Science News Explores
November 2023

AMAZON IN TROUBLE

HOW TO STOP THE ROBOT REPLICATION APOCALYPSE P26

WHEN REPTILES TOOK FLIGHT

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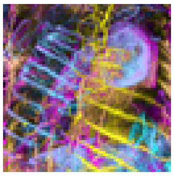

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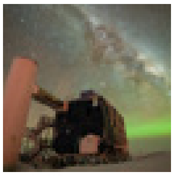

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Q Where do trees come from?

— *Shep R.*

A The word "tree" is used to describe any tall, woody plant with a single stem called a trunk. The first trees showed up around 360 million years ago. These were gymnosperms, which now also include modern conifers and gingkoes. Their sturdy wood and trunks were better at moving water and nutrients up from their roots than other plants. This allowed these trees to live in drier habitats, says Jeannine Cavender-Bares. At the University of Minnesota in St. Paul, Cavender-Bares studies how oak trees evolved. About 140 million years ago, during the time of the dinosaurs, flowering trees — known as angiosperms — emerged. These trees, which include today's oaks and maples, thrive in even more demanding environments than gymnosperms. Their wood transports water more efficiently, allowing them to grow quickly and survive droughts. They also evolved partnerships with animals that can pollinate their flowers and carry fruit long distances. Thanks to these adaptations, angiosperms make up most of the trees found today.

Q How does fermentation work?

— *Faith Y.*

A During fermentation, cells break down molecules called carbohydrates. These compounds, which include sugars and starches, are common in food. Fermentation provides energy for the cells. It also forms new molecules such as acids or alcohols. Humans have found uses for many of these chemical byproducts. A microbe called yeast, for instance, ferments sugars in bread dough to form bubbles of carbon dioxide, which make bread fluffy. And bacteria and yeast can ferment sugars and starches in corn to make fuel for cars.

Q Why do we hiccup?

— *Dia H.*

A Hiccups happen when a large, dome-shaped muscle called the diaphragm spasms. The diaphragm sits underneath your lungs and helps you breathe. When you breathe in, the diaphragm pulls down to let air into your lungs. This muscle then relaxes to force air out when you exhale. Sometimes, the diaphragm spasms when the nerves connecting it to the brain get irritated. Eating too much or too quickly, feeling excited or stressed and drinking fizzy drinks can all irritate these nerves. This causes you to suck in air. Our vocal cords snap shut to stop the incoming air, creating the strange sound we call "hiccups."

Sarah Zielinski
Editor, *Science News Explores*

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SPACE

Messages home could travel through a wormhole

Space travelers could say good-bye before a wormhole snaps shut

If you ever happen to fall through a wormhole, you won't be coming back. It will snap shut behind you. But on the way, you may have just enough time to send one last message home. That's the finding of an analysis published in *Physical Review D.*

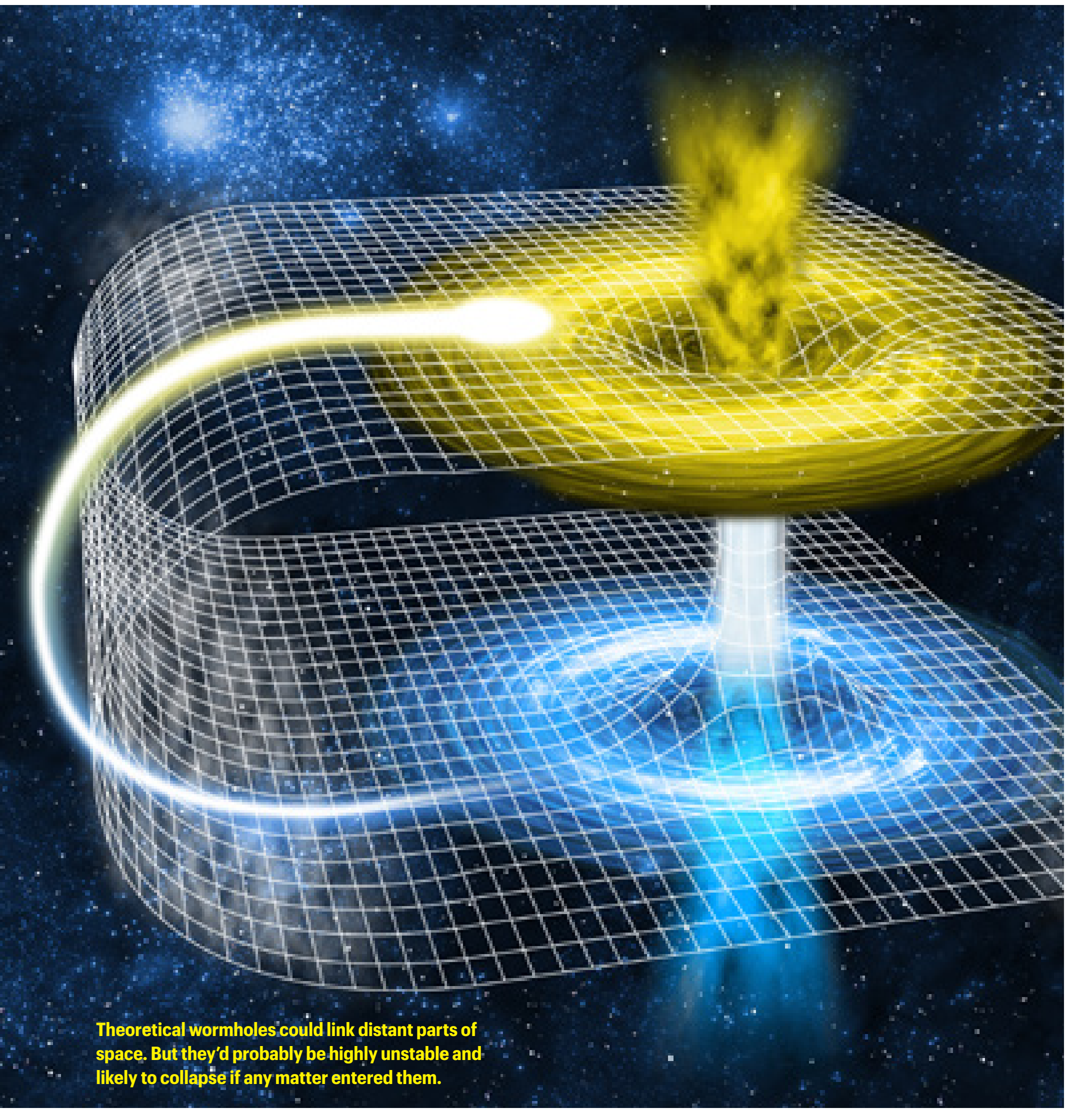
A wormhole is a tunnel in the fabric of space. It would link two points in the cosmos. Wormholes are just theoretical. That is, scientists think they could exist, but no one has ever seen one. If they do exist, wormholes could provide shortcuts to distant parts of the universe. Or, they might serve as bridges to other universes.

One of the most commonly studied types of wormholes is thought to be highly unstable. Physicists have expected it would collapse if any matter entered it. But it wasn't clear just how fast that collapse might be. Also unknown: What would it mean for something, or someone, heading into the wormhole?

In theory, says Ben Kain, you could build a probe and send it through. Kain is a physicist at the College of the Holy Cross in Worcester, Mass. "You're not necessarily trying to get [the probe] to come back, because you know the wormhole is going to collapse," Kain says. "But could a light signal get back [to Earth] in time before a collapse?" Yes, according to the computer model he and his colleagues have created.

In his team's model, Kain simulated sending probes through a wormhole. As expected, the wormhole collapsed. The probes' passage caused the hole to pinch shut, leaving something like a black hole behind. But it would happen slowly enough for a fast-moving probe to send light-speed signals back to our side — just before the wormhole completely sealed off.

Kain doesn't imagine ever sending people through a wormhole (if such tunnels were ever found). It would be a one-way trip for a probe. "But we can at least get some video seeing what this device sees."
— *James R. Riordon*



Theoretical wormholes could link distant parts of space. But they'd probably be highly unstable and likely to collapse if any matter entered them.

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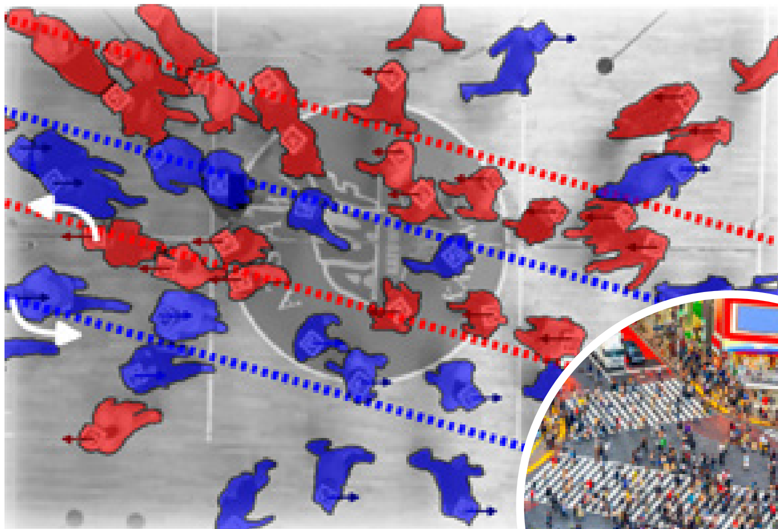
MATH

Math explains why people form lines in dense crowds

Two-way traffic flows naturally, no rules needed



Groups of people walking in opposite directions tend to form multiple parallel lanes. Telling people to pass each other on the right (white arrows) messes that up, and the lanes (dotted lines) become tilted relative to the direction people are walking (short red and blue arrows). That makes the whole crowd move more slowly.

The models help explain people's behavior at busy intersections, such as this one in Tokyo, Japan.

K. BACIK, B. BACIK, T. ROGERS; SEAN PAVONE/SHUTTERSTOCK

The school hallway between classes may seem chaotic. But there's likely more order in the crowd than you think.

In a heavy crowd with people going in opposite directions, there's often a pattern. People tend to sort themselves into lanes that run parallel to each other. In a study, researchers used math to model how those lanes form and shift. They found that people fall into a natural flow without the need for directions.

If a space is wide enough, the model shows, two groups of people passing each other head-on will form multiple lanes. Each lane will be about the width of two people.

If two groups cross paths at right angles, they still form lanes. But these lanes behave differently. Each person stays in their lane, but the lane shifts to the side as the groups cross. Attempts to direct the crowd may not help. Tell everyone to pass on the right, for example, and it will mess up this natural flow. This slows everybody down.

As it turns out, the best thing you can do to control the traffic is … nothing at all. "Anarchy is enough," says Tim Rogers.

He and Karol Bacik reported these results in *Science*. Both are mathematicians at the University of Bath in England.

Rogers and Bacik began working on crowds during the COVID-19 pandemic. They were working to design spaces where people could stay socially distanced to prevent viral spread.

Decades ago, Dirk Helbing also studied pedestrian traffic. Helbing is a physicist at ETH Zürich in Switzerland. He created a mathematical model that describes the direction a walker plans to go. It also predicts how someone will change their movement so they won't run into another person.

Rogers and Bacik added factors related to crowd patterns to Helbing's software. The resulting model describes lane formation as a result of two processes.

The first process is drift. As soon as a line of people starts to form headed one way, others going the same way are drawn to it. This encourages lane formation. People headed the other way are pushed away, into their own lane.

The second process is diffusion. Diffusion causes pedestrians to spread out from a congested space.

In general, drift leads to lane formation. Diffusion tends to erase lanes unless they are wide enough. In a crowd, Rogers and Bacik found, the end result is lanes about two people wide — just big enough to resist diffusion.

The model's predictions held up in a real crowd. The researchers filmed a group of 60 to 70 people walking through an open space. People consistently ordered themselves into lanes as expected.

This work might help avoid dangerous pedestrian situations. Past work has shown that collisions and other problems are more common where three or more routes intersect. People can die in stampedes or crowd crushes. Public spaces can be designed to help prevent such tragedies.

The takeaway: When pedestrians are traveling two ways, trust the wisdom of crowds. When there's a three-way or four-way intersection, watch out.

— *Dana Mackenzie*

MICROBES

Bacteria give some cheeses their distinct flavors

The microbes can confer a fruity, musty or oniony taste

People have been making cheese for millennia. Worldwide, more than 1,000 varieties of cheese exist. Each has a characteristic flavor. Fruity and nutty parmesan. Buttery cheddar. Musty brie. But what exactly gives each cheese its distinct flavor? Now, scientists have pinned down specific types of bacteria that produce some of cheese's flavor compounds.

Morio Ishikawa is a food microbiologist. He works at Tokyo University of Agriculture in Japan. His work aims to link various flavor molecules to specific types of bacteria. What his team has learned could help cheese makers more precisely tweak cheese flavor profiles or develop new cheeses, he says. The researchers shared their findings in *Microbiology Spectrum*.

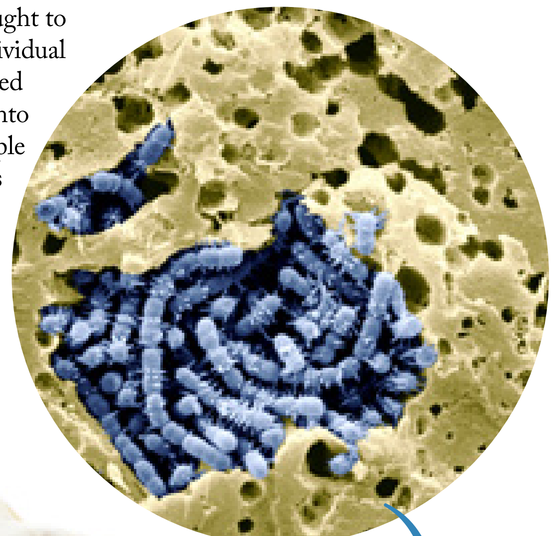
The flavor of a cheese depends on many factors. First, there's the type of milk used. Starter bacteria are added to kick off the fermentation. Then, communities of microbes move in as the cheese ripens. These, too, play a role in developing flavor.

Ishikawa likens these microbe communities to an orchestra. "We can perceive the tones played by the orchestra of cheese as a harmony," he says. "But we do not know what instruments each of them is responsible for."

Ishikawa's group sought to explore the roles of individual bacteria. The team seeded each type of microbe onto its own unripened sample of cheese. The microbes produced an array of esters, ketones and sulfur compounds. These are known to give fruity, moldy and oniony flavors to cheese. One genus of microbes — *Pseudoalteromonas* — made the most flavor compounds. Originally from the sea, this microbe has turned up in many types of cheese.

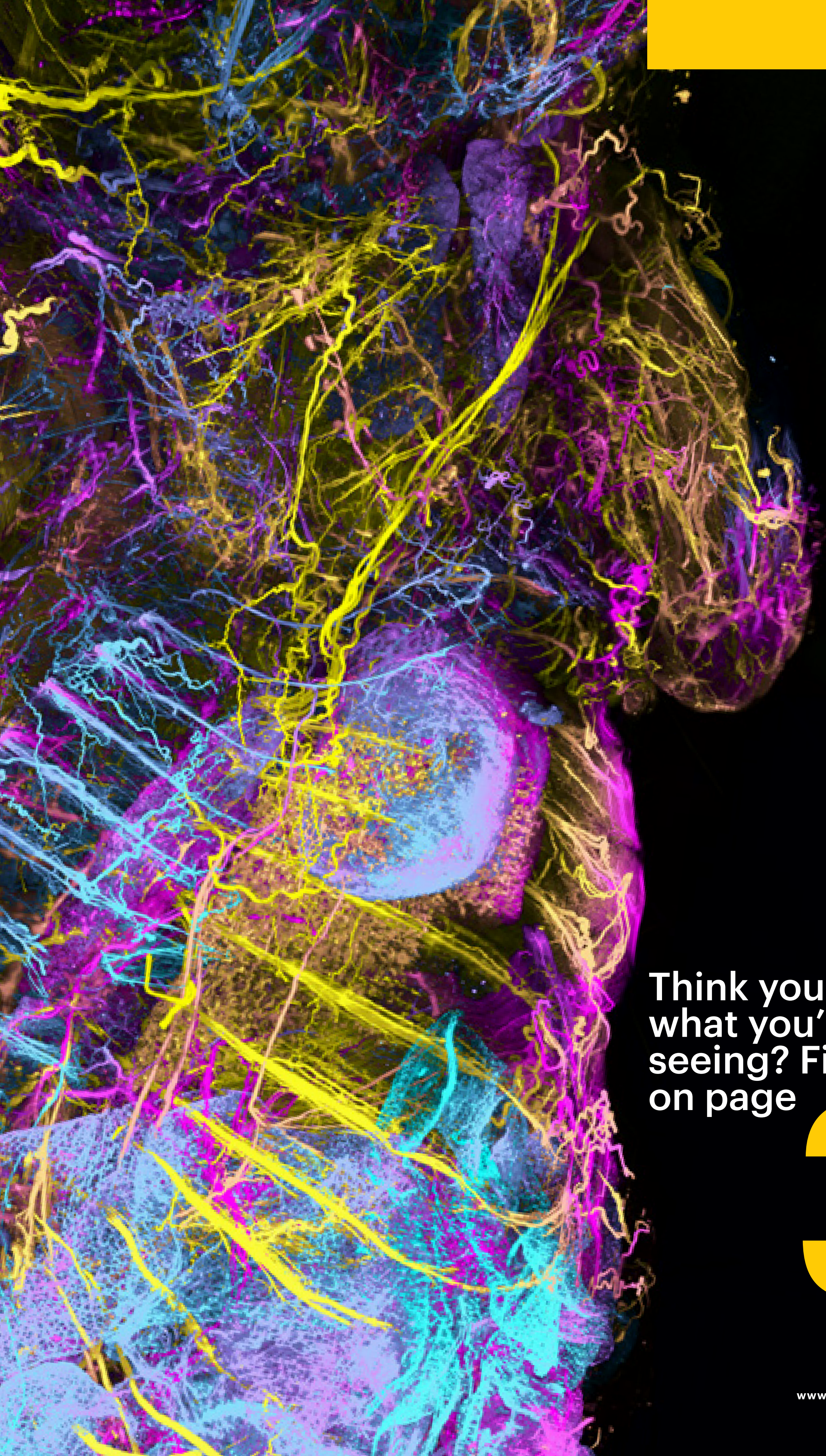
The findings could help perfect popular cheeses, Ishikawa says. And, he adds, perhaps cheese makers will learn from the findings to craft new orchestras — ones with rich new harmonies.

— *Allie Wilkinson*



Colonies of bacteria grow in cheese cultures, such as these *Streptococcus* bacteria (inset) in a goat cheese. The microbes help cheeses ripen and give them distinctive flavors.

TIMQUO/SHUTTERSTOCK; SCIMAT/SCIENCE PHOTO LIBRARY



Think you know what you're seeing? Find out on page 32

WHEN REPTILES TOOK FLIGHT

WARPAINT/SHUTTERSTOCK

By **Sid Perkins**

New fossil finds bring the world of pterosaurs to life

In an eat-or-be-eaten world, being able to fly has a lot of benefits. A creature that takes to the skies can more easily escape predators on the ground. It can drop down on its own unsuspecting prey from above. It can cover distance more quickly to find food and mates more easily. >>

So it's kind of surprising that only three groups of vertebrates have ever evolved flight: pterosaurs, birds and bats. Pterosaurs were the first vertebrate flyers. These animals arrived on the scene in the Triassic Period, perhaps as early as around 237 million years ago. That was at least 70 million years before birds appeared — and more than 180 million years before bats.

Pterosaurs' name comes from the Greek words for "wing lizards." These flying reptiles eventually lived all around the world and ate a huge variety of prey. Some grew bizarre crests atop their heads. Others sported mouths full of teeth that stuck out at odd angles. Some were so small they could sit in the palm of your hand. Other beasts soared with wingspans as wide as a fighter jet's.

"Some pterosaurs looked like creatures from your nightmares," says Brian Andres. He's a vertebrate paleontologist at the University of Sheffield in England.

The pterosaurs died out for the same reason as the dinosaurs they lived alongside. An asteroid wiped out more than 75 percent of all life on Earth about 66 million years ago. But how pterosaurs took to the air in the first place remains a big mystery. Scientists have not uncovered any fossils that directly show this transition.

But paleontologists are now discovering new clues about how pterosaurs came to rule the skies. They are learning about pterosaurs' earliest cousins. And they're figuring out how pterosaurs evolved from small, flitting creatures into such a hugely diverse group — including the biggest flyer of all time.

Where did pterosaurs come from?

Pterosaur fossils were first unearthed in the late 1700s in Germany. Scientists didn't quite know what to make of the fossils. One proposed they belonged to a weird sea creature. Another thought they were a previously missing link between birds and bats. But soon, experts settled on the fact that pterosaurs were flying reptiles, distinct from dinosaurs.

The first species discovered was named *Pterodactylus antiquus*. This species and many discovered soon after were commonly called pterodactyls. But that term officially includes only this species and some related species. This group is part of the broader pterosaur family.

The oldest known pterosaur fossils date to about 219 million years ago. At that time, pterosaurs were already able to fly. Paleontologists suspect pterosaurs originated as early as 237 million years ago. (That's when the oldest and closest relatives of pterosaurs lived. So it's probably around the time that pterosaurs split off and formed their own lineage.) But there are no known fossils to show how these earliest pterosaurs took flight.

Fossils from the time of pterosaurs' origins are scarce partly because rocks from this period are scarce. Plus, many pterosaur bones were hollow. They were easily crushed after the animals died. "Often, pterosaur remains are just a jumble of bones," says Matthew Baron. He is a freelance vertebrate paleontologist.

But there are indirect clues for what pterosaurs' immediate ancestors might have looked like. Those clues come from studies of pterosaurs and their relatives.

One of those close relatives is a critter called *Scleromochlus taylori*. Scientists think this is the kind of animal that pterosaurs might have evolved from. It was a fast-running, roughly 20-centimeter-long (8-inch-long) reptile that lived about 230 million years ago. *S. taylori* had slender limbs, small hands and straight claws. All those features suggest it lived on the ground, says Davide Foffa. A vertebrate paleontologist, he works at National Museums Scotland in Edinburgh.

A critter like *S. taylori* likely didn't spend a lot of time in trees. So pterosaurs probably didn't evolve flight by gliding down from branches. *S. taylori*'s pelvis doesn't look like it was built for leaping off the ground, either, Foffa says. That doesn't exactly match how scientists think a ground dweller would get into the air. But, Foffa notes, "it's not necessary to be a leaper to evolve flight."

Scleromochlus taylori (seen here in an artist's illustration) was tiny — only about as long as a dinner fork.

AKKHARAT JARUSILAWONG/SHUTTERSTOCK

PTEROSAUR TIMELINE

Pterosaurs originated during the Triassic Period (about 252 million to 201 million years ago). That was well before the evolution of the other two groups of flying vertebrates — birds and bats. Pterosaurs died out in the same mass extinction that killed off non-bird dinosaurs.

237 MILLION YEARS AGO
Suspected origin of pterosaurs

230 MILLION YEARS AGO
Oldest known dinosaur fossil

What did pterosaurs eat?

Figuring out what pterosaurs ate often involves a bit of guesswork.

Some fossils preserve stomach contents, which directly show an animal's last meal. But most of the time, researchers must use indirect evidence. They might imagine what a pterosaur ate based on where it lived, or how its body compares with modern creatures whose diets are known. Those lines of evidence hint that various pterosaur species ate everything from insects and worms to fish and crustaceans. Some may have even eaten small land vertebrates.

Other types of evidence help paint the picture of pterosaur dining, too.

Take *Kunpengopterus sinensis*. This pterosaur lived in what is now China between 165 million and 153 million years ago. Fossils of this species were recently unearthed alongside gastric pellets full of fish scales. (Gastric pellets are bits of non-digested food that modern birds, such as owls, throw up after eating.) Those scaly bits strongly hint that *K. sinensis* ate fish.

Still other evidence comes from fossilized poop. If ancient poo can be linked to the creature that made it, its contents were likely part of that animal's diet, says Martin Qvarnström. He's a vertebrate paleontologist at Uppsala University in Sweden.

A few years ago, Qvarnström and his colleagues analyzed three bits of fossil poo from more than 150-million-year-old rocks. The rocks, from south-central Poland, also preserved many pterosaur footprints.

One piece of fossilized poop contained many shells of single-celled organisms called foraminifera. Another contained bristles from what may have been marine worms. Qvarnström's team shared the findings in *PeerJ*.

For pterosaurs to eat such tiny prey, they must have been filter feeders, like modern flamingos, the team suggests. That would have required jaws full of closely spaced teeth. The filter-feeders from Qvarnström's study didn't leave behind any skeletons, only footprints. So it remains a mystery what they looked like or how big they were. But maybe they resembled another newly discovered species.

Pterosaurs (left, a fossil pterosaur) may have evolved from small ground-dwelling reptiles similar to *Scleromochlus taylori* (below), which lived during the late Triassic Period.

GABRIEL UGUETO

219 MILLION YEARS AGO
Oldest known pterosaur fossil

150 MILLION YEARS AGO
Oldest known bird skeleton

66 MILLION YEARS AGO
Asteroid hits and pterosaurs, along with non-avian dinosaurs, go extinct

52 MILLION YEARS AGO
Oldest known bat skeleton

This one is called *Balaenognathus maeuseri*. Its fossils were unearthed in rocks that formed between 157 million and 152 million years ago in what is now Germany.

B. maeuseri had a wingspan of about 1.2 meters (nearly 4 feet), similar to a large flamingo. The pterosaur also had a bill about 10 centimeters (4 inches) long. Shaped like a spatula, that bill sported at least 480 teeth. Those long, thin teeth were not strong enough to clamp down on struggling prey. But many of them had tiny hooks on their ends. The crochet hook–like features probably helped the pterosaur filter and trap itty-bitty prey.

To forage, this long-legged creature probably waded through shallow water. It would have faced the flow and opened its jaws just enough for plankton-rich water to flood in, says David Martill. Then, water drained away through the teeth, leaving behind the food. Martill is a vertebrate paleontologist at the University of Portsmouth in England. He and his colleagues described *B. maeuseri* in *PalZ*.

TOP INSET: D. MARTILL *ET AL*/*PALZ* 2023; MEGAN JACOBS/UNIV. OF PORTSMOUTH

Top: A pterosaur named *Balaenognathus maeuseri* was probably a filter feeder, much like modern flamingos. Little hooks at the ends of *B. maeuseri*'s skinny teeth (inset) probably helped the pterosaur trap tiny prey.

How fast did pterosaurs grow?

The discovery of one fossil forced researchers to rethink how quickly pterosaurs got big.

The well-preserved fossil was embedded in rock from about 167 million years ago on Scotland's Isle of Skye. The skeleton is missing only parts of the skull, wings, hind limbs and tail, says Natalia Jagielska. She's a vertebrate paleontologist at the University of Edinburgh. She and her colleagues dubbed the creature *Dearc sgiathanach*. In Scottish Gaelic, that means "winged reptile from Skye."

Microscope views of some of *D. sgiathanach*'s bones revealed features similar to the growth rings in trees. The pterosaur appears to have been at least 2 years old and still growing when it died. Based on the size of the pterosaur's upper-arm bone, the youngster likely had a wingspan of around 2 meters (around 6 feet). Jagielska and her colleagues shared that result in *Current Biology*.

The team looked at the growth patterns of closely related pterosaurs, too. This gave them an idea of how big *D. sgiathanach* could have gotten when it grew up. The data suggest that an adult of this species would have had a wingspan of at least 2.5 meters (8 feet). Trumpeter swans have wings about that big.

Before the discovery of *D. sgiathanach*, scientists thought pterosaurs stayed small until the late Jurassic Period or later. That was between about 160 million and 145 million years ago. At that point, pterosaurs would have been competing with newly evolved birds for food such as insects. Evolving bigger bodies would have helped pterosaurs seek out new food sources. But *D. sgiathanach* evolved tens of millions of years before the first birds took wing. So pterosaurs must have faced some other pressure to get big sooner.

How big was the biggest pterosaur?

Of all the pterosaurs ever found, none has captured imaginations as much as *Quetzalcoatlus northropi*. This beast was the largest creature to ever take flight. A fictionalized version of it even takes down a plane in the film *Jurassic Park: Dominion*.

Only a handful of *Q. northropi* fossils have been found. Most of them have turned up in southwestern Texas. The rocks they were found in formed between 69 million and about 66 million

Bottom: The recent discovery of *Dearc sgiathanach* (illustrated next to a dinosaur) suggests that pterosaurs got big by at least the middle of the Jurassic Period.

N. JAGIELSKA

Giraffe-sized ***Quetzalcoatlus northropi*** **was the largest flying creature that ever lived. It may have foraged in meadows and shallow waters, as modern herons and storks do.**

years ago. That means some of these pterosaurs could have been alive when or just before the dino-killing asteroid struck Earth, says Tom Lehman. He's a vertebrate paleontologist at Texas Tech University in Lubbock.

Much of what scientists suspect about *Q. northropi* stems from a related species. Called *Q. lawsoni*, its fossils are much more common. *Q. lawsoni* is thought to have had a wingspan of about 4.5 meters (almost 15 feet). It lived in the same area around the same time as *Q. northropi*, Lehman says. But his team estimates that *Q. northropi* had a much bigger wingspan: about 10 meters (33 feet).

Based on their measurements, the researchers made life-size models of *Q. northropi*'s bones. The models let them see how the creatures would have moved.

"Their back is so short and their legs are so long that they couldn't walk like other [four-legged creatures]," says Kevin Padian. He's a vertebrate paleontologist at the University of California, Berkeley. "Their forelimbs are so long, they couldn't avoid touching the ground." Yet pterosaur footprints suggest that those forelimbs weren't helping propel the creature forward when it walked. Instead, they appear to have been used for support only, like walking sticks.

It appears that *Quetzalcoatlus* could reach the ground with its long, toothless beak — and even lower, into bodies of water. Once it grabbed its prey, it could tilt its beak to the sky and swallow its victims whole. Padian and colleagues suggest that this pterosaur patrolled meadows or waded in shallow waters. (This is what modern-day storks and herons do.) There, the creatures would have plucked up fish, mammals or even small dinosaurs using a beak that acted like chopsticks.

The sight of a giraffe-sized predator stalking through swamps would have undoubtedly been impressive. "The worst thing about pterosaurs," Andres says, "is that they're no longer around."

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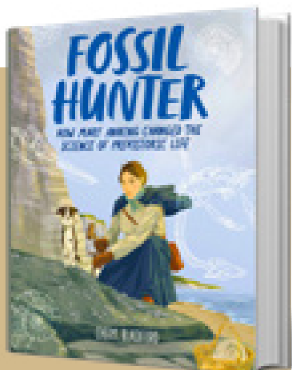
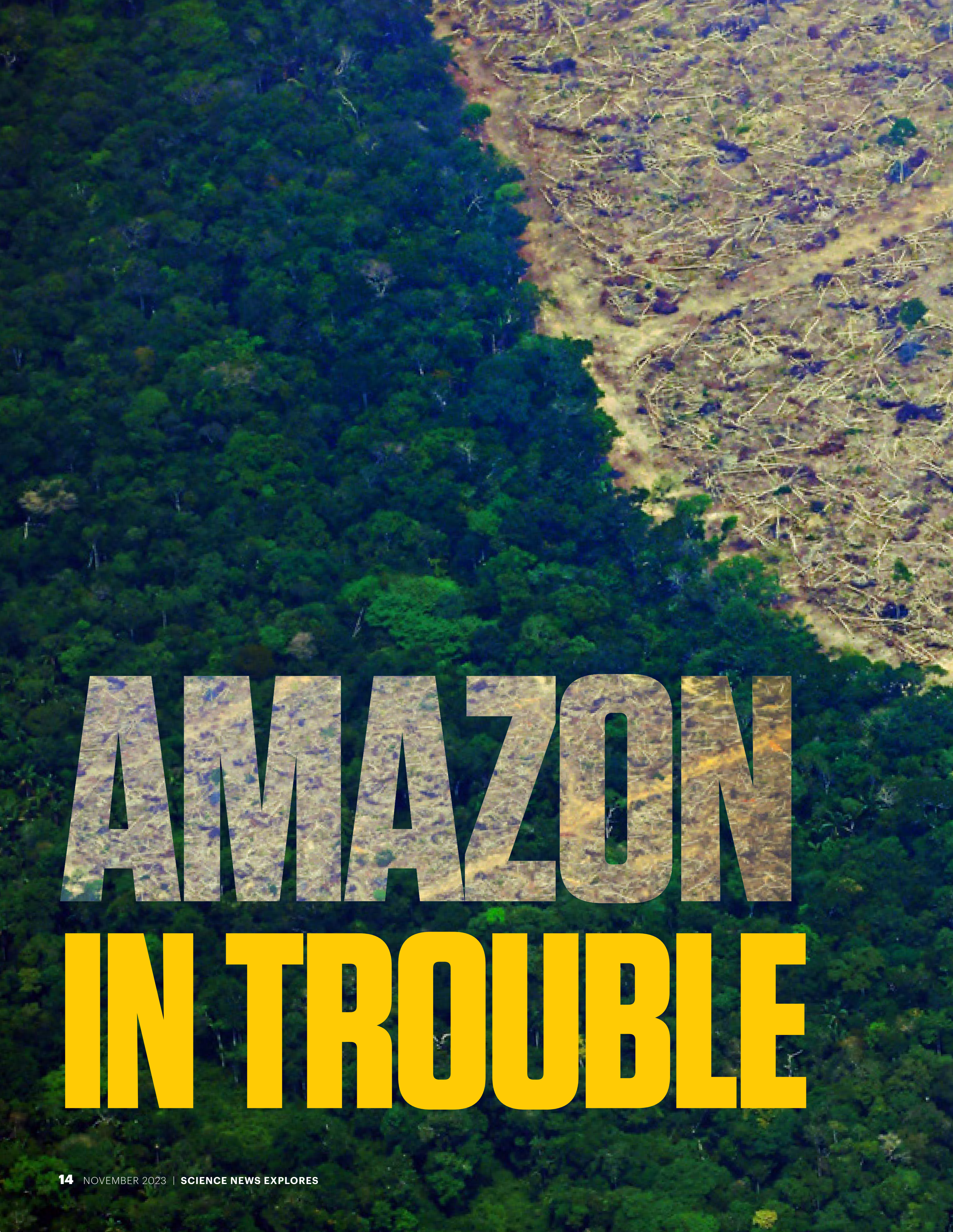


Fossil Hunter: How Mary Anning Changed the Science of Prehistoric Life

—by Cheryl Blackford

Mary Anning taught herself science by copying articles and dissecting animals. Learn more about one of history's greatest fossil hunters in this illustrated biography.

JAMES KUETHER; CLARION BOOKS



AMAZON IN TROUBLE

CARL DE SOUZA/GETTY

By **Nikk Ogasa**

What do we need to know to save it?

A shoreline winds through the central Brazilian state of Mato Grosso. But rather than water, it's the edge of a sea of nearly 400 billion trees. Here, the Amazon rainforest rubs up against the Cerrado, one of the world's largest savannas.

The two are distinct worlds. One, a wet and verdant jungle. The other, relatively dry and blanketed in wild grasses, shrubs and small trees. But no clear line marks the end of one and the start of the other. Instead, there's a messy transition zone, a jumble of vegetation that grows taller toward the rainforest. Over thousands of years, the boundary has ebbed and flowed. >>

Past shifts have been driven by natural fluctuations in climate. "But in this formula is a new element," says ecologist Beatriz Marimon. Humans, with their ambitions to control the land. She works at Mato Grosso State University in Nova Xavantina.

About half a century ago, people started streaming into the region. They came in along new highways and cleared forest for farmland and cattle ranches, Marimon notes. Fifty years is a blink in the life span of a forest nearly as old as the dinosaurs. But it's plenty of time for humans to remodel a landscape.

The Amazon is in grave trouble, scientists agree. Human activities and climate change are worsening the dry season. In some areas, it now lasts four to five weeks longer than in past decades. Fires have also become more fierce. All of that is stressing the forest out.

A multitude of poorly understood factors all affect the forest's fate: The many types of human actions. Climate change. Plants' diverse biology and adaptations. The reach of underground water. What's more, different parts of the forest may react to threats in different ways.

Ongoing research is clarifying if, when and where conditions may push the forest beyond its ability to sustain itself. Such work could help inform efforts to save the forest from potential widespread dieback. These are urgent tasks, says Matt Finer. He directs the Monitoring of the Andean Amazon Project, or MAAP, based in Washington, D.C. It's not yet clear how much time may remain to save the forest, or if it's already at the brink of some irreversible shift. In either case, he says, "we're kind of probably the last ones with the option to ponder that."

Felling the Amazon

The Amazon is an ecological marvel. It accounts for more than half of Earth's remaining tropical forests. Roughly 17 percent of the world's river water flows through here. It also houses about a quarter of all land-dwelling species. That vast bounty includes its flowers: More types of flowers bloom in the Amazon than there are stars visible to the naked eye in the night sky.

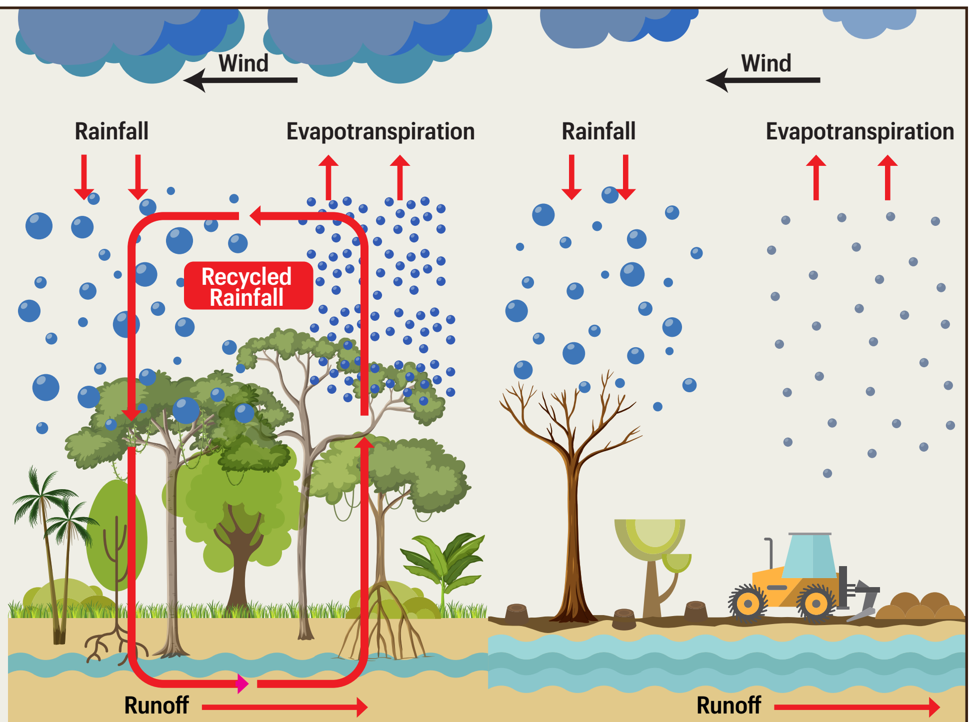
Each year, the rainforest absorbs about 5 percent of the world's annual human-caused CO_2 emissions. Amazon carbon reserves weigh as much as 230 million blue whales.

Much of the forest's vitality is sustained by the trade winds. These gusts from the Atlantic Ocean blow east to west across the landscape. The winds carry sea-born moisture into the eastern parts of the forest, where it falls as rain. Once fallen, some of this water evaporates back into the air. Much of it soaks into the soil. It's absorbed by roots, courses up through plant stems and tree trunks, and is then transpired through leaves back to the sky. A single tree in the Amazon can pump 500 liters of water into the atmosphere each day.

Winds whisk the released moisture hundreds of kilometers deeper into the forest, where it rains on more trees. A single molecule of water may repeat this cycle more than five times before exiting the forest basin. The Amazon waters itself.

THE RAINFOREST AS RAINMAKER

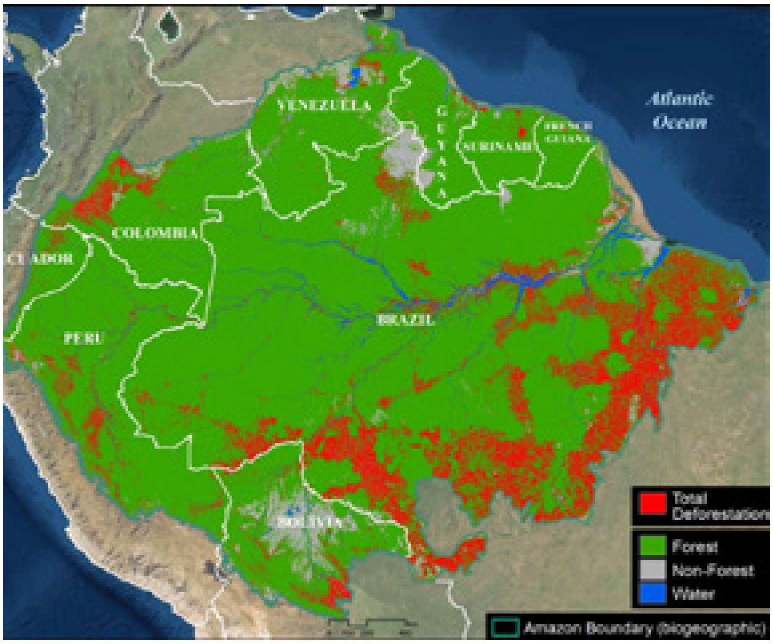
Winds carry moisture into the eastern Amazon, where it falls as rain. Much of it soaks into the ground. Some water is taken up by roots and transpired through leaves back into the air. Winds then carry this moisture deeper into the forest, where this cycle repeats (left). But cutting down trees reduces the water taken up by roots and returned to the air (right). That breaks the cycle, increasing local runoff and reducing rainfall in the forest's interior.



OLHA1981, BLUERINGMEDIA/SHUTTERSTOCK; SOURCE: L.E.O.C. ARAGÃO/*NATURE* 2012

But this cycle relies on intact forests. If too much of the eastern forest is lost, moisture may run off and out of the basin rather than sail into deeper sections of the forest that need it, Finer says. "That deforestation cuts off the whole system."

Already, about 30 percent of the Amazon's eastern third has been cleared. Finer and colleagues shared that finding in a 2022 report. If that destructive trend continues, it could cut off the Amazon's skyborne streams of moisture, he says.



ACA/MAAP

The Amazon is the largest forest in the world, but it is shrinking. About 17 percent of this area has been cleared below historic levels. Much of that forest loss has taken place in the Brazilian part of the forest, especially in the east.

NIGEL DICKINSON/ALAMY

Parts of the northern Amazon are bordered by savanna. Research suggests that much of the Amazon could collapse into savanna and shrubland if deforestation and climate change continue.

Hidden damage

Deforestation doesn't just harm the tracts where trees are felled. Its warming and drying effects may spill over into the edges of intact forests nearby. That's one of the many ways forests become degraded. Degradation is often less obvious than outright clear-cutting. But it can have big impacts on which species thrive there.

And it's pervasive. About 38 percent of the remaining Amazon rainforest has been degraded, researchers reported in January in *Science*. That's an area equivalent to nearly a third of Brazil, or more than three times the size of Texas.

Degradation can take many forms, and its consequences may vary depending on the damage's nature, intensity and scope. For instance, fires can raze parts of the rainforest. If the burned land is left alone, Amazon plants typically return on their own. Seeds and roots in the soil can resprout from the ash. But severe fires may destroy these buried remnants too. Lacking some species, the forests that grow back often have lower diversity than their predecessors. Such effects can be seen where humans have repeatedly burned the land. After just two decades, the forest may recover more slowly and be dominated by just a few fire-resistant species.

Selective logging is another problem. The practice can poke holes in a forest's closed canopy, allowing in sunlight. Sun can heat and dry the understory, killing some plants, exacerbating fires and pushing out animals.

Any place degradation reduces vegetation, it also shrivels transpiration. For each leaf lost, the forest's moisture loses one little gate back into the sky. During a typical dry season, severely degraded forests may release 34 percent less water back to the sky. That loss directly sabotages the forest's rain recycling, imperiling trees that depend on it.

A drier future

The Amazon isn't just dealing with deforestation and degradation, of course. Drought and warming are huge challenges. Over the last 50 years, the average annual temperature across the forest has climbed at least 0.6 degrees Celsius (1 degree Fahrenheit). And exceptionally severe droughts have struck the forest three times in the last two decades. Some climate models suggest that by 2060, such extreme drought conditions could occur as often as 9 in every 10 years.

Climate shifts could push patches of the rainforest to transition into different states. Wetter areas could become savanna, or a more open or dry forest. Such transitions could occur in bits and pieces and at different times.

Often, talk of "the Amazon" evokes visions of dense, dripping vines and trees. But the forest is actually a messy medley of ecosystems. There are the vivacious várzeas — floodplains occupied by dense forests, grasslands and swamps. For months of the year, they are flooded by nutrient-rich water. Várzeas sustain an abundance of fauna and flora.

The swamp forests, or igapós, also flood seasonally. Their waters, though, are dark and nutrient-poor, steeped in tannins leached from decaying plants. Igapó trees grow slowly. But their wood is dense and excels at storing carbon.

Then there are the diverse terra firme. These tall, thick, closed canopy jungles cover the uplands, above the flood line. Around 16,000 tree species have been cataloged in the basin, though just under 230 species are thought to dominate the forest.

But research projects often simulate the Amazon's vegetation as more or less uniform, says Marina Hirota. She's an Earth system scientist at the Federal University of Santa Catarina in Florianópolis, Brazil. Every tree is considered the same: a broadleaf evergreen tree. Researchers rely on these simplified "big leaf" models because they lack better data, Hirota says. But the models don't do the forest justice.

Taking a closer look at the forest's complexity may reveal ways in which it is more — or less — resilient than we think.

Over millions of years, the forest's varied plant communities have adapted to local rainfall patterns. Too-simple models may fail to reflect how diverse Amazon ecosystems cope with stress like climate change–induced droughts.

Tree species that live in more drought-prone areas, for instance, may be better adapted to drier conditions. And forests that stand atop shallow groundwater could fare well during mild droughts but be ruined by severe ones, says ecologist Flávia Costa. Costa works at Brazil's National Institute of Amazonian Research in Manaus.

Hirota and others are studying Amazonian plants' "life strategies" for coping with drought. The goal is to use the data to improve existing vegetation models. Similar efforts are needed for groundwater effects, Costa says. Better data will inform more accurate models. In turn, these will better predict how different parts of the Amazon may respond to climate and land use changes.

What comes next?

Today's computer models are trying to open doors into the future and see what's ahead for the Amazon. But with the data available today, says David Lapola, "we're looking into a room from the hole of the lock." He's an Earth scientist at the University of Campinas in Brazil.

That leaves a wide range of possible outcomes. On one hand, a web of local changes and diebacks spread across the forest is worrisome. But that fragmented fate could also carry hope that the whole forest isn't a lost cause.

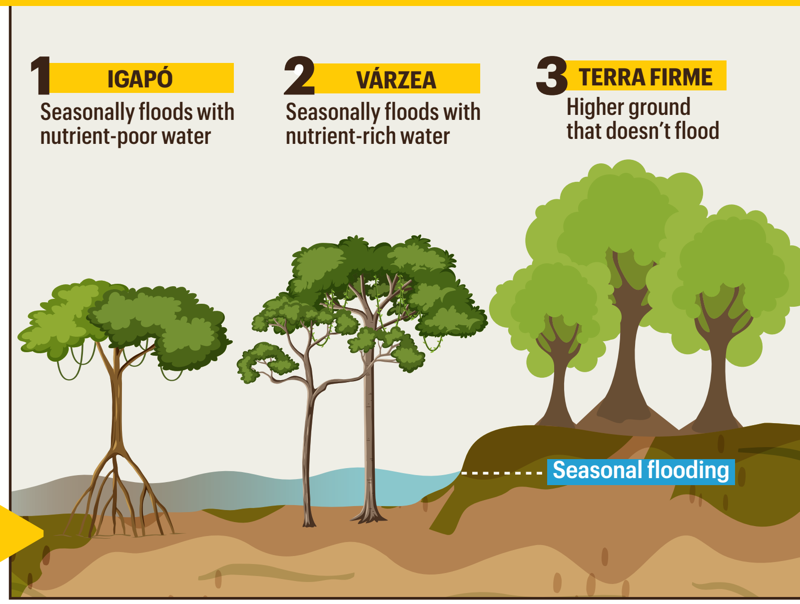
And people's resignation is a serious concern, says Carlos Nobre. An Earth systems scientist, he works in Brazil at the University of São Paulo. "If we take for granted" that the Amazon is doomed, he says, "then people say forget it."

Not all human activity has harmed the forest. People from Indigenous groups have acted as stewards of the forest's biodiversity for millennia. Plants that

The Amazon contains a diverse mix of ecosystems. Three common ones are shown here (above, diagram). (1) Igapó swamp forests flood seasonally with low-nutrient water. The slow-growing trees are good at storing carbon. (2) Várzeas also flood seasonally but with nutrient-rich water. Lots of flora and fauna live in these forests and grasslands. (3) Terra firme sits at higher elevation, where floods can't reach. Around 16,000 tree species have been found here.

(TOP FROM LEFT) IMAGEBROKER.COM GMBH & CO. KG/ALAMY; EUG PNG, THIAGO ORSI LARANJEIRAS/SHUTTERSTOCK; OLHA1981, BLUERINGMEDIA/SHUTTERSTOCK

ECOSYSTEMS OF THE AMAZON



they domesticated long ago, such as Brazil nut trees and umari trees, are still abundant in some areas. Today, Indigenous territories as well as protected areas make up more than half of the forest in the Brazilian Amazon. Since 2000, only 5 percent of forest loss has occurred on these grounds. Working with the people living in these areas to stave off further deforestation and degradation will be key, researchers say.

But the forest's fate will depend on more than restoration and conservation efforts in South America. Greenhouse gases emitted by nations around the world are driving many of the challenges the Amazon faces.

This also means that people around the world have some power to counter the negative effects. People should stop buying products that support deforestation, Marimon urges. Amazonian beef is a big one. Brazil is the world's largest exporter of beef. Around 75 percent of the land deforested in the Amazon is used as pastures for grazing cattle.

Ultimately, the Amazon is a critical part of many global systems. Its biodiversity is irreplaceable. Its plants and soil house colossal carbon stores. Wind and ocean currents connect the forest to regions across the globe. Temperature fluctuations in the Amazon have been linked to effects on ice in the Tibetan Plateau and Antarctica. Taking real steps to protect this ecological jewel is in the best interest of all who call this planet home. And the best time to take those steps is now.

JACQUES JANGOUX/ALAMY

Brazil is the world's largest exporter of beef. Around three-fourths of the Amazon's deforested land is used as pastures for grazing cattle.

This ecologist is looking at the Amazon's past to save its future

Carolina Levis turns to Indigenous knowledge to understand Earth's largest rainforest

One of ecologist Carolina Levis' favorite memories of working in the Amazon rainforest involves ceramics. Early in her career, she visited an Indigenous town to learn more about the history of the people there. She noticed beautiful pottery lying on the ground. The pieces, she learned, came from the ancestors of those people. "Some were more than 500 years old," says Levis.

But people have left more than ceramics behind in the Amazon. Today, over 2 million Indigenous people call the Amazon home. Their ancestors have been growing crops such as squash, tubers and nut trees for thousands of years. At the Federal University of Santa Catarina in Florianópolis, Brazil, Levis is studying how these practices led to the variety of plants currently found in the rainforest. She wants to know how Indigenous knowledge can be used to help protect the Amazon rainforest. In this interview, Levis shares her experiences and advice with *Science News Explores*. (This interview has been edited for content and readability.) — *Aaron Tremper*

Q How do you get your best ideas?

A Sometimes when I go to bed, I'll think about my work while drifting off. I'm not entirely sure if I'm dreaming or not. When I wake up, though, everything is clearer, and I know what to do. Right now, I'm working with Indigenous researchers. They told me that they create new knowledge through dreaming. I found that interesting because we don't practice that in formal science.

Q How has that influenced your current work?

A I'm working on an article that's about how we can engage Indigenous knowledge in conservation science. We've been holding small meetings with five Indigenous researchers and five non-Indigenous researchers. We talk about how they view the Amazon and produce their knowledge. We are trying to understand how we can maintain the Amazon in the future.

These conversations led me to start reflecting on how we do science. Sometimes, we find a lot of differences in the way that we do things. On one hand, we need to be objective in science and follow a protocol. But to have innovative ideas, we also need to not just follow procedure. We may also be inspired by an experience or conversation that provides us with a different insight.

Q What is one of your biggest successes?

A Having my work published in the scientific journal *Science*. I felt that our message reached a big audience. It was great to see people acknowledging our work. In my personal life, the birth of my son two years ago really transformed my life.

Q What is a big challenge in your work?

A Doing research in the field. We often go to really isolated places when doing field work. We are aware that if something happens to us, we can die. If a venomous snake bites you out there, you are far away from a hospital. We need to manage those feelings while doing our work and collecting data.

INSET: CLAIDE MORAES; BERNARDO FLORES

Levis is a proud mom. In 2022, she brought her son Davi, then age one, with her to an important meeting between researchers and Waiwai Indigenous people.

Carolina Levis has traveled deep into the Amazon (here, she's on a boat returning from Lake Acará in 2013) in her efforts to better understand how Indigenous knowledge can help protect the rainforest.

CHEMISTRY

Kimchi chemistry

Investigate chemical reactions in homemade kimchi

By Science Buddies

Kimchi is a popular Korean dish made with cabbage, other vegetables and spices. Making it involves fermentation — a process in which microbes in the cabbage break down carbohydrates in the ingredients, creating glucose and lactic acid. In this experiment, we monitor the glucose levels and acidity, or pH, in homemade kimchi as it ferments.

OBJECTIVE

Investigate the chemical changes that occur in the process of making kimchi

Kimchi by Science News Explores reader Addie Mason

EXPERIMENTAL PROCEDURE

1. Prepare four identical batches of kimchi in resealable bags following our recipe (use the QR code below) or your own.

2. Use pH and glucose test strips to measure the starting pH and glucose levels of each bag of kimchi. Record the data in a notebook.

3. Place all four bags in a cool, dry place at room temperature. Allow them to ferment for three days.

4. Measure the pH and glucose levels of each bag at least three times per day. Log those data, as well as the time and date of each measurement, in your notebook.

5. Place all four bags of kimchi in the refrigerator for three weeks.

6. Continue measuring and recording the pH and glucose levels of each bag once per day.

7. Create a graph with time on the x-axis and pH on the y-axis. Create another graph with time on the x-axis and glucose level on the y-axis.

8. Graph the data for each bag of kimchi separately, then graph the average pH and glucose levels across all four bags.

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

Kimchi is a popular Korean dish made from cabbage, cucumbers or other vegetables. Like rice, kimchi is a staple of Korean cuisine and is often served with other small side dishes.

A. MASON; FUNNY FACE/SHUTTERSTOCK

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 will 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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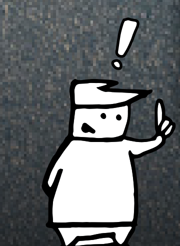
AMBER	DEGRADE	MIGRATE	PTEROSAUR
ANARCHY	FERMENT	MODEL	ROBOT
BACTERIA	FLAVOR	MOLECULE	RAINFOREST
CABBAGE	FOSSIL	NEUTRINO	VERTEBRATE
CLIMATE	GALAXY	PAPERCLIP	WINGS
COLLAPSE	INDIGENOUS	PETRIFIED	WORMHOLE



PATPITCHAYA/SHUTTERSTOCK

SPACE

The Milky Way gets a ghostly new portrait

The new map is the first of our galaxy made without light

The Milky Way is visible in the night sky over an aboveground lab that's part of the IceCube neutrino detector in Antarctica. Neutrinos spotted by the detector were used to draw a new type of map of our galaxy that differs from the usual look (as shown in an artist's concept, far right).

YUYA MAKINO, ICECUBE/NSF

Ghostly particles from space are giving us a new view of our galaxy.

Known as neutrinos, these subatomic particles have little mass and no electric charge. They're sometimes called "ghost particles." That's because they easily pass without a trace through gas, dust and even stars. About a hundred trillion neutrinos pass through every human each second. High-energy neutrinos zip everywhere throughout the cosmos, carrying information about distant places. But where the particles come from has typically been a mystery.

Now, researchers found the first signs of high-energy neutrinos coming from within our Milky Way. A team mapped the particles to create a new image of our galaxy. It's the first made with something other than light. Our galaxy's new portrait was unveiled in *Science*.

The map also hints at possible sources for these high-energy neutrinos. They could be the remains of past supernovas — star explosions. Or they might come from the cores of collapsed supergiant stars or other unidentified objects. More research is needed to figure out the sources for all these neutrinos.

Only a few high-energy neutrinos have been traced back to their potential birthplace before. Those all came from outside the Milky Way. Two appeared to come from black holes shredding their companion stars. Others came from a type of galaxy called a blazar.

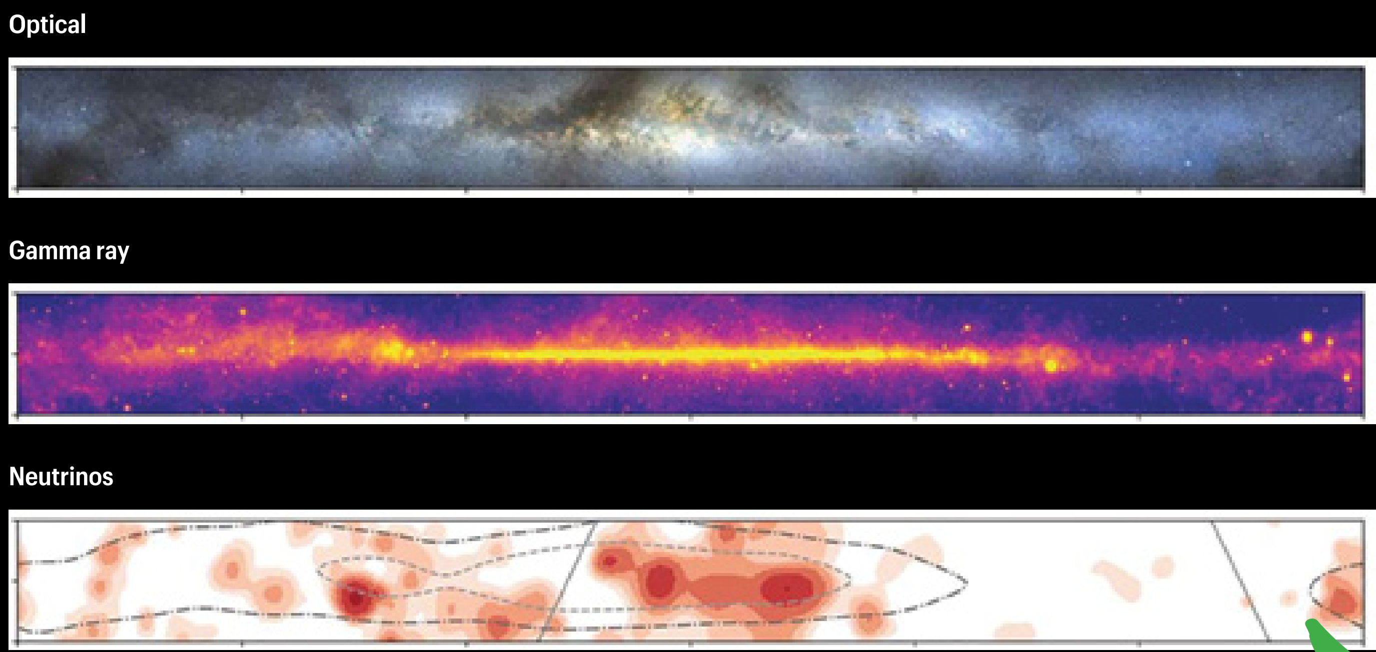
"There's so much more to learn," says Kate Scholberg. She's a physicist at Duke University in Durham, N.C., who did not take part in the new mapping project. "It can be tremendous fun to figure out how to see the universe with neutrino eyes."

Those neutrino "eyes" might one day allow us to see distant objects in a way that no other telescopes can match.

Some telescopes rely on visible light. Others pick up X-rays, gamma rays or the charged particles that make up cosmic rays. All of those types of light can be deflected or absorbed as they travel through space. Neutrinos, though, can cross huge expanses without being deflected. This allows the particles to tell us about very distant objects.

Neutrinos' ghostly ability to pass through things so easily also makes them very hard to detect. Scientists found the Milky Way particles using a neutrino detector in Antarctica. Called IceCube, this detector is embedded deep in the ice. To better detect hard-to-spot particles, it's enormous. Its 5,160 sensors are arranged in a cube one kilometer (3,281 feet) on each side.

Even so, the experiment sees only a tiny share of the neutrinos that zip through space. IceCube scientists observe 100,000 or so



Three ways to map the Milky Way

Here are views of the Milky Way in visible light (top), gamma rays (middle) and high-energy neutrinos (bottom). Dust obscures portions of the visible-light map, and a variety of sources can generate gamma rays. Neutrinos have the potential to pinpoint remnants of supernovas, cores of collapsed stellar giants and other cosmic features.

neutrinos a year. Some of these neutrinos leave tracks in the detector. Sometimes scientists can trace these tracks back to the neutrinos' source. Most of the neutrino signals that IceCube picks up, though, are a type called a cascade event. These leave bursts of light in the detector but do not reveal a neutrino's origins as well as tracks can.

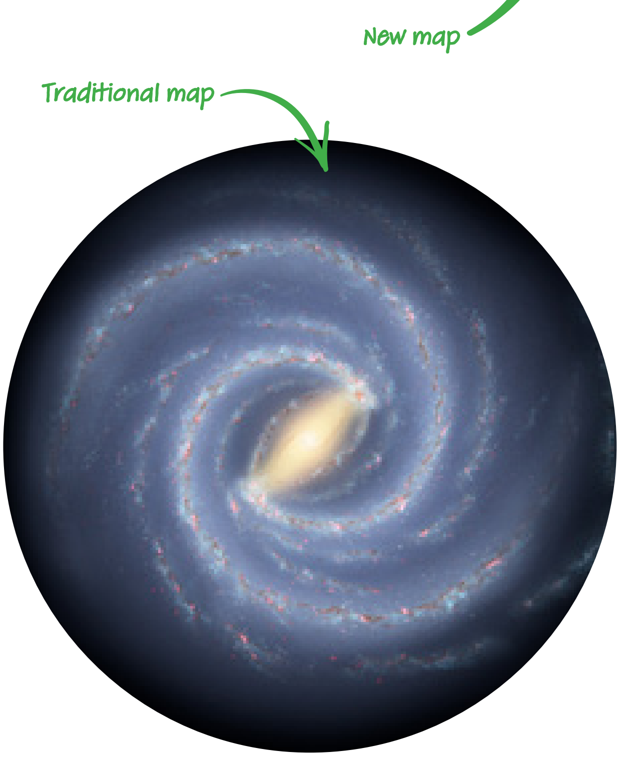
Astronomers used to throw away data on cascade events, says Naoko Kurahashi Neilson. She's a physicist at Drexel University in Philadelphia, Pa. Those data can hold useful information about where the neutrinos come from. It's just hard to pick out which of those tens of thousands of cascade events are most important.

Kurahashi Neilson and her team took up the challenge. They dug through a decade of IceCube cascade event data. They got help from an artificial intelligence system known as a neural network. "You can train the neural nets to identify which events are worth keeping," Kurahashi Neilson explains.

She started this approach in 2017. Over the years, Kurahashi Neilson has steadily improved it. She and her colleagues have now used it to identify the neutrinos used to make the new map.

"It's an impressive analysis," Scholberg says. And the technique may have the potential to be developed even more. "Clearly a lot more work needs to be done," she says. "But it's very exciting to see the basic expectation [of Milky Way neutrinos] verified."

— James R. Riordon



ICECUBE COLLABORATION/*SCIENCE* 2023; NASA; NASA/JPL-CALTECH/R. HURT (SSC-CALTECH)

TECHNOLOGY

How to stop the robot replication apocalypse

Robots that make copies of themselves have perks — and potential dangers

Robots that can make copies of themselves, or self-replicate, have a bad reputation. For a long time, science fiction writers have imagined these robots as villains. Think of Ultron building drone versions of himself to fight the Avengers. Or the Faro machines ravaging Earth in the *Horizon* video games. The robots are agents of destruction designed to overwhelm our heroes.

But a self-replicating robot doesn't have to be a bad thing. People use machines to build other machines all the time. Robots help build cars, medical instruments, microwave ovens — why not more robots? Now scientists are building self-replicating bots that could one day do all sorts of jobs humans can't do. With the right safeguards, those robots probably won't take over the world.

Amira Abdel-Rahman is a roboticist at the Massachusetts Institute of Technology in Cambridge. She's building self-replicating robots that can work in dangerous places, such as space. These robots work together like ants to build large structures or even bigger robots, piece by piece.

The robots are made of a few different parts that can be assembled with magnets in different ways, depending on what the robot needs to do. A typical robot looks and moves like a big inchworm. It could carry parts from place to place and attach those parts to a bigger structure or robot. The bots could work together to build anything from airplanes to houses.

Right now, Abdel-Rahman's robots need some help to replicate. Each bot is built from premade parts. An existing robot connects those parts together to make a new robot. But someone has to make the parts ahead of time. The robots can't go out into the wild and build new robots out of whatever they find.

The robots, though, don't need a human to control the replication process. A computer program calculates how many robots are needed to build a structure. The program then tells each robot to start building the structure, a copy of themselves or a bigger robot.

ROBOT REVOLUTION

Some people worry about what could happen when humans don't have direct control over robots. Could the machines ever rise up against us?

Abdel-Rahman says that's not likely for her creations. The robots she builds are programmed to do individual steps. They can't think or act like humans do. In short, they don't have artificial intelligence.

And because the bots need humans to build their parts, notes Hod Lipson, runaway replication — robots making too many copies of themselves — wouldn't be an issue. Lipson is a roboticist at Columbia University in New York City.

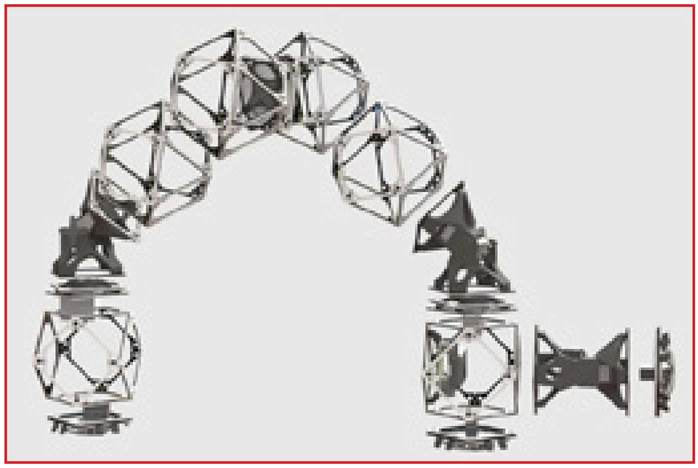
But robot-building technologies could overcome those limits at some point in the future. They could build parts of themselves from materials that other robots have collected. One day, the bots might not need humans at all. If that happens, we'd have a lot of questions to address, Lipson says.

First, we'd need to make sure that the robots' values match human values. Here's an example that helps explain why: Imagine a robot whose only job is making paperclips. The robot is incredibly powerful and advanced. We give it no instructions or limits other than that it needs to make paperclips. In the worst-case scenario, that robot could be so focused on making paperclips that it consumes everything on Earth. It could turn the whole planet into a great big pile of paperclips and paperclip-making machines.

This example, called the Paperclip Maximizer, might sound silly. But it illustrates why robots need guidelines. The paperclip-making robot wouldn't know how important — or unimportant — paperclips are to humans. It wouldn't know that humans value having a planet to live on more than we value having a pile of paperclips. It also wouldn't necessarily know to prioritize what humans want over its own goals. We'd have to tell the bot what we care about most.

Building self-replicating machines could lead to a future where robots like the Marvel villain Ultron can build more versions of themselves. But it's not likely, scientists say.

Abdel-Rahman's robots are made up of small pieces that can be magnetically connected into larger machines.



The same applies for robots designed to make more robots, rather than paperclips. Without guidelines, they might make more copies of themselves than wanted or needed. Roboticists and philosophers call this the "value alignment problem."

The value alignment problem is difficult to address, says Lipson. But one possible solution is to show robots lots of examples of what we want. It's like teaching kids right from wrong, he says.

Still, we can't give a robot guidelines for everything it will ever experience, says Ryan Jenkins. He's a philosopher at California Polytechnic State University in San Luis Obispo. He studies ethical issues surrounding robots and artificial intelligence. "There's always going to be things that come up in the real world that you hadn't prepared for or couldn't prepare for," he says.

So could self-replicating robots take over the world? Probably not anytime soon, says Jenkins. The thought "doesn't keep me up at night." But scientists and philosophers are devising more airtight ways to address these issues, he notes, just in case.

— *Skyler Ware*

PHOTO 12/ALAMY; A. ABDEL-RAHMAN *ET AL*/COMMUN ENG 2022

FOSSILS

How fossils form

These rocks provide a glimpse of the past

Most times, when a living thing dies, it just rots. It leaves no trace that it was ever there. But when the conditions are just right, a fossil of that organism may form.

For this to happen, the organism typically must become quickly buried in sediment on the floor of the sea or some other body of water. Sometimes it may even land in something like a sand dune. Over time, more and more sediments pile atop it. Eventually, this growing pile of sediment is compressed by its own weight and transforms into hard rock.

Most organisms buried in that rock eventually decay and dissolve. But for some, minerals may replace any bone, shell or once-living tissue. Minerals also may fill in the spaces between these hard parts. And so a fossil is born.

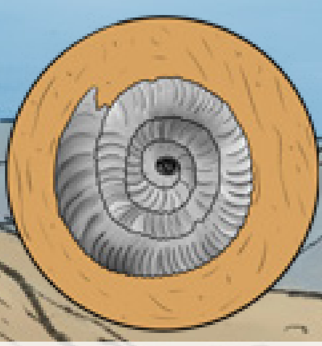
Some fossils contain important information about how an animal lived or died. Or they might even provide clues to what the climate was like when an ancient animal died.

Fossils come in other forms, too. They can be any trace of an ancient living thing. For instance, scientists consider ancient, preserved footprints and burrows to be fossils. For these trace fossils to form, the impression they make on sediment has to quickly harden or get buried in sediment and remain undisturbed until it can be transformed into rock. Even animal poop can form trace fossils, called coprolites.

Most people associate fossils with animals. But plants and other types of organisms also can leave preserved traces of their existence other than their bodies. And they tend to form in much the same way as animal fossils. A special type of fossil is called petrified wood. It forms in the same way as fossils of dinosaurs or other creatures. These fossils often look similar to real wood, though. In this case, colorful minerals have moved in and replaced tree tissue.

— *Sarah Zielinski*

SOME FOSSIL TYPES YOU SHOULD KNOW



CAST AND MOLD

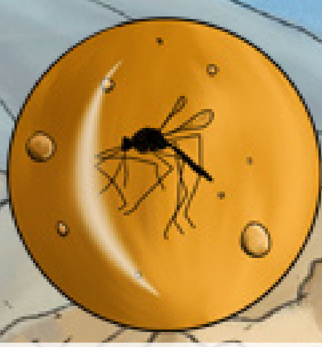
When a living thing dies, gets buried and decays, minerals fill the cavity left behind by its body. This creates a hard version, or CAST, of part or all of the life form. A MOLD holds an imprint of the exterior of such an organism.

How to create a fossil dinosaur skeleton

Illustrated by JoAnna Wendel

TRACE

TRACE fossils preserve evidence of an organism's activity, rather than the organism itself. Examples include coprolites (fossilized poop) and footprints.



AMBER

Thousands of species have been found trapped in **AMBER**, which is tree resin that has been fossilized.

PETRIFIED

Minerals can replace all the organic material in a specimen, turning it to stone. One example is **PETRIFIED** wood.

BIOLOGY

White spots may help monarchs fly far

Butterflies that finish migrations have more white on their wings

Each monarch butterfly you see flitting through the garden weighs less than a jelly bean. Yet these pipsqueak insects are mighty enough to journey up to 4,000 kilometers (2,485 miles) each fall. Now, research hints that their white wing spots may help them go the distance.

People have known that monarch butterflies' (*Danaus plexippus*) orange warns predators to steer clear, says Andy Davis. An ecologist, he works at the University of Georgia in Athens. But no one had examined how monarchs' wing colors might impact their migrations.

Monarch butterflies breed in Canada and the United States. From there, the butterflies migrate south and spend the winter in California or Mexico. Davis' team analyzed the wing colors of butterflies starting the trip and ones that completed the journey. Monarchs that had less black and more white on their wings were more successful at making it to the winter colonies.

The team then compared monarchs' wing colors with those of related butterflies that don't migrate. Monarchs had more white area on their wings. That suggests that migration has nudged monarchs to evolve bigger white spots. The researchers shared their findings in *PLOS ONE*.

It's not clear yet exactly how white spots help the monarchs soar. Areas of white on the wing absorb less sunlight than dark areas, and they heat the air above them less. When these areas are next to each other, the differences in air temperature can send the air swirling. Such currents could help the butterflies glide, Davis says.

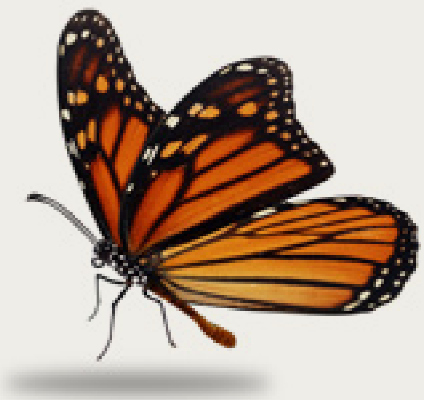
Experiments in wind tunnels could reveal how wing colors influence butterflies' motion. That could provide clues for engineering, Davis says. "We might be able to improve the flight efficiency of drone technology just by applying different colors."
— *Carolyn Wilke*

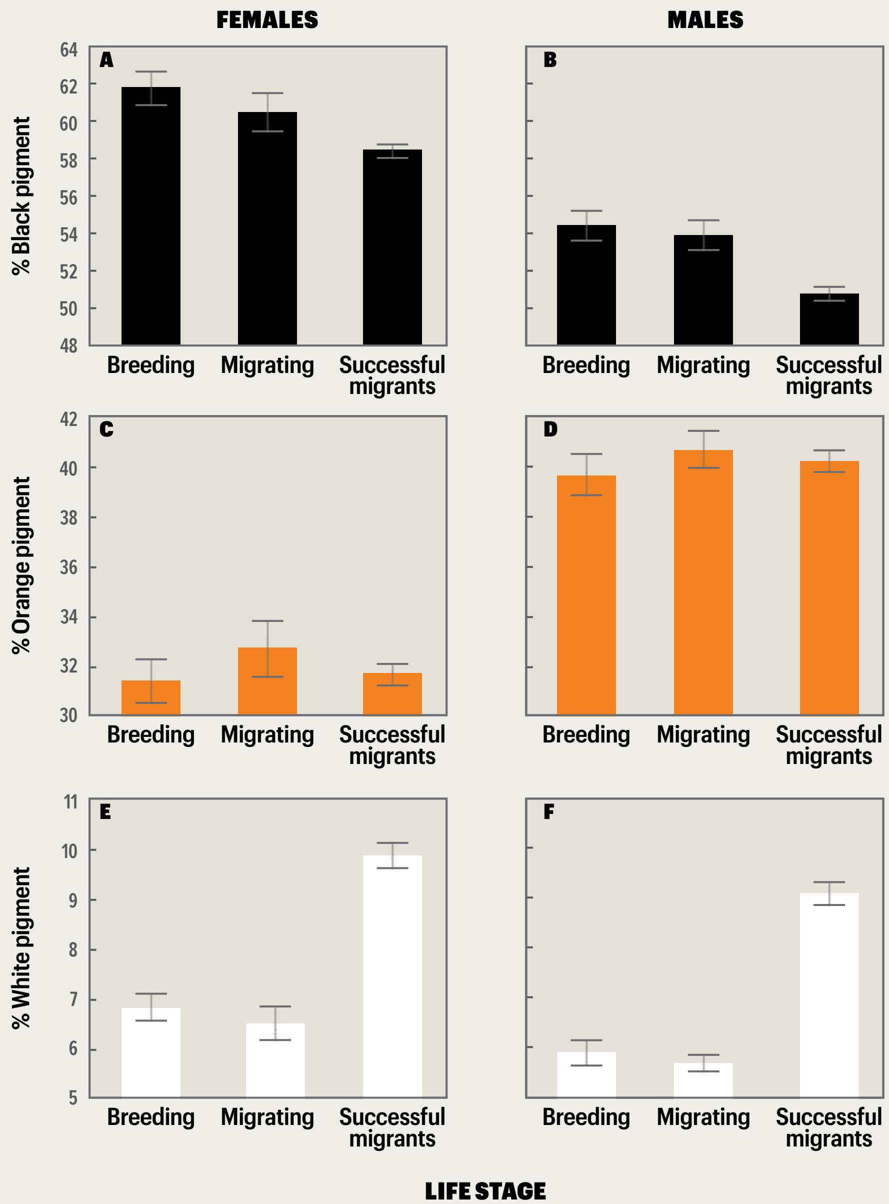
Monarch butterflies are famous for their vibrant orange wings. But the insects' little white speckles may be their secret weapons for flying far.

SARI ONEAL, MICHAEL WARWICK/SHUTTERSTOCK

COLORFUL BUTTERFLIES

Researchers examined the wings of monarch butterflies that had been collected at different stages of their lives. Breeding butterflies were collected at northern sites before starting their migrations. Migrating butterflies were collected at spots along the journey south. Successful migrants had made it to their winter destination in Mexico. The scientists analyzed pictures of the butterflies' wings for clues to how wing color may impact the monarch's ability to fly so far. These graphs show the average amount of wing pigment of different colors for each group of butterflies.





DATA DIVE

1. Look at Figures A and B. What is the range — or spread — of percentages for monarchs' black pigment? At which stage of migration do butterflies have the highest amount of black?

2. Look at Figures C and D. How does orange pigment compare between female and male butterflies?

3. Look at Figures E and F. What is the range of percentages for monarchs' white pigment? At which stage of migration do butterflies have the highest amount of white color?

4. Why do the pairs of figures have different values on the y-axis? What would each graph look like if the y-axis started at 0 and went to 100 percent?

5. What other flying animals have light and dark colors next to each other? How might air currents caused by their color pattern affect these animals?

ANSWER

This method gives mice an inner glow

It's like Google Maps for a body

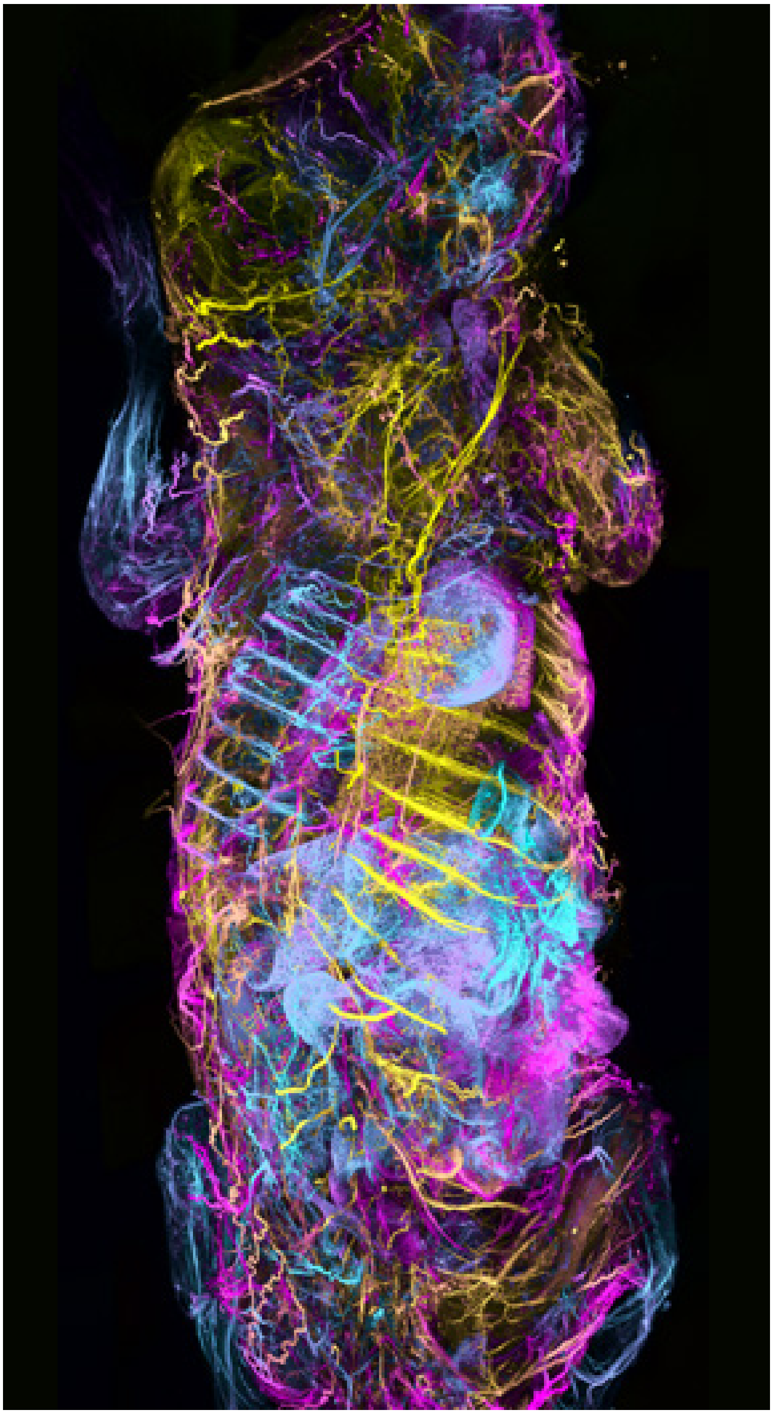
A mouse's entire nervous system glows in shades of blue, pink and yellow.

To learn about the inner workings of a body, it can help to see inside. A new method makes imaging a whole body cheaper and faster. And it gives an amazingly detailed peek at hidden internal structures.

A research team applied chemicals to a dead mouse to remove cholesterol. That's a key part of cell membranes. Taking out the cholesterol created spongelike holes in the cells. Then the scientists added molecules that can stick to structures of interest. The holes let these molecules reach every corner of the mouse's body. Under fluorescent light, they made entire body structures glow.

The team reported the technique in *Nature Biotechnology*. It's a little like Google Maps for the body, says neuroscientist Ali Ertürk. He led the work at Helmholtz Munich in Germany. Researchers can make different maps by using different molecules.

Such maps could guide many types of future studies. They might even help train computer programs to simulate mouse biology. That could reduce the need for animal experiments, Ertürk says.
— *Erin Garcia de Jesús*



Glowing proteins light up the entire nervous system of a dead and transparent mouse. The animal's head is at the top. Colors show how deep nerve cells are in the body, from blue (closest to the camera) to pink and then yellow (farthest away).

INSIDE THE MIND OF A YOUNG SCIENTIST

A Regeneron International Science and Engineering Fair competitor 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? Marisol Enguidanos, who competed at the 2023 Regeneron International Science and Engineering Fair (ISEF), shares some of her science inspiration and advice.

Q What inspired your project?

A I do a lot of snorkeling and scuba diving, and so I could see firsthand the coral bleaching. And then also just learning about it in school and learning how big of a problem bleaching actually is. From there, I got inspired to see what I can do to help. I created a filtration system to make water optimal for coral survival.

Q What was the biggest challenge in doing the work?

A Coral is found across the world, and the ocean is so much different than how I tested my system in tanks in my house. I had to create temperatures, carbon dioxide levels, salinity, all that represent our current oceans and specific coral reef areas. I also had to adjust my currents by moving the water around. Throughout the years, I had to tweak different things to make sure it was the closest I could get to the ocean.

Q What advice would you give to other students starting a science project?

A Even if there are setbacks or you think what you're doing isn't big enough to matter, don't let that affect you. As long as what you're doing is helping, it's doing something. Anything that helps is going to help make an impact, and it's going to help our world as a whole in the end.

Earth and Environmental Sciences

Marisol Enguidanos

Ocean acidification occurs when excess carbon dioxide in the atmosphere dissolves into seawater. That acidification can contribute to coral bleaching and coral death. Marisol, 18, worked for four years to create and test a solar-powered device to extract carbon dioxide from water, making it less acidic and more hospitable to coral. She hopes her research can help with the protection of coral reefs. Marisol is a senior at Niceville High School in Florida.

EXPLORE
OUR SOCIAL MEDIA

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