cake fairly. (Nearly all focus on rectangular cakes. The related but more recent "pie-cutting" problem addresses circular desserts or pizza.) The simplest rules show how two people can fairly share a cake: One person cuts the cake into two pieces that they believe to be equal in value. The other person chooses between them. Each eater receives a piece that they feel is at least as valuable as the other's, if not better.

Reports of this strategy date back to ancient Greece.

In the 1940s, mathematicians started using cake-cutting as a way to study fairness. The "I cut, you choose" method works for two people. What about sharing among three or more? That has led to new challenges, such as: What is fairness, exactly — and how do you prove it?

Here's one way to think about fairness. Maybe each person is satisfied if they feel like their slice represents a fair share of the total. For two people, a fair share would be 1/2; for three, it would be 1/3, and so on. (And for some arbitrary n number of cake eaters, a fair share would be $1/n$.) If the cake is the same throughout, all the slices just need to be the same size. That's not too hard to manage with a knife and a ruler or kitchen scale.

But what about when the cake is not all the same? Maybe it's topped with a few icing roses or artfully placed cookies. The corner pieces may have more frosting. A maraschino cherry–lover might be happy with the smallest slice if they get the cake's only cherry. To them, that piece is more valuable than a larger slice.

ILLUSTRATION BY STEVE MCCRACKEN

For two people, "I cut, you choose" still works with a non-uniform cake. The divider cuts the cake into two pieces they view as equal; the chooser then picks their preferred piece. But add more cake eaters, each with their own preferences, and easy solutions crumble.

More eaters, more cuts

Hugo Steinhaus was one of the first mathematicians to dive into this complexity. He worked at the University of Warsaw in Poland in the 1940s. During World War II, he saw questions about fair division of land playing out on a large and violent scale. Steinhaus came up with a modified "I cut, you choose" strategy for three players.

It came to be called the "lone-divider" method.

Here, someone cuts the cake. Let's call her Ava. She cuts three pieces that she values equally (each at 1/3 of the total). Then a second person, Ben, says which of the pieces he would accept. If he approves at least two pieces, then the third person, Chloe, can take any piece she wants. At least one of the remaining pieces is acceptable to Ben. So he picks next. Ava gets what's left.

If Ben and Chloe both turn down the same piece, that piece goes to Ava. She valued all pieces equally, so it still seems fair to her. The remaining two pieces are recombined and shared between Ben and Chloe using "I cut, you choose."

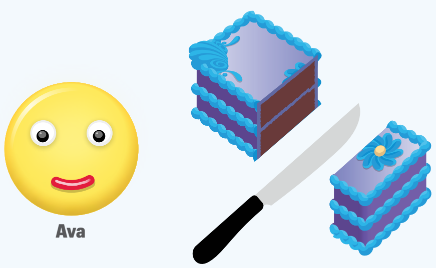
Steinhaus described this method in a short paper published in 1948. It was one of the first serious studies in the field of cake-cutting. And it worked for three eaters.

In the same paper, though, he discussed an algorithm developed by two of his colleagues. This "last-diminisher" method could work for any number of cake eaters.

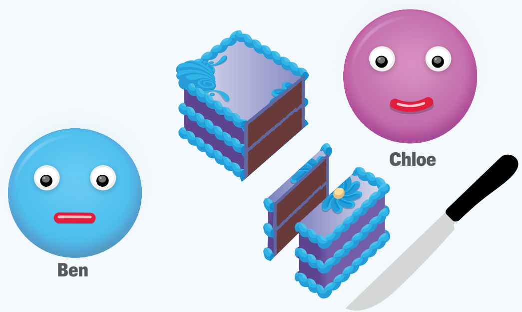
HOW THE "LAST-DIMINISHER" METHOD WORKS

Sharing cake among three people is harder. In the "last-diminisher" method, three people — Ava, Ben and Chloe — each believe they are getting a piece that they value at one-third of the total. Each piece should represent a fair share. But whoever exits the game first could still be envious of someone else's piece.

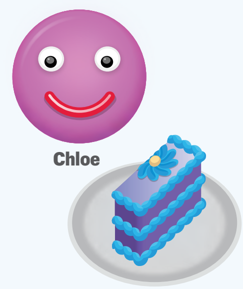
ROUND 1



In round 1, the first person — here, Ava — cuts a piece that she thinks represents one-third the value of the cake. She passes it to the second person, Ben.

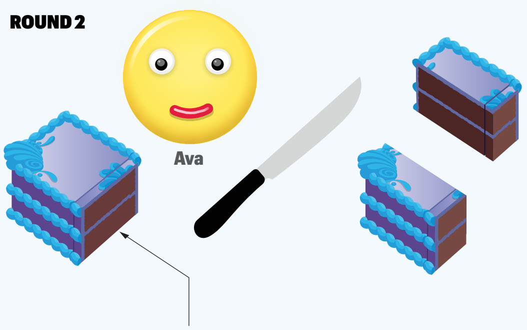


Ben is given a chance to trim the piece, if he thinks it is worth more than 1/3 the value. Or he can pass it to the third person, Chloe. She gets the same chance to trim if she wants to. In this case, Ben passes and Chloe trims.

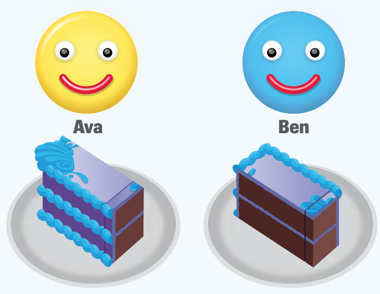


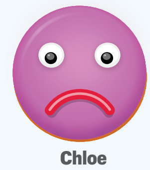
The piece goes to whoever trimmed it last. In this case, that's Chloe. If both Ben and Chloe had passed, Ava gets the piece.

ROUND 2



In round 2, any pieces trimmed off are added back to the remaining cake. The two people left then use the "I cut, you choose" method. Ava cuts the cake into what she thinks are two fair slices.





Ben chooses between the two slices Ava cut. Ava gets the remaining slice. Everyone appears to be happy with their piece. But Chloe, who exited the game early, could still think that Ava's or Ben's piece is better than hers.

Here, someone cuts off a piece of cake they think is a fair share and passes it to the next person. Each other person at the party has a choice. They can pass the piece along, if they agree it's fair or less than a fair share. Or, if they think it's too big, they can trim it. Once everyone has had a chance to trim, or "diminish," the slice, the last person who trimmed gets the piece and exits the game.

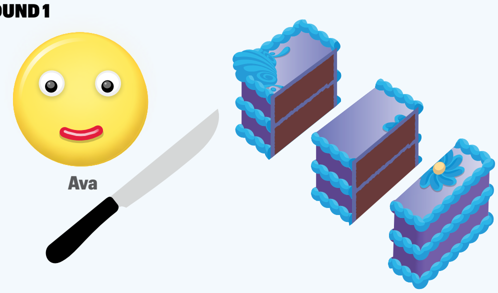
Any bits trimmed off are added back to the remaining cake, and the process begins again with the remaining players. When only two players are left, they use "I cut, you choose."

The "last-diminisher" method guarantees that everyone judges their own piece to be at least a fair share. But it's not perfect. That's because it doesn't account for envy. In both the "lone-divider" and

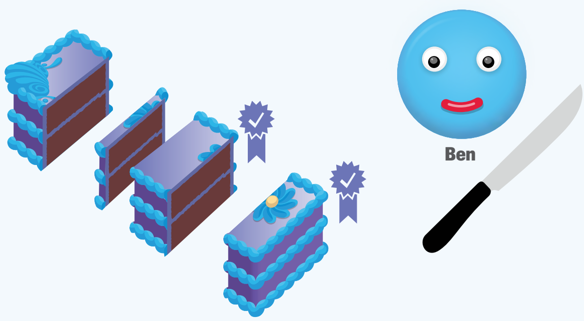
HOW TO DIVIDE CAKE WITH NO ENVY

Another way to divide a cake among three people aims to avoid envy. Each person — Ava, Ben and Chloe — is guaranteed to feel that their piece represents a third the total value of the cake. This method has also been extended to work for any number of people. But with more people, the cutting process can last a very long time.

ROUND 1



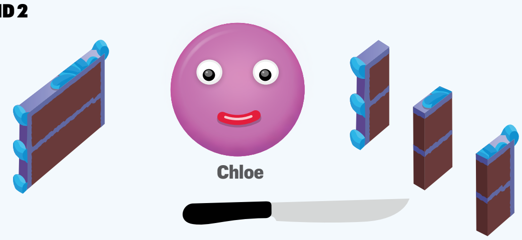
In round 1, the first person, Ava, cuts the cake into three pieces. She considers all three to be equal.



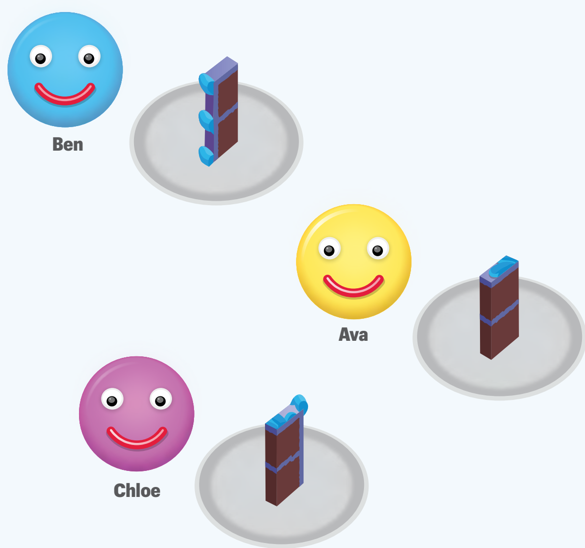
The second person, Ben, can either pass or trim one — and only one — of the pieces. That makes two pieces that he thinks are tied for the best. Anything he trims off is set aside.

The third person, Chloe, gets to pick first. She gets her favorite piece. Ben chooses next. Since he valued two piece equally, he's guaranteed to get one he thought was tied for the best. Ava gets the remaining piece, one of her original pieces.

ROUND 2

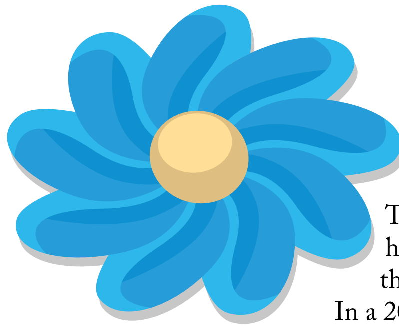


Round 2 divides the trimmings. Whoever between Ben and Chloe got the untrimmed piece (in this case Chloe) cuts the trim into three equally valuable pieces.



Now Ben chooses first, getting his favorite piece. Ava goes next. Chloe ends up with one of the pieces she cut. This approach should be free of envy. Since Ben picked first, he got what he considered the best trim piece. Chloe valued all the trims equally, so she's happy with any of them. And Ava feels like any trim is a bonus, since she would have been happy with her original piece alone.

ILLUSTRATION BY STEVE MCCRACKEN



"last-diminisher" approaches, a person who gets an early slice may see a later one they wish they had instead — even though they had at first thought their piece was fair.

"Last diminisher" has another flaw, too. If lots of people trim, the cake may be reduced to crumbs in later rounds. And that might feel unfair no matter how big your pile is.

Can cake-cutting be free of envy?

Mathematicians continued to search for envy-free ways to divide something. In the 1960s, John Conway and John Selfridge each came up with the same idea for how three people can each feel they got a fair share, with no envy by others.

In their plan, Ava first splits the cake into three pieces. She believes each are of equal value. Then, Ben can trim one piece — at most — to create a two-way tie for the most valuable. (Any trimmings are set aside.) Chloe is left to choose among the three. Then the order reverses. If Chloe didn't choose the trimmed piece, Ben takes it. Ava gets the one that remains. Then the eaters turn to the trimmings. They follow a similar process of cutting, trimming and choosing.

In 1995, another team showed how to extend this approach to any number of people. Brams at NYU worked with Alan D. Taylor of Union College in Schenectady, N.Y. Their method applied the "trimming" idea using all possible pairs of cake diners. "That was considered a breakthrough of sorts," Brams says.

The approach still had its limits, however. There was no guarantee of how many cuts it might take. "We showed in general that you could require three cuts or 3 million cuts," Brams says. Or even more.

The cake-cutting problem endures

The algorithms discussed so far assume that all eaters play fair. That is, all try to achieve pieces that will feel like a fair share to everyone else. But people aren't always honest.

This is something Biaoshuai Tao recognizes. Tao is a computer scientist at Shanghai Jiao Tong University in China. And he studied what happens when you try to account for dishonest cake eaters. "If everyone knows how the cake is allocated, then I should get more if I tell the truth," he says.

But in some cases, dishonesty can give an advantage. Say Ava and Ben are going to split a cake. If Ava knew that Ben always preferred chocolate, she might cut the cake unequally on purpose so the smaller piece contained more chocolate. Then, if Ben chose according to his preference, Ava would get the larger slice.

In a 2010 paper, Procaccia asked a curious question: Can there be a way to cut cake that guarantees honesty and fairness? More than 10 years later, the answer seems to be: no.

Tao used math to show it is impossible to cut cake in a way that promises truthfulness and fairness, with no envy. He presented this at a July 2022 meeting in Boulder, Colo. It was held by the Association for Computing Machinery Conference on Economics and Computation.

Beyond cake

Cake-cutting is easy to relate to, says Bettina Klaus. And it has lots of practical uses. At the University of Lausanne in Switzerland, Klaus studies fairness in real-world situations. Dividing things fairly "is mathematically interesting and challenging," she says. And its complexity grows with the number of people who want to share.

One example she studies is school choice. Here, a school district has limited seats in certain schools. "In the past, schools were just assigned [to students] … without asking people what they want," Klaus says. More recently, she notes, schools have tried to place students where they want to go (or where their parents want them to go). They also have to follow rules set by the school board. Deciding how to fairly assign those seats means balancing the priorities of these groups.

Other real-world applications show up almost everywhere you look.

Brams has used ideas from cake-cutting to study fair voting procedures. (To elect their leaders, at least four scientific societies adopted an algorithm he developed. The Mathematical Association of America was one.)

In 2014, Procaccia was part of a team that designed a web-based tool called Spliddit. Based on users' preferences, it produced mathematically fair ways to divide anything. It might be rent among roommates or even possessions among divorcees.

Even after decades of study, cake-cutting defies a simple solution. Indeed, the more researchers explore it, the more there seems to be to explore.

"I'm interested in it now not only because it's beautiful in math," Tao says, but also because "I still believe there's a lot to be done."

SPACE

Make your own craters!

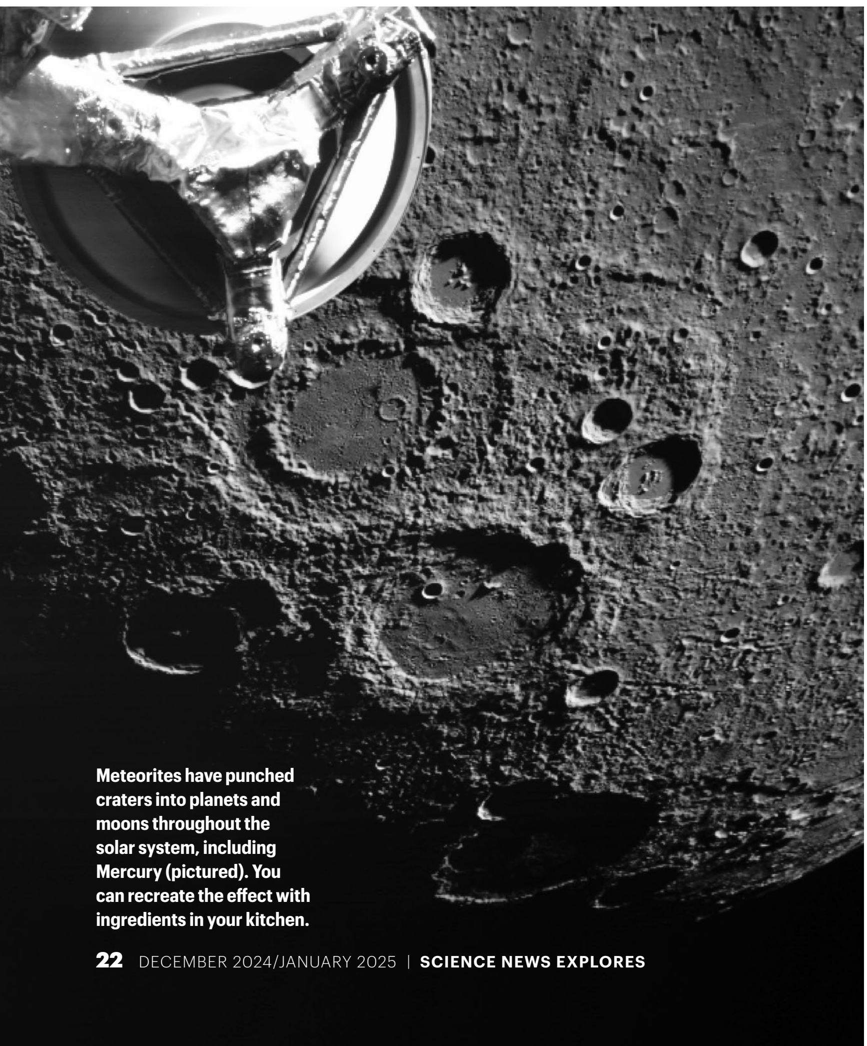
Let's explore how meteorites punch craters into moons and planets

By Science Buddies

Craters are bowl-shaped dents that form when space rocks, or meteorites, hit planets or moons. Meteorites often explode on impact, so all that remain of their collisions are craters. But these marks may offer clues about the space rocks that created them. In this experiment, we investigate what the size of a crater can tell us about the size of the meteorite that made it.

OBJECTIVE

Investigate how a meteorite's size affects the crater it creates.



Meteorites have punched craters into planets and moons throughout the solar system, including Mercury (pictured). You can recreate the effect with ingredients in your kitchen.

ESA/BEPICOLOMBO/MTM

EXPERIMENTAL PROCEDURE

1. Collect at least three round objects of different sizes, such as a baseball, rubber ball and round fruit, to serve as "meteorites."

2. Measure the diameter of each "meteorite" and record it in a notebook.

3. Evenly coat the bottom of a cardboard box with a 4.5-kilogram (10-pound) bag of flour. Sift a thin layer of cocoa powder over the flour.

4. Drop one of your "meteorites" into the box from a height of 50 centimeters (20 inches).

5. Remove the object from the flour without disturbing the "crater" left behind.

6. Repeat steps 4–5 twice more with the same object, dropping from the same height onto different spots in the box.

7. Measure the diameter of the three "craters" and record the results. Calculate the "craters'" average diameter and record the result.

8. Mix the cocoa powder into the flour and coat the smooth surface with a new layer of cocoa.

9. Repeat steps 4–8 for all your objects.

10. Plot the diameter of each "meteorite" against the average diameter of its "craters." Do you see any patterns between the sizes of "meteorites" and the sizes of their "craters"?

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

SCIENCE BUDDIES

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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?

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AURORA
CORK
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GINI
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LAVA
MAGMA
MOON
OIL SPILL
OXYGEN
PATHOGEN
PIZZA
PREDATOR
PROTIST
SCHOOL
SPEED
TITANIUM
TYRANNOSAURUS
VOLCANO
WOOD

PATPITCHAYA/SHUTTERSTOCK

TECHOLOGY

Lasers help put the cork on spilled oil

An accidental experiment led scientists to a smart solution for an environmental menace

Oil spills at sea pose risks to aquatic life and people. Attempts to remove that oil tend to be messy and costly and are often not very effective. But scientists in China and Israel think they've found a new way to "sponge" up that sticky pollution: cork.

Past research had shown that cork could collect oil. Treating cork with lasers speeds up the pace at which cork picks up oil on water, reports Yuchun He. Indeed, the treated cork keeps water out. He works at Central South University in Changsha, China. This materials scientist was part of a team that developed the new treatment.

The new finding "looks terrific," says Nancy Denslow, "at least in the lab." Denslow works at the University of Florida College of Veterinary Medicine in Gainesville. There, she studies water contaminants that pose threats to wildlife. The materials don't cost much, she adds. However, she cautions, right now no one knows how well the treated cork will work on spills outside the lab.

He's team stumbled onto the new treatment by accident.

The team had been using lasers to etch patterns into wood. These researchers hoped the patterns might help them build electronic devices from the wood. They'd never tried etching cork (the bark of the cork oak tree) before. But when they did, something unexpected happened.

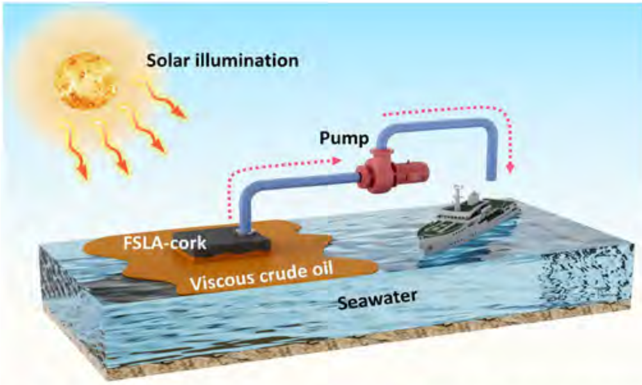
The cork darkened. That change suggested the cork might be photothermal — something that can convert light into heat.

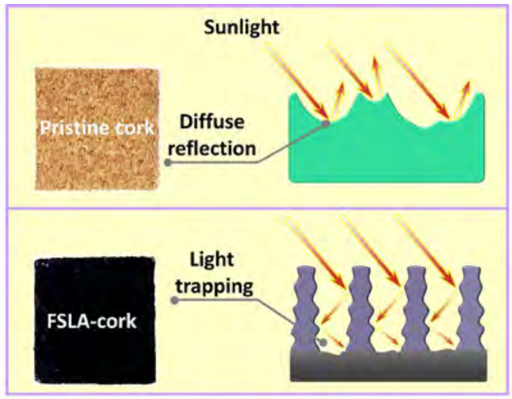
They already knew that untreated cork could sop up oil. But adding heat could help. Oil is highly viscous, or thick. But oil gets thinner when it warms up. And thinner oil should more easily soak into cork or stick to its surface.

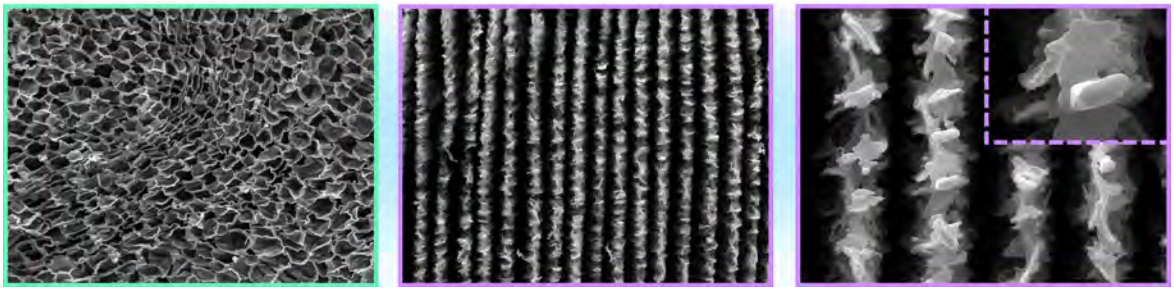
The scientists had a hunch that tiny cavities created by the laser might help the cork store

ROSLAN RAHMAN/AFP VIA GETTY IMAGES PLUS

Oil spills are a problem worldwide. Here, workers are cleaning up spilled oil from a beach on Singapore's resort island of Sentosa in June 2024. Oil spilled at a nearby port spread through the water and polluted beaches.







more heat. This treated cork should warm up more quickly than usual in sunlight. And that warmth should thin nearby oil, making it easier for the cork to sop it up.

To test this, they compared small, thin slices of pristine cork to laser-treated cork. In the dark, both corks took about 45 minutes to sop up a mere two droplets of oil. With a camera, the researchers watched as this happened. Then, they repeated the experiment in sunlight and compared the results.

In the sun, untreated cork needed 10 minutes to sop it up the oil. Laser-treated cork took just two minutes.

To simulate what would happen outdoors, the researchers next poured oil onto water and watched it float. Then they added some treated cork and shone a sunlamp on it. Heat from the lamp warmed the oil, lowering its viscosity.

The treated cork now sopped the oil up out of the water.

The laser's light scuffs the surface of the cork ever so slightly, He's team showed. This makes

the cork extra hydrophobic, or water-repellent. Those scuffs also make the cork more oleophilic, or attractive to oil.

The hardest part was testing ways to etch the cork, He says. His team had to balance the cork's oil, water and photothermal traits. "We need to continuously adjust these three properties," He says, to get "the best-performing cork."

The treated cork is an example of something that is adsorbent. It can clean up a spill because the oil now sticks to its surface. (That's in addition to being absorbent, which means the cork soaks up some of the oil.) "Using [cork materials] as adsorbents can better separate oil and water," He says.

Today, cleaning up a spill takes a mix of tools. Crews may skim oil off the water's surface and apply some harsh chemical that aims to break down the oil. They may even set fire to the slick. The new tests took place in a lab, so cork cleanup will need to be tested in real-world conditions, too — at sea. That will determine if the technique works on a large scale and without harming aquatic life.

Cork appears to offer a greener alternative. It's renewable and environmentally friendly. After it's harvested from a tree, the cork grows back in about 10 years. So far, no one has tested whether the new cork "sponges" can be reused. "To my knowledge, there are almost no truly reusable oil-absorbing materials," He says. But even if cork isn't either, it may still offer a preferred way to clean oil from the environment.

— *Stephen Ornes*

Cork is the bark of the cork oak tree (inset). One possible treated-cork oil spill cleanup approach is shown above (top left). A laser creates deep grooves in the cork that can trap heat (top right). Microscope images show pristine cork (bottom left), deep grooves carved in the cork by the laser treatment (middle) and a closeup of the grooves (bottom right).

Y. HE; JENS OTTE/SHUTTERSTOCK

PHYSICS

To clear a loop, Sonic's gotta go fast

The science of roller coasters and race cars could keep this speedy hedgehog on track

Sonic isn't your typical hedgehog. He boasts incredible superspeed that lets him launch off springs, sprint over water and even clear loop-de-loops. In the *Sonic the Hedgehog* games, our favorite blue hedgehog runs through these loops to complete levels. If he enters one too slowly, though, he risks falling off the track.

Animals — including hedgehogs — don't typically run through loops. Instead, climbing creatures rely on specialized limbs to scale vertical surfaces. But roller-coaster carts, race cars and even advanced parkour runners can clear loops. Sonic could take advantage of the same physics for his stunts, says Paolo Segre. He studies biomechanics at the University of Wisconsin–Green Bay.

Most animals haven't evolved to zip through loops, hedgehogs included. These small insectivores can only move at a top speed of about six kilometers (four miles) per hour.

The key to clearing a large loop is "speed, speed, speed," Segre says. "That's all that really matters — and some decent shoes."

As Sonic approaches the top of the loop, two downward forces act on him: gravity and the "normal force" exerted by the track. Together, these forces create a *centripetal* force that keeps Sonic on his circular path through the loop. Sonic's inertia, which is his resistance to a change in motion, helps him maintain his high speed as he moves through the loop. That allows him to clear the top without falling off the track.

Like a roller-coaster car, Sonic needs to reach a minimum speed to do this. But that speed would barely be a light jog for such a fast hedgehog, says Segre. Sonic can sustain speeds of some 1,200 kilometers (760 miles) per hour. That's about the speed of sound.

A HAIRY SITUATION

Loops pop up in most *Sonic the Hedgehog* levels. But since loops are rare in nature, most animals haven't evolved to run through them, says Mostafa Hassanalian. At the New Mexico Institute of Mining and Technology in Socorro, Hassanalian designs robots inspired by animals.

Real animals such as insects and geckos use specialized limbs to climb vertical surfaces. Many insects run up surfaces using tiny claws and hairs on their legs that grip pits and cracks. Geckos have thousands of tiny fibers under their feet that bond with a surface's molecules. Called *van der Waals* forces, these weak bonds are easily broken when the gecko lifts its foot.

Sonic's hair may also help him clear loops — but not by gripping the track. Hedgehog quills are actually hardened, modified hairs. In the real world, these needle-like hairs protect hedgehogs from predators. Sonic's quills, though, may make him more aerodynamic, notes Hassanalian.

Speedy animals such as cheetahs and horses need to reduce drag, or resistance to their motion caused by moving through air. Sonic's crestlike quills might reduce drag on his body by preventing large vortices, or whirls of air, from whipping up around him. The quills' jagged edges could cut these whirls into smaller vortices less likely to disturb airflow, says Hassanalian.

MARIUSZ SZCZYGIEL/SHUTTERSTOCK

In the *Sonic the Hedgehog* games, players complete levels by passing through loops as the Blue Blur. To clear a loop, a real-life Sonic would need to rely on the physics behind roller coasters and race cars.

He likens it to the vortex generators found on a race car. As a car speeds along, air passes along its surface. If this flow drifts away from the car, it can make the airflow turbulent, increasing drag. Vortex generators are fins on a car that create small vortices, which redirect air back toward the car's surface. That helps stabilize the car at high speeds.

RUNNING UP THAT HILL

The physics behind race cars don't just apply to Sonic. Birds also take cues from racing to scale vertical surfaces. Most birds tackle tricky inclines using wing-assisted incline running, says Segre. When running up a slope, two-legged animals angle their bodies parallel to the surface. This makes it hard to maintain the proper grip needed for climbing.

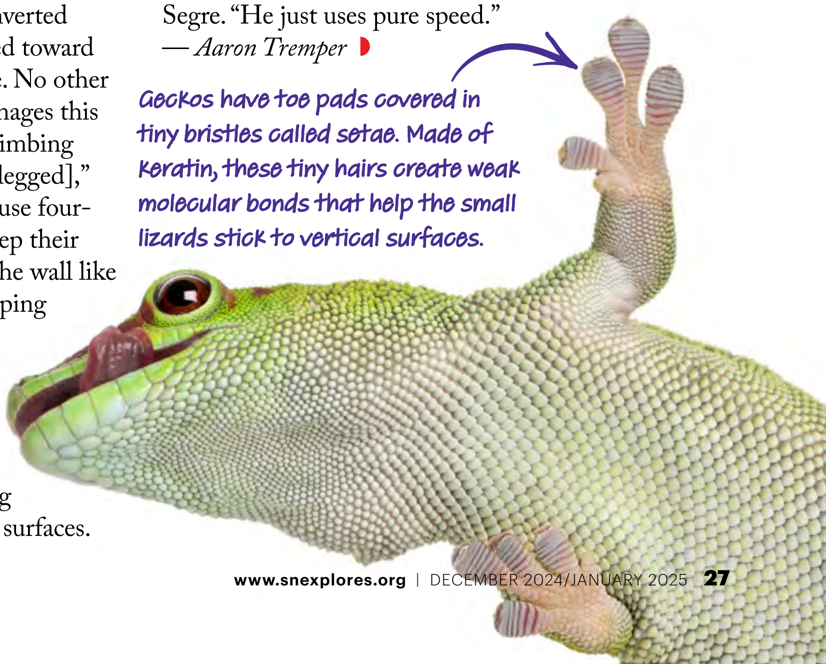
So what can birds do? Flap their wings. "The wingbeats push them into the ground," improving their grip, says Segre. "Once [birds] have that traction, they can actually use their legs to run," Segre says. This lets birds navigate different terrain, forage for food and escape predators. "We especially see it in baby birds who are not yet good at flying."

In experiments, this clever trick even let birds run up inverted walls — surfaces slanted toward the climber as they rise. No other two-legged animal manages this feat. "We see tons of climbing animals that are [four-legged]," says Segre. This is because four-legged animals can "keep their body right up against the wall like a rock climber." By keeping their center of gravity close to the surface, they're less likely to tip over backward. Wing-assisted incline running helps birds hug similarly close to steep surfaces.

Still, even wing-assisted birds aren't able to run upside down like Sonic. And their tactic for scaling inclines isn't what Segre would expect for our blue hero. While birds mostly use their legs to ascend, their wings are essential to getting enough traction. "This isn't really what Sonic does," says Segre. "He just uses pure speed."

— *Aaron Tremper*

Geckos have toe pads covered in tiny bristles called setae. Made of keratin, these tiny hairs create weak molecular bonds that help the small lizards stick to vertical surfaces.



SEGA; ERIC ISSELEE/SHUTTERSTOCK

EARTH

How volcanoes erupt

An influx of new magma or a gush of gas can trigger an eruption

Rocks from around the globe have helped researchers learn about how volcanic eruptions happen. All eruptions start with magma — molten rock found deep within the Earth.

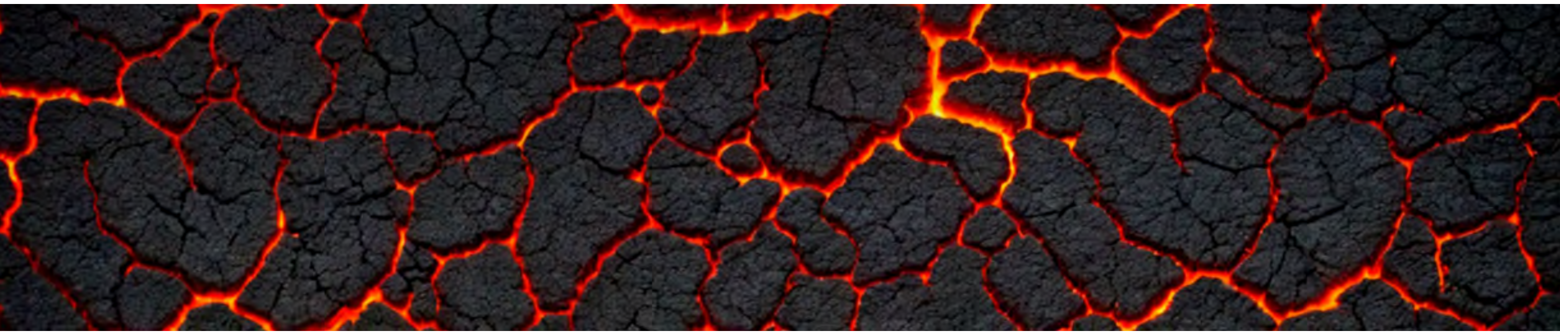
When volcanic eruptions occur, it's generally because gas can't stay dissolved in the magma, and bubbles form. This can happen when a new batch of magma joins a pocket of magma that's been sitting around below the surface. Or bubbles can form when some magma cools, crystallizing into rock. This forms a magma slushy within a volcano. Eventually there's not enough magma to dissolve all the gas, so bubbles form.

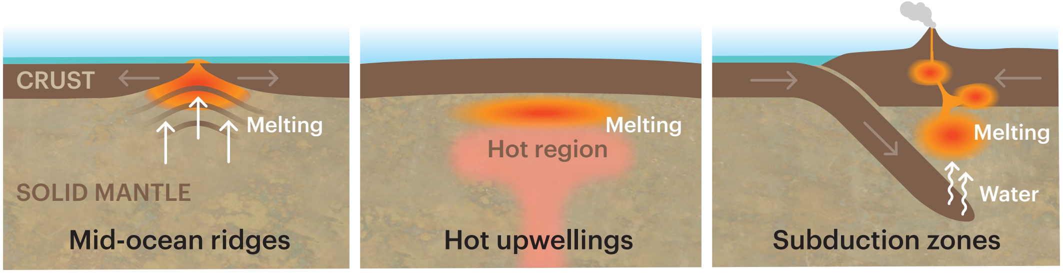
Lava — erupted magma — contains crystals that started forming on the magma's journey to the surface. These crystals hold clues about the "personality of a particular volcano," says Teresa Ubide. She's a volcanologist at the University of Queensland in Brisbane, Australia. These crystals can reveal features such as the depths at which magma is stored and the processes that trigger an eruption.

A new injection of magma to a pocket stored underground might be accompanied by earthquakes. Scientists can use the location and depth of those earthquakes to track the rise of magma, Ubide says. And gases sampled at the surface may reveal that new magma has been added to an underground cache.

Together these volcanic messages — rocks, gases and earthquakes — might help scientists catch the signs of an upcoming eruption sooner. That could give people more time to get ready. Says Ubide, "We cannot stop a volcano from erupting, but we can get as prepared as we can for it."

— *Carolyn Wilke*





All volcanic eruptions start with molten rock underground, called magma. Once that magma reaches the surface, it's known as lava.

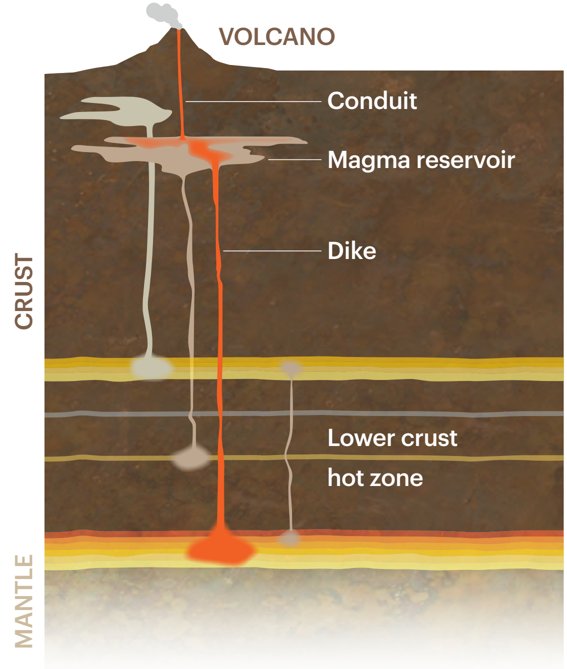
WHERE TO FIND VOLCANOES

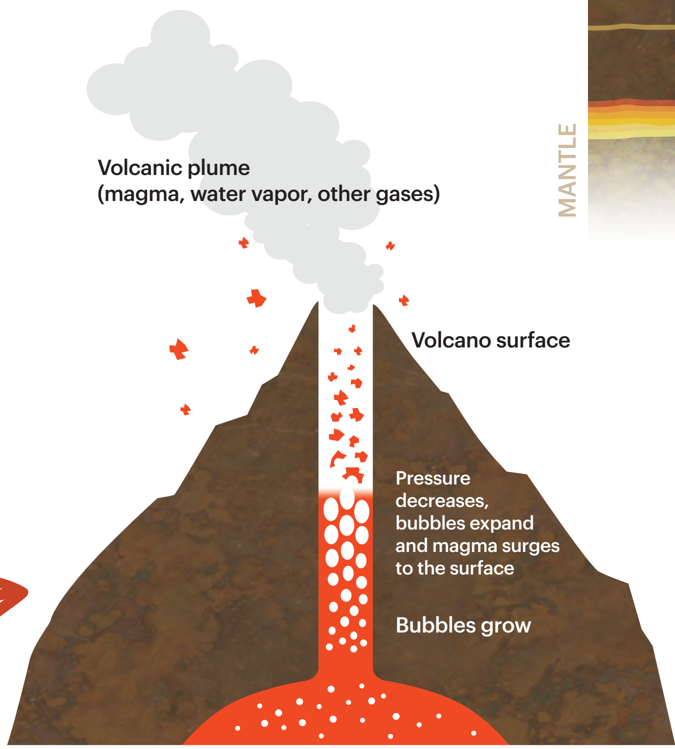
Volcanoes occur where magma — molten rock from within the Earth — breaks through to the surface, where it becomes known as lava. This regularly happens where the Earth's tectonic plates are drifting apart, such as at mid-ocean ridges (left). Here, the mantle pushes through the gap and melts, making magma.

The mantle can melt where one tectonic plate plunges beneath the edge of another (right). This is called subduction. As the subducting plate dives under the other plate, it brings water with it. That water can trigger melting. The mantle can also melt and push through the crust at places where the Earth is hotter than typical beneath the surface (center). Such hot upwellings produced the chain of the Hawaiian islands.

MAGMA STORAGE

Magma comes from the mantle, the layer sandwiched between Earth's core and its thin outer crust. The mantle is typically solid and can melt to form magma. The Earth's core heats the mantle from the bottom. In some spots, heated rock — which is less dense than the surrounding mantle — rises toward Earth's surface, but sometimes it gets stuck on the way. It can sit in melted pockets and in some places hangs around for tens, hundreds or thousands of years. In others, magma can move from mantle to crust in days or hours.





FORMING BUBBLES

What happens in a volcano is similar to what happens in a bottle of soda, says Christy Till. She's a volcanologist at the University of Arizona in Tempe. Just like magma, bottled soda contains dissolved gas. This gas stays dissolved because it's bottled under high pressure. But when you open a bottle, the pressure in the bottle decreases. The gas can no longer stay dissolved. Bubbles make a "big foam," she says. And shaking the soda will make it explode.

In a volcano, magma is stored in a magma reservoir under high pressure. Here, gases in the magma stay dissolved. As magma moves toward the surface, more bubbles tend to form as the pressure decreases. The bubbles expand as the pressure decreases. The bubble-filled magma takes up more and more space, becomes more buoyant and surges faster toward the surface.

Magmas can differ in how thick or runny they are based on their chemistry. And that can relate to how explosive an eruption is. Magmas that are thicker tend to explode when they can't hold more gas. These magmas start as a liquid containing bubbles but can become a gas that contains bits of magma. Runnier magmas tend to cause oozier, less-explosive eruptions.

MARSEL ID/SHUTTERSTOCK; ILLUSTRATION BY STEVE MCCRACKEN

FOSSILS

How big was the biggest *Tyrannosaurus rex*?

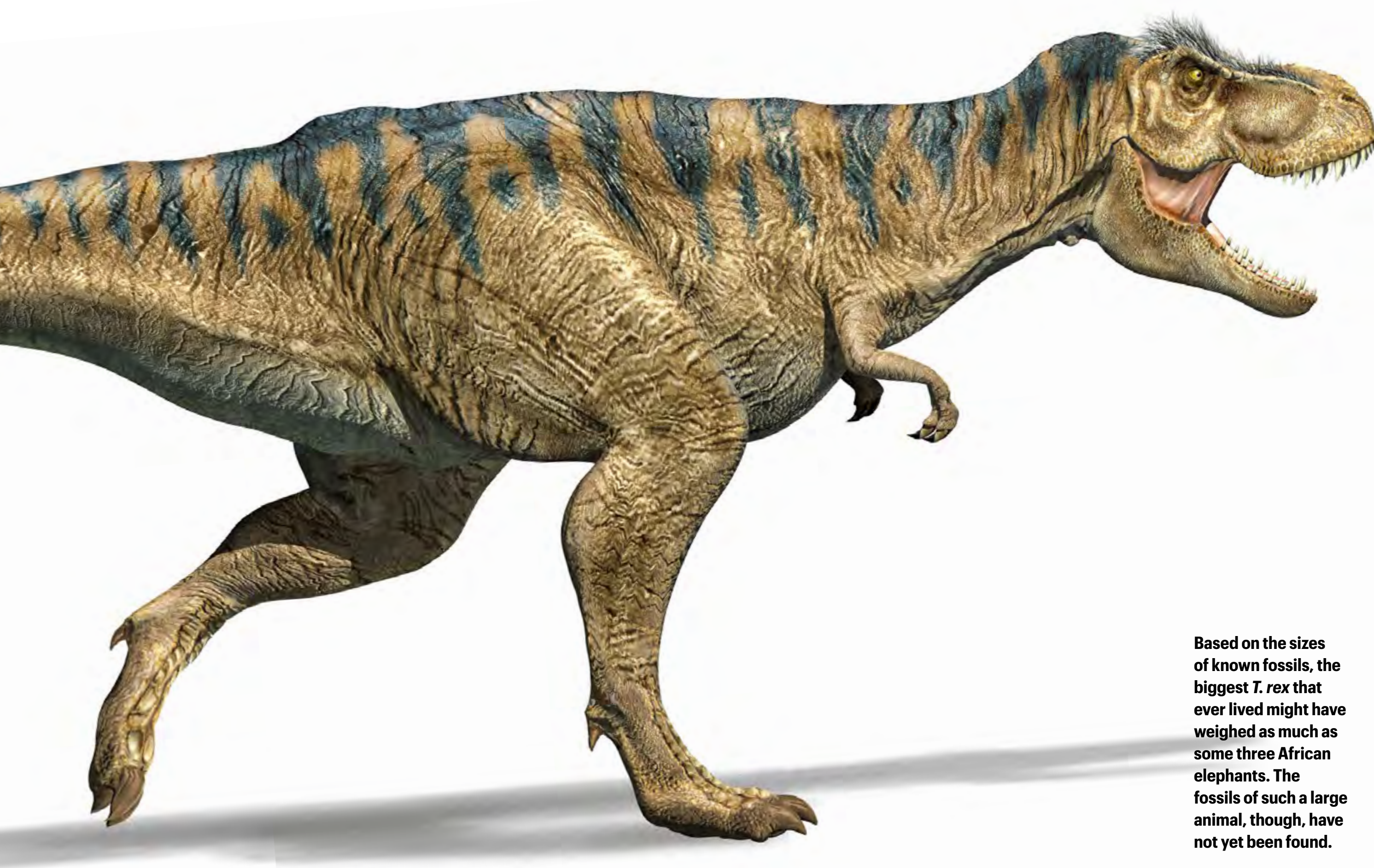
We probably haven't found the largest *T. rex* that ever lived, a new analysis contends

Tyrannosaurus rex towered over many other dinosaurs. But the biggest of the king of the dinos may have been even heftier than fossils hint.

Only around 80 fossil *T. rex* skeletons have been found so far, and not all of them are complete. "We know that there must have been millions and billions of *T. rex* on Earth," says Jordan Mallon. This paleontologist works at the Canadian Museum of Nature in Ottawa. It's unlikely that the biggest *T. rex* ever is among those 80 skeletons. After all, a group of 80 people picked at random probably wouldn't include the tallest person on Earth.

To calculate the potential size of the biggest *T. rex*, Mallon teamed up with David Hone. He's a paleontologist at Queen Mary University in London, England.

They calculated the spread of sizes across 140 million *T. rex* with a computer model. They based the spread of ages for those *T. rex* on alligators — living relatives of *T. rex*. From reports on fossils, the team worked out how *T. rex* grew as it aged. But not all dinos of the same age would be the same size. So the researchers figured out how the animals' weight may have varied by looking at the variation in alligators. Alligators are one of the largest reptiles alive today, and



Based on the sizes of known fossils, the biggest *T. rex* that ever lived might have weighed as much as some three African elephants. The fossils of such a large animal, though, have not yet been found.

MATIS75, SIMPLEVECT/SHUTTERSTOCK

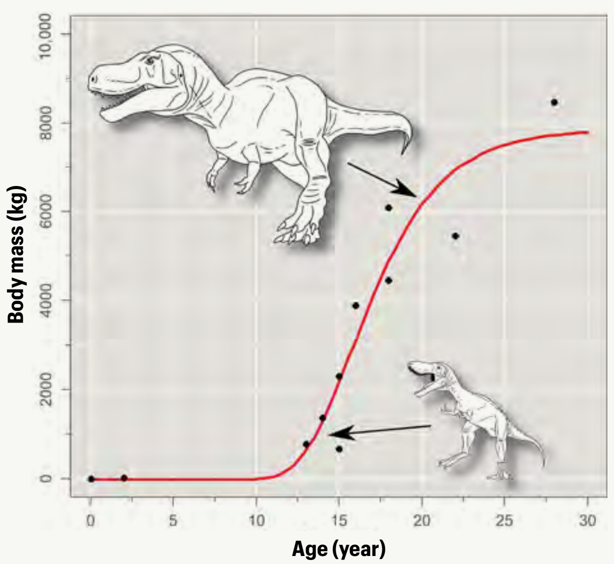
they're meat eaters like *T. rex* was. Finally, Mallon and Hone used all that information to calculate the biggest potential size in a batch of 2.5 billion *T. rex*.

"We estimate that the largest conceivable *T. rex* was probably 70 percent larger than the biggest animal we know of currently," Mallon says. "That's a bit of a mind-boggling thing to think about." This dino would be 15 meters (49 feet) long and weigh 15,000 kilograms (33,000 pounds). Mallon and Hone shared their results in *Ecology and Evolution*.

This size is just a rough estimate. Mallon and Hone don't have the fossils to back up their hypothesis. And it's not clear yet whether the bones of this enormous animal could support the weight suggested by this new study.

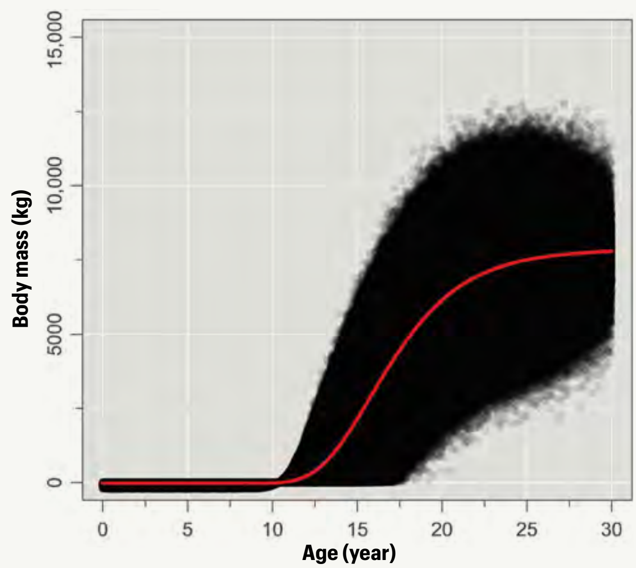
— *Carolyn Wilke*

FIGURE A



Fossils can reveal information about an animal's age and weight. For instance, patterns of growth in bones can hint at the age of an animal when it died. Based on reports of *T. rex* fossils, the researchers made a growth curve for this species. The growth curve shows how the animals' body mass increases with age.

FIGURE B



Using a computer model, the researchers estimated the distribution of 140 million theoretical *T. rex* individuals of different ages and sizes. Only around 80 *T. rex* skeletons have been found. The researchers needed more information to figure out how age and size might be spread across a much larger group. So they looked to living *T. rex* relatives. They based the distribution of ages and variation in body size for *T. rex* individuals on alligators.

DATA DIVE

1. Look at Figure A. What is the body mass of a *T. rex* that is about 12 years old? What about a *T. rex* that is 20 years old?

2. How does *T. rex*'s growth during its teenage years (13 to 19) compare with its growth after age 20?

3. Think about how humans grow. How does *T. rex*'s growth compare with that of humans?

4. Look at Figure B. What does the spread of body mass values look like for *T. rex* at age 10 and below? What does it look like for *T. rex* after age 10?

5. What is the range of body mass values for *T. rex* individuals that are 15 years old? What about 25 years old?

6. What is likely to be the age of the biggest *T. rex* that ever lived?

MALLON AND HONE/*ECOLOGY AND EVOLUTION* 2024

ANSWER

Sunny saunas help these frogs heal

Balmy brick shelters boost their body temperature to beat fungal infections

Backyard spas could help frogs fight off a deadly fungal infection. That's the finding of a new study.

Scientists in Australia placed small brick structures in sunny and shady spots to shelter frogs infected with chytrid fungus. Over a few months, the frogs kept warm long enough to fight off that fungal pathogen.

The chytrid fungus (*Batrachochytrium dendrobatidis*) invades the thin skin of amphibians. This infection disrupts the animal's ability to move and feed itself. These effects can be fatal.

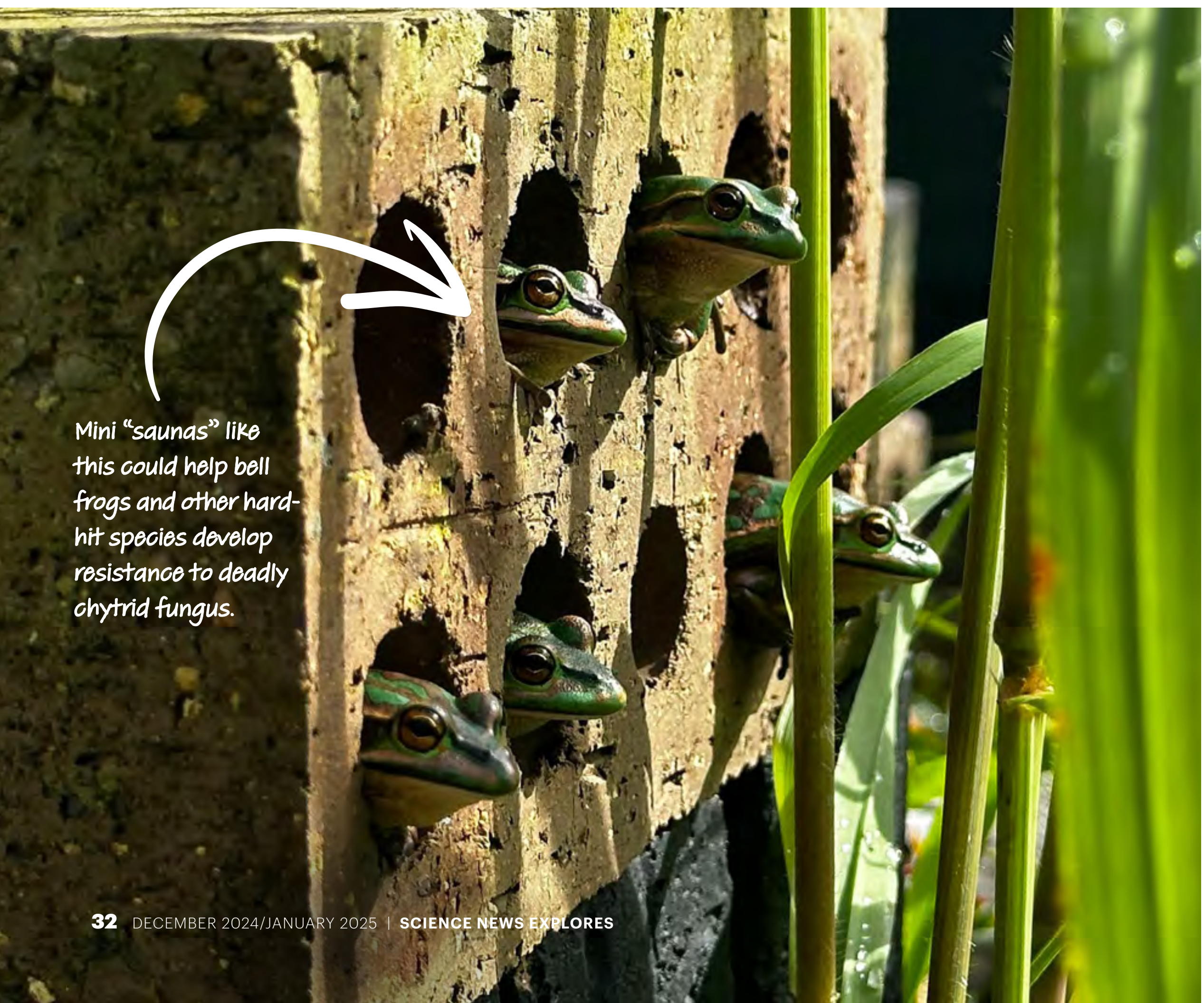
Chytrid doesn't do well in heat. Anthony W. Waddle is part of a team that tested whether warm hideouts could help frogs fight the fungus. A conservation biologist, Waddle works at Macquarie University in Australia.

The team set up 12 outdoor brick habitats in little greenhouses for both healthy and chytrid-infected frogs. Half received sunlight and half got shade.

During the 15-week study, sick frogs in sunny saunas had milder infections than those in shaded shelters and survived at a similar rate as healthy frogs. Frogs with chytrid that cleared their infections were 23 times as likely to survive reinfection as healthy frogs, the team found.

"Chytrid is a huge, massive problem," Waddle says. The study "is a glimmer of hope."

— *Skyler Ware*



Mini "saunas" like this could help bell frogs and other hard-hit species develop resistance to deadly chytrid fungus.

These green and gold bell frogs are resting in a sunbathed brick shelter built by researchers. While the shelters are low-cost and easy to make, scientists say to hold off from building a backyard frog spa just yet. They need to do more research to make sure they're effective for all species that might use the shelters.

A. WADDLE

INSIDE THE MIND OF A YOUNG SCIENTIST

A Regeneron International Science and Engineering Fair 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? Nandini Rastogi, a finalist at the 2024 Regeneron International Science and Engineering Fair, shares her experience and advice.

Q What inspired your project?

A Nandini had been learning about the gene-editing tool CRISPR. "What really inspired me is that [CRISPR] won the Nobel Prize [in Chemistry] in 2020, especially the fact that it was won by two women," she says. Since CRISPR's invention, scientists have used it for a variety of uses, such as making some vegetables more nutritious and shelf-stable. Nandini set out to use the technology to make rice more resilient to climate change. "Rice is such an important crop. It's responsible for feeding 50 percent of the [global] population," she says.

Q Did you encounter any unexpected obstacles?

A "It's really funny because the biggest challenge was actually getting the rice and growing it. You wouldn't really expect that, but it was very, very difficult," Nandini says. She grew almost 600 rice seedlings to conduct her experiment. "My project changed a lot over time. And I was adding things and taking some stuff away. A lot of it was just improvisations."

Q Do you have advice for students who are interested in science fairs?

A "It's really important to read what's already been published. Even if you don't have an idea yet but you know what you're interested in," Nandini says. "For me, that was CRISPR. But I didn't know what route I wanted to take it. Then through my research and my reading, plant sciences really caught my eye."

Regeneron International Science and Engineering Fair finalist

Nandini Rastogi

Nandini, 18, used the gene "scissors" known as CRISPR to unleash a biological cascade of events in rice cells. Activating this cascade should make rice plants better able to withstand dry and salty growing conditions — ones expected in a steadily warming climate. A high-school senior, Nandini is homeschooled in Monroe Township, N.J.