Next-Gen Nuclear Reactors | Why Cats Act Like Liquids

ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ NOVEMBER 16, 2024

LEGENDARY LUCY

How a fossil unearthed 50 years ago became an evolutionary icon

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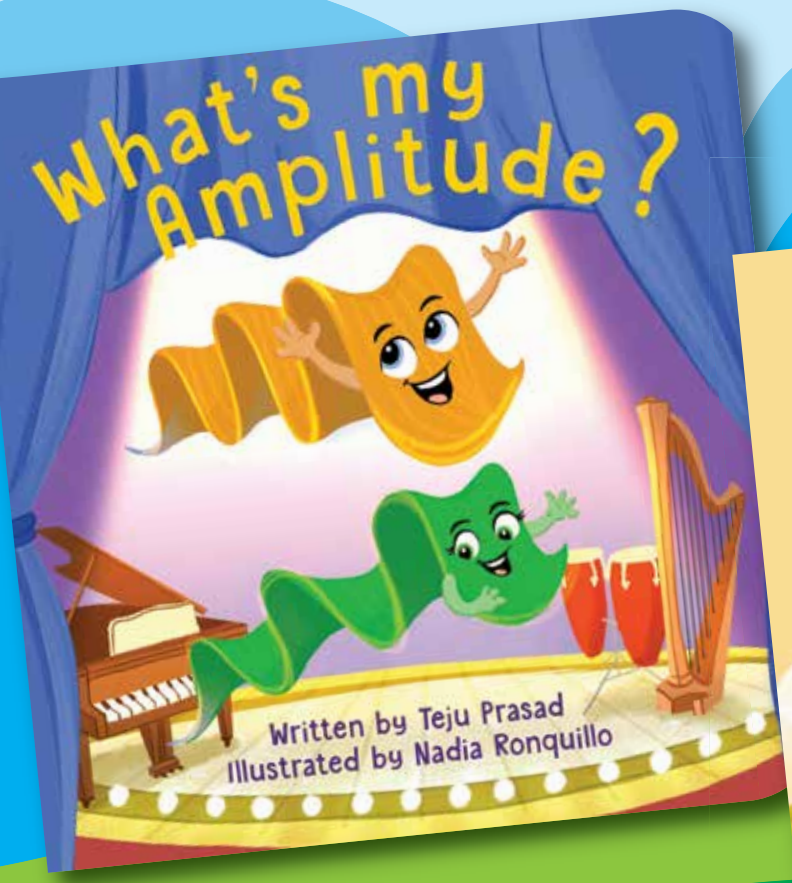

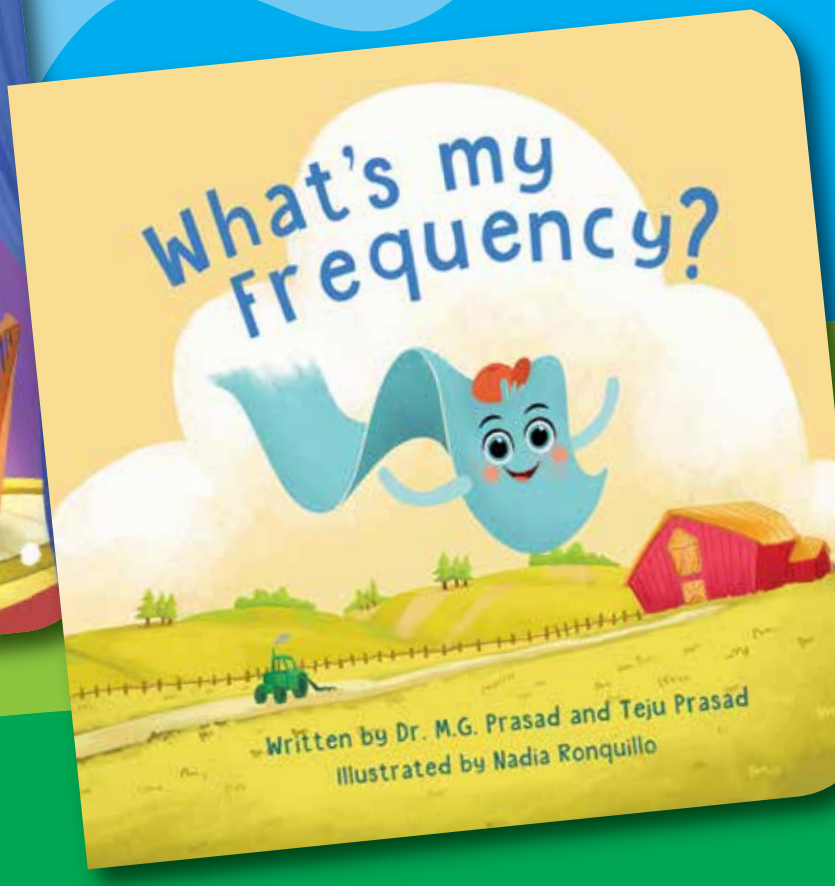

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ScienceNews

Features

News

FROM TOP: SAM FALCONER; PETRA RICHLI/GETTY IMAGES; PEI-FENG SUN

Departments

COVER Lucy, as shown in this reconstruction, may have looked like an ape but shared key traits with humans. © *Sculpture Elisabeth Daynes/Photograph Elisabeth Daynes*

50 years on, Lucy still sparks our curiosity

Since her public debut in 1978, Lucy has been on a first-name basis with the world. Not bad for someone from rural Ethiopia who had been an unknown for 3.2 million years or so.

Paleoanthropologists Donald Johanson and Tom Gray had discovered Lucy's fossilized bones a few years earlier. That spectacular moment 50 years ago quickly upended how many scientists thought about human evolution. Until then, the history of our species was drawn as an orderly progression, with one member of the big-brained *Homo* species leading to the next. The famed anthropologists Louis and Mary Leakey, and later their son Richard, had spent decades excavating fossils that they said supported that theory. Lucy, who walked upright like a human but had a petite brain and other apelike features, didn't fit in. Her existence proved that the story was more complicated—and much more interesting.

As Bruce Bower, *Science News*' behavioral sciences writer, reports in this issue, scientists knew of only a few hominid species when Lucy's partial skeleton was discovered in 1974 (Page 18). Today, scientists recognize more than 20 hominid species, including Lucy's *Australopithecus afarensis*. "Johanson calls that particular point in time the beginning of a golden decade in paleoanthropology," Bower told me. "It was changing the way everyone thought."

Even for those of us who have been reading about Lucy for decades, Bower's retelling of the tale is a treat. Lore has it that she was named after the Beatles song "Lucy in the Sky with Diamonds," which was playing on repeat at a celebration in camp the evening of her discovery. Bower, a longtime Beatles fan, doesn't shirk from further invoking the Fab Four. He notes that other fossils discovered nearby helped Lucy top "the hominid hit parade with a little help from her friends." And he uses the lyric "I thought I knew you, what did I know?" from the song "I'm Looking Through You" to address hot-topic questions about Lucy, including whether she climbed trees, what she ate and whether she and her compatriots used stone tools.

The gully where Lucy was found lies in a parched, treeless desert. But when I look at the photos from the 1974 dig, the people toiling away in that heat and dust look so happy. Perhaps the photos were taken after they found Lucy, a major discovery made after weeks, months—who knows, possibly years—of fruitless toil. It was the day when they finally found a fossil that changed everything. Or maybe the photos were taken before the debut of our celebrity hominid, and those smiling, dusty people were just happy to be doing the work.

Today, scholars of human evolution have many more tools at their disposal than did the crew in Ethiopia. That includes ancient DNA analysis that has revolutionized our ability to better identify hominid populations and the relationships between them, including the genetic connections between Neandertals and present-day humans.

It's not known if Lucy and her kind are among our direct distant ancestors; like many things in the study of human evolution, it's debated. But she can count me among her many fans. —*Nancy Shute, Editor in Chief*

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SOCIETY FOR SCIENCE

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Excerpt from the November 16, 1974 issue of *Science News*

50 YEARS AGO

EPA to study tap water

There is evidence that clean drinking water in some localities may contain carcinogenic compounds. Many of the compounds detected contain chlorine and some scientists think chlorine added to purify the water may be combining with organic substances not removed during filtration to form the dangerous substances.

UPDATE: Those findings hastened the passage of the Safe Drinking Water Act, which authorized the U.S. Environmental Protection Agency to set minimum standards for levels of contaminants (*SN: 3/29/75, p. 208*). Chlorine is still used to kill waterborne pathogens, but the EPA limits levels of its byproducts trihalomethanes and haloacetic acids. Long-term exposure to these chemicals has been linked with an increased risk of cancer. Now, the agency is targeting lead and PFAS, or forever chemicals, which have been linked with myriad health problems (*SN: 11/19/22, p. 18*). The EPA recently set standards for PFAS and mandated that most lead pipe service lines be replaced within a decade.

Cats' ability to pour themselves into containers and flow through tight spaces is well-documented.

PETRA RICHLI/GETTY IMAGES

THE SCIENCE LIFE

One scientist put cats' liquid nature to the test

Cats may seem solid, but they're actually somewhat liquid — at least according to one 2017 theoretical physics paper inspired by photos of cats pouring themselves into vases and fitting into tight crevices. Now, one researcher has taken this idea a step further, testing dozens of cats to see when they act more like liquids or solids.

Cats fluidly move through tall and narrow nooks but hesitate when they approach uncomfortably short holes, biologist Péter Pongrácz of Eötvös Loránd University in Budapest reports in the Oct. 18 *iScience*. The finding suggests that cats are aware of their own body size and may form mental images of themselves.

> Cats are aware of their own body size and may form mental images of themselves.

Because cats tend to be reclusive, they are difficult to test in the lab. So Pongrácz brought the lab to the cats. With help from colleagues, he built a portable lab that they set up in 29 homes.

In each home, the team attached two cardboard panels to a doorframe: one with five rectangular holes of the same height but decreasing width and another with five holes of the same width but decreasing height. An owner stood on one side of the panel while the cat and the experimenter stood on the other. For each trial, the cat had to squeeze from the experimenter's side to the owner's side through the holes while being filmed.

Once a cat oozed through the hole, the owner had to catch their pet and hand them over the panel to a researcher to start a new trial. But some cats hated being handled and evaded their owners.

Thirty out of 38 cats finished the experiment. When faced with holes of varying height, 22 cats hesitated to crawl through the shortest. When the holes varied in width, only eight cats paused before approaching the narrowest cranny. Most cats squeezed through slim openings without hesitating.

Hesitation may be a self-preservation tactic, Pongrácz says. If a cat squeezes through a hole without being able to see what's on the other side, the cat may be vulnerable to potential threats. That some cats paused in the safety of their homes suggests that they also rely on their body size representation, or how they imagine their body size, to plan their approach.

Pongrácz had a lot of fun with the cats, but "the funniest things are how the people behave," he says. Some owners thought their cats were geniuses, only for those cats to struggle with the test. Other owners thought their felines lacked intelligence and were shocked when the cats easily completed the test.

— *Andrea Tamayo*

SAY WHAT?

Ventography /ven-tah-gruh-fee/ n.
The study of politicizing wind for energy development

Wind ownership is up for grabs.

As an unpaid intern at an energy company in England, Emilia Groupp created wind maps for renewable energy development. Colleagues told Groupp to ignore wind blowing across British borders, saying things like, "Oh, we don't want French wind," recalls Groupp, an anthropologist of energy at Stanford University. Groupp dubs this politicizing of wind for energy development as "ventography" in a study published September 18 in *Environment and Planning D: Society and Space*.

Some nations are taking an old blueprint for expanding territorial claims to drill for fossil fuels and applying it to the sky. But if wind can be owned, it can also be stolen. Wind theft occurs when one entity builds turbines close to and upwind of an existing wind farm. That can slow wind speeds and tank power generation at the existing farm. To fight for control over wind resources, countries such as Greece are generating maps that use satellite data to "forensically trace wind currents," Groupp writes.

Lest anyone think that wind ownership is unique, Groupp is also studying the politicization of solar power but has yet to coin a word for owning the sun. —*Sujata Gupta*

MYSTERY SOLVED

The largest arthropod to ever live now has a head

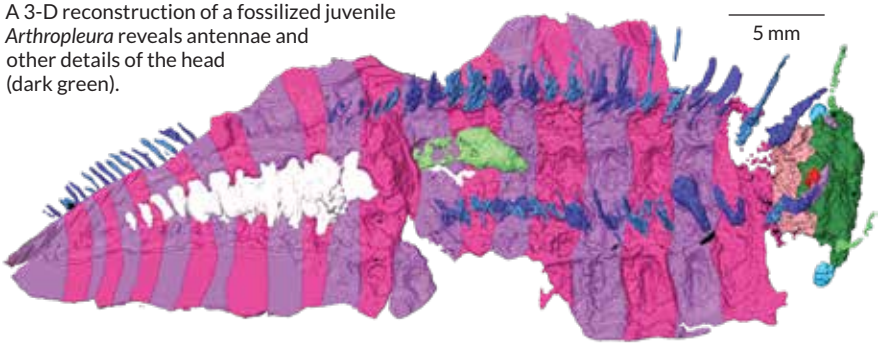
Two newly discovered fossils are helping scientists wrap their heads around the anatomy of the largest arthropod of all time—a millipede that grew longer than a king-sized bed and lived between 346 million and 290 million years ago.

Arthropleura was discovered in 1854, but no one had ever managed to find a fossil that included a head. "It was more than 100 years since we start trying to find a head. And now we finally have one," says Mickaël Lhéritier, a paleontologist at Claude Bernard University Lyon 1 in France.

Micro-CT scans of the fossils, unearthed from France, reveal new details about the giant millipede's anatomy, including its antennae, eyes, mandible and other feeding appendages, Lhéritier and colleagues report October 9 in *Science Advances*.

Until now, scientists had assumed that the head of *Arthropleura* would be similar to that of modern millipedes. However, the fossils reveal a more intermediate state in the lineage's evolution, Lhéritier says. "*Arthropleura* has the body of a millipede, like for example, with two pairs of legs per [body] segment, but also the head of a centipede," he says. Though the mouthparts are particularly centipede-like, anatomical observations and other data place *Arthropleura* in the millipede camp.

Though the specimens provide a wealth of information about *Arthropleura*, there's a lot left to learn about this mighty millipede, including what it might have eaten and whether it walked on land, underwater or both. —*Jason Bittel*



A 3-D reconstruction of a fossilized juvenile *Arthropleura* reveals antennae and other details of the head (dark green).

FROM TOP: WENYING LI; M. LHÉRITIER *ET AL*/*SCIENCE ADVANCES* 2024

Some of China's Xiaohe mummies (like this one) were found with cheese on their necks.

THE –EST

Digging into the world's oldest cheese

When scientists discovered the world's oldest preserved cheese smeared on the necks of 3,600-year-old mummies in China, it raised a lot of questions. Now, a DNA analysis is answering some of them.

Two of three curdled samples of kefir cheese were probably made from cow milk, while the third came from goat milk, paleontologist Qiaomei Fu of the Chinese Academy of Sciences in Beijing and colleagues report in the Oct. 17 *Cell*.

A closer look at the kefir's bacteria is offering new insights into the origin story of dairy fermentation in Asia. Kefir can be created only from existing cultures, so bacteria in the cheese can be a proxy to trace the spread of fermentation techniques. Fu's team compared bacterial DNA from the cheese with modern samples to build a family tree of bacterial evolution. Previous work suggested that kefir fermentation spread from Russia to Europe. But the family tree suggests a route from Xinjiang, where the tombs are, into Tibet.

What the cheese was doing on the mummies' necks, however, remains a mystery. —*Sophie Hartley*

PLANETARY SCIENCE

The origins of Earth's meteorites

Abundant chondrites hail from just three asteroid families

A brilliant meteor blazes through the sky over the Atacama Large Millimeter/submillimeter Array in Chile.

CHRISTOPH MALIN, ESO

BY ROBIN GEORGE ANDREWS

Most of Earth's meteorites can be linked to just a few collisions within the asteroid belt between Mars and Jupiter.

The upside to this discovery, reported in the Oct. 17 *Nature*, is that it provides researchers with vital context: By knowing the return address of meteorites, scientists can more easily work out how and where the building blocks of planets came together to create the solar system we see today. The downside is that it may mean researchers have an extremely biased meteorite collection that can tell only a sliver of the story.

Meteorites frequently record the history of the solar system's formative years, but the origins of these space rocks are often unknown. "It's absolutely like a pot of gold at the end of a rainbow for a meteoriticist to know what asteroid the sample's come from," says planetary scientist Sara Russell of London's Natural History Museum. Without that information, a meteorite is like a jigsaw puzzle piece without a picture of the full puzzle to accompany it.

Most meteorites on Earth are stony ones called ordinary chondrites. Two classes of these chondrites, H and L, make up 70 percent of all meteorite falls.

Scientists had suspected that the L chondrites originated from a single parent asteroid. Many have features indicating they were shocked, scorched and degassed before gradually cooling, implying they were liberated from a giant asteroid at least 100 kilometers long.

Radioactive dating determined the age of the L chondrites and revealed that they first emerged from a collision that happened 470 million years ago. Astronomer Michaël Marsset of the European Southern Observatory in Santiago, Chile, and colleagues searched for the site of that destruction derby in the asteroid belt using the NASA Infrared Telescope Facility in Hawaii. They scanned many prominent stony-type asteroids, comparing each one's mineral signatures to L chondrites'.

A group of asteroids named the Massalia family fit the bill. Their scattered presence and current orbits could effectively be rewound by the scientists — and it looked like the asteroids all formed between 450 million and 500 million years ago after splitting from an older, larger asteroid. That timing suggests that the impact that created the L chondrites also created the Massalia family. One of the Massalia asteroids is about 140 kilometers long, a perfect fit for the estimated size range of the L chondrite parent body.

Other data, including the trajectories of L chondrite meteors and near-Earth asteroids with L chondrite–like signatures, also point to the Massalia family as the source of L chondrites. "All point at the same thing. There's no doubt," Marsset says.

That ancient impact also set the stage for a more recent bombardment, sending streams of L chondrite material tumbling back onto the largest asteroid remnant. Another impact no more than 40 million years ago then sent that rubble Earth's way.

H chondrites are 5 million to 8 million years old and came from two different impact events, it seems. Reconstructing the past orbits of the mineralogically matching Koronis2 asteroid family suggests that many of those asteroids were a single asteroid 7.6 million years ago. Previous research had found that many asteroids in another group, the Karin family, had been united as a solitary asteroid 5.8 million years ago, just before another asteroid struck it. Since both families cover each end of the date range for the H chondrites, the team concluded that they are the source of this meteorite class.

That Earth's meteorite collection could be highly biased to just a few asteroids is distressing, Russell says. The asteroid belt is home to an array of rocks, boulders and even a dwarf planet, each revealing something unique about the solar system. "Maybe we're only just seeing a tiny fraction," she says. Future space missions could hunt down these rocky archives. ■

PLANETARY SCIENCE

Saturn boasts a Trojan asteroid

The companion has shared the planet's orbit for 2,000 years

BY KEN CROSWELL

Astronomers have found an asteroid keeping pace with Saturn in its orbit around the sun. Such objects, called Trojan asteroids, were already known for the other three giant planets in our solar system.

"Saturn was sort of the odd man out," says Paul Wiegert, an astronomer at the University of Western Ontario in London, Canada. "Even though it's the second most massive planet in the solar system, it didn't have any Trojans."

Like Saturn, the newfound asteroid takes about 30 years to revolve but lies 60 degrees ahead of the planet in its orbit, Wiegert and colleagues report in the Nov. 1 *Astrophysical Journal Letters*.

Most asteroids in the solar system revolve around the sun between the paths of Mars and Jupiter. In 1906, however, German astronomer Max Wolf discovered the first Trojan, named Achilles, orbiting the sun 60 degrees ahead of Jupiter. Since then, astronomers have found thousands of additional Trojan asteroids sharing Jupiter's orbit — some are 60 degrees ahead of Jupiter, others are 60 degrees behind. Trojan asteroids also exist for Uranus and Neptune and even for Earth and Mars (*SN: 2/26/22, p. 15*).

After a telescope image in Hawaii captured the newly identified asteroid in 2019, an amateur astronomer in Australia, Andrew Walker, suggested that the object might be a Saturnian Trojan — if it had the right orbit around the sun.

"The key to getting a good orbit for something in our solar system is having a lot of observations of it through different telescopes over a long period of time," Wiegert says. Astronomer Man-To Hui of Macau University of Science and Technology in China looked for previous images of the asteroid and planned new observations as well. Measurements of the asteroid's position from 2015 to 2024 confirmed its Trojan nature.

Named 2019 UO_{14}, the Trojan asteroid is only about 13 kilometers across, the same size as Deimos — the smaller of Mars' two moons.

Scientists have long predicted Saturnian Trojans, says astronomer Carlos de la Fuente Marcos of Complutense University of Madrid. But computer simulations show that Saturnian Trojans should have unstable orbits, because Saturn has giant planets on either side of it.

"Jupiter seems to be the culprit," de la Fuente Marcos says. The simulations indicate that Jupiter's great gravity gradually pulls on a Saturnian Trojan, making its orbit around the sun more and more elliptical. The asteroid then wanders so close to Jupiter or Uranus that one of those giant planets yanks the small body out of its Trojan orbit.

By considering the gravitational pulls of those planets, Wiegert, Hui and colleagues estimate that 2019 UO_{14} has been a Trojan for about 2,000 years and will remain so for another 1,000 years. Before its affair with the ringed planet, the asteroid was probably a Centaur, an asteroid moving around the sun among the orbits of the giant planets.

2019 UO_{14} probably isn't Saturn's sole Trojan. "I'm quite sure there are more — maybe only a few, but this can't be the only one," Wiegert says. ■

NASA, ESA, LEAH HUSTAK AND RALF CRAWFORD/STSCI

PLANETARY SCIENCE

The first known steam world makes its debut

This exoplanet's atmosphere is going full steam ahead. GJ 9827d, which orbits a star about 100 light-years from Earth, has an atmosphere made almost exclusively of hot water molecules, astronomer Ryan MacDonald of the University of Michigan in Ann Arbor and colleagues report in the Oct. 10 *Astrophysical Journal Letters*. Using the James Webb Space Telescope, the team analyzed light filtering through GJ 9827d's atmosphere as the planet passed in front of its star (illustrated). Combining those observations with Hubble Space Telescope data revealed the atmosphere is mostly water. At about 340° Celsius, GJ 9827d's temperature means the water is probably vapor. This is the first direct evidence that steam worlds exist, MacDonald says. "I feel like a *Star Trek* explorer." — *Lisa Grossman*

TECHNOLOGY

Nuclear energy entices Big Tech

Small reactors get a boost from Amazon and Google

BY EMILY CONOVER

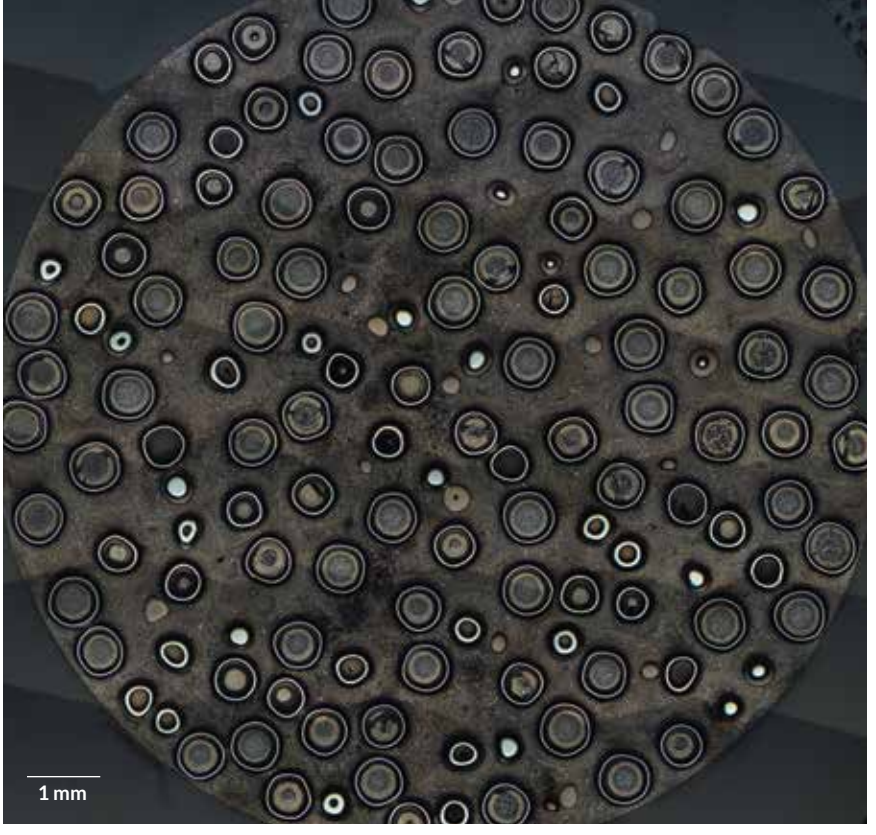
Tech companies are going big on small nuclear reactors.

Both Google and Amazon recently announced agreements with companies that are developing small modular reactors. These reactors, which would produce less power than current reactors, are touted for their potential to be cheaper and safer than conventional designs.

The announcements have amplified the buzz around small modular reactors, which have attracted attention in recent years, given that nuclear power doesn't contribute significantly to climate change.

A variety of companies have sprung up to meet the need, producing a cornucopia of proposed designs for small modular reactors. Funding from the U.S. government has further fed interest in these reactors.

So what's on the horizon for this potential new nuclear generation? *Science News* breaks down some big questions about how and why nuclear reactors are going small.



Some small modular reactor designs make use of advanced types of fuel such as TRISO, tiny particles of uranium that are encapsulated in multiple layers of material (shown).

What are small modular reactors?

A typical commercial reactor in the United States produces about a billion watts of electrical power when running at capacity. Each small modular reactor would produce less than a third of that.

Traditional nuclear plants require massive investment up front, a hurdle that has stalled the building of new reactors in the United States for decades. The first newly constructed reactors built in 30 years — two in Georgia that switched on in 2023 and 2024 — together cost about $30 billion. The construction was years behind schedule and billions over budget.

By pivoting to smaller reactors, companies and policy makers aim to propel the proliferation of nuclear power, which is touted as a source of reliable energy free from greenhouse gas emissions. Small modular reactors are expected to be a fraction of the cost of big reactors. Plus, for smaller reactors, less residual heat needs to be removed to safely shut down the reactor in the event of an accident, simplifying safety systems.

With small reactors, components could be built off-site in a factory and shipped where they're needed, says nuclear engineer Kathryn Huff of the University of Illinois Urbana-Champaign. "The more you can build these reactors like airplanes rather than airports, the cheaper it's generally going to be."

What's fueling interest?

In the United States, nuclear power currently boasts support from both Democrats and Republicans, which has allowed the sector to thrive even as political powers shift. "In the past 10 years, it's been pretty consistent and growing support, and I think it's a big deal," says nuclear engineer Todd Allen of the University of Michigan in Ann Arbor. Nuclear energy is a pillar of the Biden administration's plan to achieve climate goals.

Meanwhile, AI's insatiable need for energy has created a problem for tech companies that don't want to be seen as climate change baddies. Google announced October 14 that it would purchase energy from small modular reactors to be built by California-based Kairos Power, which aims to have reactors starting up in the 2030s. And on October 16, Amazon announced an investment in the Maryland-based company X-energy and agreements with utility companies in Virginia and Washington state to establish small modular reactors.

Also on October 16, the U.S. Department of Energy announced $900 million in funding for deployment of small modular reactors. And both X-energy and the Bill Gates–backed TerraPower, headquartered in Bellevue, Wash., are building demonstration projects with DOE support.

Traditional nuclear plants still play a role for the foreseeable future. In September, Microsoft announced a deal to restart the Three Mile Island power plant near Middletown, Pa., which shut down in 2019. (Yes, *that* Three Mile Island. After the infamous partial meltdown in 1979, another reactor at the plant continued operating.)

"Companies that traditionally shied away from mentioning nuclear energy as part of their portfolio … are coming forward and embracing it," says nuclear engineer Koroush Shirvan of MIT.

DOE

How is the technology different from current nuclear reactors?

Traditional nuclear reactors generally use the same type of uranium fuel and are cooled by water. But many small modular reactor designs break that mold.

Most reactors use uranium enriched to include more of the relevant variety of uranium, U-235. While current reactors use uranium enriched to a few percent, many small modular reactors would use uranium enriched up to 20 percent. This fuel, known as HALEU, allows small modular reactors to run more efficiently than reactors with conventional fuel. The United States doesn't produce HALEU in large quantities, but efforts are revving up.

Some small reactors would use fuel that's different in more obvious ways. X-energy and Kairos, for example, will use TRISO fuel: encapsulated pellets of uranium contained within tennis ball–sized spheres of material. The fuel is "extremely robust to very high temperatures for very long times," Huff says.

The coolant, which transfers heat from the reactor to the power generation portion of the plant, is a crucial choice as well. TerraPower uses liquid sodium, Kairos uses molten fluoride salt and X-energy uses helium gas. Different coolants can increase heat transfer efficiency or eliminate the need for pressurized vessels.

The designs also incorporate safety features that don't require human intervention to kick in, helping to ensure the reactor can shut down safely in an emergency. They harness simple physics — relying on gravity, pressure differences or the natural convection of liquid coolant — to cool the core.

What's next?

The concept of small modular reactors has been around for many years, but previous attempts haven't panned out. Now, with big tech companies throwing themselves into the mix, proponents are hopeful that small modular reactors will get off the ground soon. "You can see the momentum building," Allen says. "It doesn't mean you're going to have a new commercial version this year, but it's also way more stuff going on that feels real than we've seen in nuclear for a very long time." ■

ARCHAEOLOGY

Silk Road cities reached for the sky

Mountainous Central Asia may have had a medieval urban zone

BY BRUCE BOWER

Two high-altitude, medieval cities built by mobile herders along Silk Road trade routes in Central Asia have been hiding in plain sight — until now.

Mountainous regions typically have been seen as obstacles to trade and communication. But these ancient settlements, located roughly 2,000 meters above sea level, show that herding communities developed a distinctive form of urban life where such activities thrived, archaeologists report October 23 in *Nature*.

"Think of these high-altitude cities as nodes in a network that moved power and trade through Asia and Europe," says study coauthor Michael Frachetti of Washington University in St. Louis.

His team focused on two archaeological sites in southeastern Uzbekistan: Tugunbulak and Tashbulak. Earthen mounds and pottery pieces indicate that Tugunbulak was occupied from the sixth to 10th centuries, while Tashbulak was first inhabited in the eighth century. But erosion and sediment buildup have obscured the urban features of both sites beneath undulating grasslands.

Researchers mapped both sites using a drone mounted with light detection and ranging, or lidar, technology. The maps indicate that Tugunbulak covered just over a square kilometer, making it one of the largest Central Asian cities of its time.

The more than 300 structures at Tugunbulak included clusters of buildings, narrow corridors between those clusters, watchtowers connected by walls along a ridgeline and a central fortress or citadel. The layout mirrored that of small and large lowland cities in medieval Asia.

Tashbulak covered roughly one-eighth the territory of Tugunbulak but was still a bustling community, Frachetti says. A string of large defensive structures overlooked terraced platforms, walls and houses. At least 98 structures resemble the types of buildings at Tugunbulak.

The findings highlight the ability of high-altitude herding groups to band together as early city builders, says archaeologist Michael Fisher of the Max Planck Institute of Geoanthropology in Jena, Germany. It shows that "mountain ranges can actually be conduits for cultural and economic transmission, not barriers."

The highland pastures supported livestock, which could have been traded to lowland settlements for grains, legumes, fruits and more. Recent excavations suggest Tugunbulak and Tashbulak produced iron, Frachetti says, a valuable trade item. ■

A map generated from lidar data revealed the borders of structures and roads (black lines) at Tugunbulak, a medieval city spanning about a square kilometer in the mountains of Central Asia.

SAIELAB, J. BERNER AND M. FRACHETTI

EARTH

Why rivers abruptly change course

The answer could help communities prepare for potential floods

BY NIKK OGASA

Shifting is in a river's nature. But when a river breaks free of its channel and carves a new path across the landscape, devastating floods may descend upon communities with little to no warning.

For decades, researchers have struggled to explain exactly how river channels become primed for such sudden diversions, or avulsions. A study published in the Oct. 3 *Nature* may have finally quelled the debate, showing how two factors work together to stage the rerouting of a river. The researchers, building on their findings, also developed an algorithm that can predict the new path of an avulsed river.

In some cases, "these are monumental floods, civilization-changing floods," says sedimentologist Douglas Edmonds of Indiana University Bloomington. In 2010, avulsions on the Indus River in Pakistan contributed to flooding that forced roughly 20 million people from their homes. Nonetheless, flood hazard models remain unable to predict where rivers will reroute, Edmonds say. "It's really an invisible flood hazard."

Avulsions require a setup and a trigger, an overburdened camel's back and a final straw (SN: 8/10/24, p. 15). "The trigger could be a flood, an earthquake, it could be a logjam in a river," Edmonds says. The setup refers to how the deposition of sediment has primed a river for diverting—and it's the fundamental cause of avulsion, Edmonds says. "Rivers experience floods all the time, but they don't avulse all the time."

Edmonds and colleagues focused on defining the setup, for which there had been two competing hypotheses. One held that avulsions happen when a river becomes superelevated, or the deposition of sediment raises a river's banks and water level above the surrounding land. The other contended that avulsions occur when there is a slope advantage, that is, once the slope of a new, potential path becomes steeper than that of the river's current path.

Using satellite data to investigate roughly 170 avulsions, the team noted how far downstream rivers tended to divert and found that avulsions are about three times as common near river mouths and mountain fronts as in between.

Focusing on 58 river channels for which high-resolution topographical data were available, the researchers measured the superelevation and slope advantage before avulsions. They found that superelevation best explained avulsions near the mountains, while slope advantage best explained those near river mouths and deltas.

There's so much sediment flowing out of the mountains that the rivers just pile it up until they're superelevated and spill over, Edmonds says. Meanwhile in deltas, there's a lot of cohesive mud that forms very steep natural levees around deep channels, and avulsions need a steep slope advantage to start cutting through the levee, he adds.

These two factors—slope advantage and superelevation—work together in an inverse fashion, the researchers found. The more superelevated a river becomes, the less of a slope advantage it needs to avulse, and vice versa. "It is the first time that anyone's been able to show that with data," says geologist Elizabeth Hajek of Penn State.

Avulsions occurred when the mathematical product of the two factors surpassed a threshold value, the scientists found. So long as precise topographical measurements of a river's channel are available, which is more likely for larger rivers and in places with clear skies, you could probably use that threshold metric to identify where avulsions are likely to occur, says geomorphologist Vamsi Ganti of the University of California, Santa Barbara.

The researchers developed a computer algorithm that highlighted where on a map an avulsed river might go, factoring in the steepness of the terrain and momentum of the river. When tasked with predicting the pathways of 10 past avulsions, the algorithm correctly captured the path of each one. "It's a really nice tool," Hajek says. "It could be really, really helpful for identifying areas of concern."

The plan is to develop avulsion hazard maps for vulnerable regions or even globally, Edmonds says. "Now that we have this metric, we can go measure it on rivers all over the world." ■

In 2019, the mouth of Kenya's Turkwel River (arrow, left) moved two kilometers north (right). Such abrupt shifts can flood nearby communities.

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MICROBES

Inflation is a phytoplankton's travel tip

Unicellular marine algae balloon up to migrate from the deep

BY GENNARO TOMMA

It's one of the most massive migrations on Earth: a huge assortment of plankton traveling from the deep sea toward the surface. Many phytoplankton have no limbs to propel themselves upward, so how do they undergo a journey that can take days?

Now, scientists have the answer for at least one species: It swells to six times its original size. By reducing density, the single-celled organism can then float upward like a helium balloon, bioengineer Manu Prakash and colleagues at Stanford University report October 17 in *Current Biology*.

"This is unique," says Andre Visser, an oceanographer at the Technical University of Denmark in Kongens Lyngby. "They've actually made a case for a novel way where these cells can actually stay buoyant or stay near the surface."

About 160 kilometers off the coast of Hawaii, the team collected water samples containing the 1-millimeter-long *Pyrocystis noctiluca*. This bioluminescent phytoplankton makes a once-in-a-lifetime trip from about 125 meters deep to about 50 meters, where there's more of the sunlight needed for photosynthesis.

On the boat and back in the lab, the team used microscopes that put the phytoplankton on a kind of hydrodynamic treadmill to re-create the movement of the cell traveling up the water column. "This is a little bit like a virtual reality machine for single cells," Prakash says.

P. noctiluca is denser than seawater and should sink. But at the beginning of its life cycle, it swells, reducing its density and traveling up the water column, the team found. At the end of its seven-day life cycle, the cell divides into two daughter cells as it sinks. Then the two newborn cells fill up with seawater, inflating to about six times their original size in about 10 minutes. And so the cycle begins again.

The researchers hypothesize that the cell becomes less dense and more buoyant as aquaporin proteins in the cell filter out dense salt from the incoming seawater. "In this way, you can have much less dense material flooding into the cell, making it able to be less dense than the surrounding seawater," says Stanford bioengineer Adam Larson.

This phytoplankton inflates to float up the water column (shown before and after swelling).

Inflation doesn't just help the phytoplankton rise. "Getting big actually has huge consequences for other parts of their life," Visser notes. "Bigger cells tend to have lower predation risk. There's fewer things that can eat them."

Size also helps with nutrient uptake and photosynthesis: A bigger surface lets the cell capture more sunlight. ■

PLANTS

A fungus helps plants eat meat

Insects have plenty to beware when it comes to carnivorous plants. Add an acid-loving fungus to the list of dangers. Sundew plants have tentacle-like leaves that curl around and entrap insects in a sticky secretion (shown). As stuck prey suffocate or die from exhaustion, the plant produces enzymes that dissolve the bodies into nutrients later absorbed by the leaves. But plant enzymes aren't the whole story. A fungus called *Acrodontium crateriforme* that lives on the plants produces additional digestive enzymes, researchers report in the October *Nature Microbiology*. The fungus also makes the leaf environment more acidic, helping plant and fungal enzymes work more efficiently. In lab tests, *A. crateriforme* reduced digestion time: Sterile plants took an average of 92 hours to digest powdered ants compared with 73 hours for plants inoculated with the fungus. Finding that a specific microbe supports digestion "reshapes our understanding of plant carnivory," says evolutionary biologist Jason Tsai of Academia Sinica in Taipei, Taiwan. "This opens up new avenues to explore other carnivorous plants and their potential microbial helpers." — *Erin Garcia de Jesús*

FROM TOP: ADAM LARSON/PRAKASH LAB/STANFORD UNIV.; PEI-FENG SUN

OCEANS

Saharan dust helps sustain ocean life

Atmospheric transport makes a key nutrient water-soluble

BY DOUGLAS FOX

As dust from the Sahara blows thousands of kilometers across the Atlantic Ocean, it becomes progressively more nutritious for marine microbes.

Chemical reactions in the atmosphere chew on iron minerals in the dust, making them more water-soluble and creating a crucial nutrient source for the iron-starved seas, scientists report September 19 in *Frontiers in Marine Science*.

Dust clouds settling on the Atlantic can spawn phytoplankton blooms that support marine ecosystems, says Timothy Lyons, a biogeochemist at the University of California, Riverside. "Iron is incredibly important for life," he says. Phytoplankton require it to convert carbon dioxide into sugars during photosynthesis.

By studying dust transport and chemical reactions in the atmosphere, scientists could better understand why parts of the oceans are biological hot spots for phytoplankton and fish.

Over 240 million metric tons of Saharan dust blow over the Atlantic Ocean each year. On Bermuda, the Bahamas and other islands, it turns soils red. But much of it settles on the ocean, providing a major source of iron to areas that are too far from land to receive it from rivers.

Lyons and marine geologist Jeremy Owens, then at UC Riverside, set out to answer a different dust question: Had the types of dust settling on the Atlantic changed over the last 120,000 years? The pair analyzed dust-derived minerals in four cores plucked from the seafloor in the eastern Atlantic near Africa and from farther west near North America.

What they found prompted a different line of inquiry.

In dust and soils around the world, roughly 40 percent of iron is ordinarily present within "reactive" minerals such as pyrite or carbonates. This kind of iron can be decomposed by weak acids and potentially used by life. In the core samples from the bottom of the Atlantic, only about 9 percent of iron in the dust minerals sampled from near North America was made up of reactive iron minerals, compared with about 18 percent in dust minerals taken from closer to Africa. That, Lyons says, was "the big surprise."

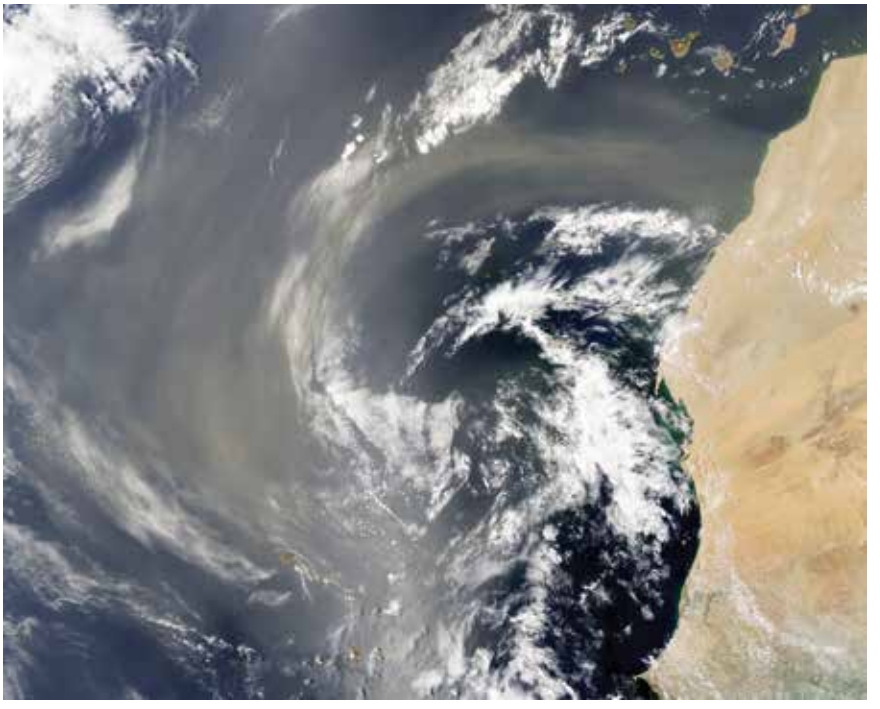
During dust's several-day transatlantic flight, more and more of its reactive iron is altered—attacked by acids and ultraviolet radiation, which pries apart the minerals, Lyons and Owens, now at Florida State University in Tallahassee, concluded.

"There are photochemical transformations that tend to make the iron more soluble" in water, Lyons says. As that modified iron settles into the ocean, it dissolves and gets devoured by phytoplankton. The only reactive iron that makes it to the seafloor is the stuff that isn't altered during air transport and later gobbled up. The researchers' results suggest that the farther the desert dust flies, the less of that iron is left.

By spawning phytoplankton blooms, dust-derived iron may also nourish small fish and other animals that graze on plankton, as well as the predators that eat the grazers. A recent study suggests that Atlantic skipjack tuna, an important commercial fish, are attracted to areas where Saharan dust has settled.

The new results are plausible because previous studies have shown that iron minerals react in the atmosphere, says atmospheric scientist Natalie Mahowald of Cornell University. The new conclusion "goes along with what I thought was happening," she says. But Mahowald points out that Saharan dust isn't the only possible source of that iron: The samples came from far enough north in the Atlantic that some of the iron could have come from smoke, from wildfires in North America over the last 120,000 years, she says.

To assess the dust's origin, Owens, Lyons and colleagues measured the ratios of iron to aluminum and the ratio of light iron atoms to heavy iron atoms in the samples. Both measurements were consistent with the kind of dust that comes from the Sahara, they found. Analyzing sediment from more sites in the Atlantic could provide a clearer picture of how dust has blown across the ocean and changed chemically. ■



As strong winds carry Saharan dust over the Atlantic Ocean, as shown in this satellite image from 2022, chemical reactions can make the dust into a suitable nutrient source for marine ecosystems.

NASA EARTH OBSERVATORY

ENVIRONMENT

Planting trees may help monarchs

Climate change threatens the butterflies' overwintering spot

BY SOPHIE HARTLEY

An experiment to grow new forests in central Mexico offers hope that the crucial winter habitat for millions of migrating monarch butterflies could survive into the next century.

When deciding to plant hundreds of baby oyamel fir trees (*Abies religiosa*) about 100 kilometers from their native habitat, scientists weren't sure how many trees would survive. Today, most of the saplings are flourishing, researchers report September 17 in *Frontiers in Forests and Global Change*. Even at an altitude of 3,800 meters, high above where the trees usually grow, almost 70 percent of the saplings survived at least three years.

While moving a whole forest may sound drastic, "desperate times call for desperate measures," says Karen Oberhauser, a conservation biologist at the University of Wisconsin-Madison who wasn't involved in the project. "If we don't help organisms move around, we're just going to lose a lot of ecosystems."

Each fall, after many monarchs (*Danaus plexippus*) migrate from as far north as the milkweed-laden meadows of southern Canada to the mountains of central Mexico, they hibernate exclusively on the oyamel fir. Thousands might cluster on a single branch, causing it to droop under their collective weight. But the forests — and the hibernating butterflies — are at risk. Monarch butterfly populations continue to decline. And climate change projections predict that oyamel firs will vanish almost entirely by 2090.

"I know that this sounds crazy, but we need to move the forests to a higher elevation," says forest geneticist Cuauhtémoc Sáenz-Romero of the Universidad Michoacana de San Nicolás de Hidalgo in Morelia, Mexico. Oyamel firs, which grow at altitudes of about 2,400 to 3,500 meters, need cold mountain air to survive. The high-elevation chill also works to slow the metabolism of butterflies, allowing them to survive the long winter. As central Mexico gets warmer, new generations of oyamel firs will probably creep higher up their native slopes but could soon run out of mountain to climb.

Sáenz-Romero wants to move the trees to taller mountains, but he's aware that they won't get there by themselves. "Unfortunately, the scene in *The Lord of the Rings*, where the trees are walking toward battle — it's just fiction. It doesn't happen."

His team collected oyamel fir seeds from inside the Monarch Butterfly Biosphere Reserve, located about 100 kilometers northwest of Mexico City, and grew them in a tree nursery. Then in 2021, in partnership with the Indigenous community in Calimaya, the team replanted about 750 trees at four different elevations in the community's forest on the Nevado de Toluca volcano.

Some seedlings were planted at 3,400 meters — similar to typical oyamel firs that live inside the butterfly preserve. But Sáenz-Romero wanted to determine just how much altitude an oyamel could take. Other trees were planted higher, in colder climates, at 3,600 meters, 3,800 meters and 4,000 meters above sea level.

If the firs could take root at higher elevations, the trees might thrive there in the future as temperatures rise, Sáenz-Romero hoped.

Three years later, he and colleagues found that young fir trees were smaller and shorter the higher they sat on Nevado de Toluca. Still, many made it past the first year, which can indicate long-term survival. Across elevations, an average of 80 percent of the seedlings that were planted in locations that were 2.3 degrees Celsius lower than their home regions survived at least three years.

Turning Sáenz-Romero's dream of growing new forests into reality would require getting community and government support. And even if the trees can survive longer term, another question remains: Will the monarch butterflies find them?

During the winter of 2023–24, some monarch colonies didn't hibernate within the Monarch Butterfly Biosphere Reserve. They flew to other forests. "My guess is that monarchs are already searching for colder places," Sáenz-Romero says. ■

Foresters from the Indigenous community in Calimaya plant young oyamel fir trees on the Nevado de Toluca volcano in Mexico. The trees are at a higher, colder elevation than their normal habitat.

FROM TOP: LILIBOAS/GETTY IMAGES; C. SÁENZ-ROMERO/UMSNH (CC BY)

ANIMALS

Elephant trunk wrinkles tell tales

There's a Sherlock Holmes story in here somewhere: A clever observer could check wrinkles and whiskers on an elephant trunk to catch a left-trunker pachyderm perp masquerading as a righty, thanks to a study of trunk skin wrinkles.

Rather like people grabbing a pen with the preferred hand, an individual elephant tends to bend its trunk toward the left or right when scooping up an object of desire. Trunk whiskers on the opposite side of the curl get scuffed against the ground, and so become shorter and sparser, mechanical engineer Andrew Schulz and colleagues report in the October *Royal Society Open Science*. And trunk skin gets a bit wrinklier on the curled-in side over the years as more little creases form with the bending.

Clues to this trunkedness are just some of the novel details of elephant skin wrinkles that Schulz, of the Max Planck Institute for Intelligent Systems in Stuttgart, Germany, and colleagues describe.

A trunk's roughly 40,000 muscles form a hydrostat, a boneless tube that easily changes shape. The thick outer skin puts limits on the trunk's movement. Still, that skin is stretchier on the trunk's upper surface than underneath.

Looking at preserved tissue, the team tracked how wrinkles start forming in utero, doubling about every 20 days during an early, rapid-wrinkle stage.

Trunks get wrinklier with age. For instance, in African elephants (*Loxodonta africana*), newborns averaged 87 while adults averaged 109. These wrinkles are key to making an elephant an elephant. They help protect the hydrostat and allow for shape change, Schulz says, especially when gripping heavy objects with the underside of the trunk. — *Susan Milius*

NEUROSCIENCE

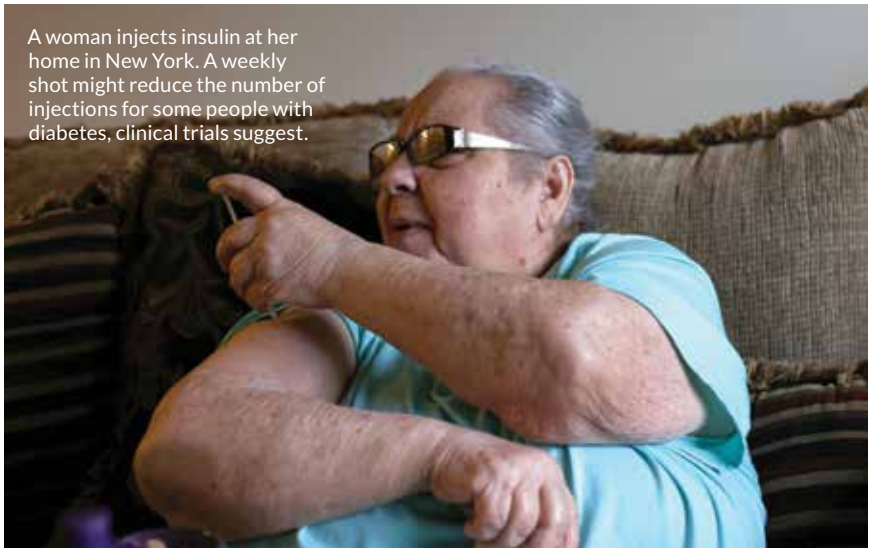
The brain can perceive odor changes in a single sniff

Human sniffs last between one and three seconds, but whether people can perceive odor changes within that time frame has been an open question. Now, research shows that people can perceive odor changes in fractions of a second.

Psychology researcher Wen Zhou of the Chinese Academy of Sciences in Beijing and colleagues created a device that uses changes in nasal pressure to detect the beginning of a sniff and then triggers the release of two odors with millisecond precision. More than 200 participants were exposed to a sequence of two chemical odors in a single sniff. Some scents smelled like apples or flowers, while others smelled like onions or lemon. Participants reported which order of odors they perceived.

Test subjects discerned different sequences with above-chance accuracy, even when the odors were delivered just 60 milliseconds apart, the team reports October 14 in *Nature Human Behaviour*.

Next, the scientists want to investigate what's going on from sniff to sniff, given that the nose can detect more than a trillion odors. — *Nora Bradford*



A woman injects insulin at her home in New York. A weekly shot might reduce the number of injections for some people with diabetes, clinical trials suggest.

MICHAEL M. SANTIAGO/GETTY IMAGES

HEALTH & MEDICINE

Weekly insulin shots show promise

For type 2 diabetes, a weekly may work as well as a daily shot

BY AIMEE CUNNINGHAM

Life with diabetes usually includes many injections of the blood sugar–controlling hormone insulin. Recent research suggests that a once-weekly shot might help lessen that burden a bit for some with the disease.

Two pharmaceutical companies have developed weekly insulin formulations and have tested the drugs in clinical trials.

Efsitora, from Eli Lilly, worked as well as a once-daily formulation for adults with type 2 diabetes, scientists reported in September in the *New England Journal of Medicine*. With type 2 diabetes, the body doesn't make enough insulin or doesn't respond to insulin effectively.

But a trial of adults with type 1 diabetes, reported in September in the *Lancet*, found there were more episodes of dangerously low blood sugar in the group on efsitora than in the group taking a once-daily insulin shot. Type 1 diabetes is an autoimmune disease that destroys the cells that make insulin.

Meanwhile icodec, from Novo Nordisk, has received approval for use in adults with diabetes by the European Union and Canada and a few other countries. But the U.S. Food and Drug Administration announced in July that it is not ready to approve icodec. An FDA advisory committee raised concerns about the increased risk of hypoglycemia (blood sugar that's too low) for adults with type 1.

An estimated 38 million people have diabetes in the United States, according to the U.S. Centers for Disease Control and Prevention. Close to 2 million of those have type 1. Managing diabetes means monitoring blood sugar levels throughout the day and, for those with type 1 and some with type 2, figuring out how much insulin to take.

If an insulin dose is too high, blood sugar drops too much. The effects can include shakiness, nausea, fatigue and dizziness, among other symptoms. If blood sugar levels become severely low, a person can become confused, have difficulty walking and even lose consciousness. Severe hypoglycemia is a medical emergency.

With diabetes, there's "a lot of thinking about food and thinking about numbers," says endocrinologist Laura Young of the University of North Carolina School of Medicine in Chapel Hill. "It doesn't ever stop."

People with type 1 diabetes and some with type 2 can face multiple daily injections. Short-acting insulin covers the spike in glucose that comes with meals. Long-acting insulin, which can last about 24 hours, manages the time between meals. Covering three meals and the rest of the day and night adds up to "at least four shots, and that's probably the minimum," Young says.

In the body, special cells in the pancreas, called beta cells, make insulin. These cells detect glucose in the blood and secrete the needed amount of insulin, responding to changes in glucose due to meals, exercise, illness and stress.

There's "continuous regulation to keep sugar in a good range, even if we don't eat," says endocrinologist Giulio Romeo of Harvard Medical School and the Joslin Diabetes Center in Boston. "It's hard to replicate our body's ability to fine tune" this process, he says.

Once-weekly insulin is meant to take the place of a once-daily long-acting shot. It could make a difference for people's quality of life "to have to take one less shot a day," Young says. But the key, she says, will be making sure that it's the right dose. With a once-daily shot, if the dose is too high, "it's a lot easier to deal with hypoglycemia for that period of time versus the whole entire week."

In the clinical trials of the two weekly formulations, there were more episodes of severe hypoglycemia in participants with type 1 diabetes taking once-weekly insulin compared with those taking once-daily. This wasn't an issue in participants with type 2.

People with type 2 diabetes may have a lower risk of developing hypoglycemia than people with type 1 because they "still make a little bit of their own insulin," Young says, and "for the most part, have lower variability in their blood sugar."

Weekly insulin is certainly promising for managing type 2 diabetes, Young says. For type 1, researchers need to "show some more data and be a little more precise" about which people with type 1 might benefit, she says.

It's harder to make needed adjustments to a medication that is injected once a week, Romeo says. People with type 1 need a "level of fine-tuning on a day-to-day basis that makes the weekly insulin possibly not the best option." ■

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Fossil Superstar

Discovered 50 years ago, Lucy remains an evolutionary icon

By Bruce Bower

Inside a specially constructed safe at the National Museum of Ethiopia in Addis Ababa sit the fragile remains of the world's most celebrated human ancestor. She was once a hardy survivor in an unforgiving environment, but now her partial skeleton receives round-the-clock protection in a temperature-controlled setting.

In her prime, nearly 3.2 million years ago, this ancient female roamed East Africa's landscape. Standing a bit over 1 meter tall and weighing no more than about 30 kilograms — slightly taller and lighter than an average adult female bonobo chimp — she was not physically imposing.

But her evolutionary stature and cross-cultural appeal are huge. Today, half a century after the discovery of her partial skeleton, people everywhere know Lucy.

Discovering Lucy ushered in a new way of thinking about human evolution among late-20th century paleoanthropologists. At that time, many viewed human evolution as having proceeded along a straight line, with one ancient *Homo* species leading directly to the next until the emergence of present-day people.

But Lucy's blend of humanlike features, such as a curved spine, with apelike traits, including a brain no larger than a chimp's and long arms, pointed to a more treelike picture of human evolution. In that scheme, myriad species branched off in different directions, some dying out and others leading to the *Homo* genus and eventually to us.

Lucy's anatomical potpourri also sparked new questions about how two-legged walking evolved and the origin of humans' large brains.

Perhaps most importantly, Lucy's discovery foreshadowed a series of fossil finds that filled in the scientific picture of her species. By 1978, enough evidence had accumulated to establish Lucy as the founding member of a previously unrecognized species, *Australopithecus afarensis*.

On the 50th anniversary of her partial skeleton's discovery, Lucy commands much more name recognition than other fossils from humankind's evolutionary family, known as hominids or, increasingly, hominins (SN: 9/25/21, *p.* 20). A look back at Lucy's story reveals how she has remained atop the hominid A list. In this case, geologic good fortune, skilled scientific scrutiny and an inspired musical reference helped to turn an ancient relative into a household name.

Geologic good fortune, skilled scientific scrutiny and an inspired musical reference made Lucy a household name.

Get buried but not too deep

Paleoanthropologist Donald Johanson and graduate student Tom Gray spent the morning of November 24, 1974, mapping and surveying possible fossil-bearing spots in a desolate region of Ethiopia. Walking back to their Land Rover through a gully at a site known as Hadar, Johanson noticed a forearm bone sticking out of the ground. A closer look confirmed that the bone came from a hominid.

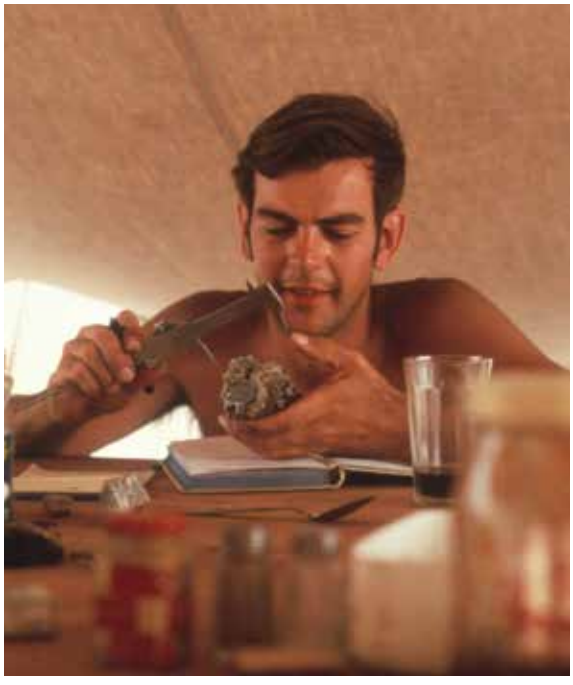
Johanson and Gray gingerly removed several more skeletal pieces from loose soil nearby. After two more weeks, the researchers and their colleagues had uncovered several hundred bone fragments — a big haul considering finding one ancient hominid skullcap or partial jaw can require weeks or months of careful excavation.

From those finds, the team pieced together 47 fossil bones to form a small fossil skeleton about 40 percent complete. It was the most complete early hominid skeleton at that time — by a lot (SN: 1/4/75, *p.* 4).

Geology had worked in Johanson and Gray's favor. Lucy's remains were not found where she died. Flooding had carried her body, probably shortly after death, into a sandy channel where a lake quickly formed. The burial under moist lake sediment kept her fossilized bones in relatively good shape. And the fossils were near enough to the surface that, much later, after the lake had dried up, they began to emerge from eroding, sandy sediment.

Scientists continue to debate how Lucy died (SN: 9/17/16, *p.* 16) and whether scavenging by hyenas and other animals, trampling or other factors explain her skeleton's missing pieces. But what remained popped out just enough from Hadar's surface to get the fossil party started.

The Lucy skeleton (a cast shown) belonged to an individual who lived more than 3 million years ago and possessed a mix of human- and apelike characteristics.



Stay close to fossil comrades

Part one of the geologic good fortune involved Lucy's skeleton. Part two ushered her species mates into view.

Lucy was found on land that, although not evident at first, preserved bones of many of her contemporaries. Fossils unearthed from 1973 to 1977, including a knee joint that predated Lucy's discovery but was only later recognized as part of her species, cemented Lucy's membership in a larger *A. afarensis* population (SN: 1/20/79, p. 36). Those finds enabled scientists to distinguish between Lucy's East African species and a previously identified species of South African hominid in the same genus, *Australopithecus africanus*.

Other generally accepted hominid species known at the time mostly belonged to the *Homo* genus — including *Homo habilis*, *Homo erectus* and *Homo neanderthalensis*.

As evidence for *A. afarensis* grew, Lucy came to symbolize the entire species.

Fossils from several East African sites, some excavated as early as the 1930s, have since been incorporated into *A. afarensis*. Hadar has yielded about 90 percent of the nearly 600 fossils so far attributed to the species.

Hadar's geology also gave Lucy a big advantage in the ancient dating game. The three Hadar sediment formations with *A. afarensis* remains each contain layers of volcanic matter and ash. Measures of the decay of radioactive argon into related forms in that volcanic material provided age estimates for the fossils. The ability to narrow down Lucy's evolutionary age in this way shortly after her discovery reinforced her status as an especially early hominid — the oldest known at that time — with an exceptionally preserved skeleton.

While Lucy lived an estimated 3.2 million years ago, her species at Hadar and elsewhere existed from about 3.9 million to 3 million years ago, making her a flag bearer for a hominid species that had a 900,000-year run.

To paraphrase an old Beatles song, Lucy topped the hominid hit parade with a little help from her friends.

Names matter

Another Beatles song advanced Lucy's worldwide fame by providing a catchy, memorable name.

After the initial Hadar discovery, when Johanson and Gray returned to camp for the night with what looked like pieces of a hominid skeleton, they joined the rest of the team in a celebration. A tape recorder played the song "Lucy in the Sky with Diamonds" over and over during the festivities. The tune's psychedelic lyrics echoed the surreal events of that day. Joyous partyers started calling the newfound fossil Lucy.

With that thoroughly modern moniker, familiar to people around the world, Lucy from the gully in Hadar received a big boost toward fossil stardom.

The origin of Lucy's nickname was far more raucous and spontaneous than is typical for fossil hominid specimens, which often get named for the place where they were found. Consider the Taung Child, a 3-year-old's fossil skull uncovered by miners at South Africa's Taung quarry in 1924. Researchers generally agree that the discovery of the Taung Child — which may have lived anywhere from around 3.7 million to 2 million years ago, depending on age-estimation methods — launched the modern era of fossil hominid studies.

The Taung skull turned researchers' attention away from Asia and toward Africa as the birthplace of hominids. In 1925, anatomist and anthropologist Raymond Dart assigned the find to *Australopithecus africanus*, a new species that he considered a direct ancestor of the *Homo* line.

PREVIOUS SPREAD: DEANNA DENT/ASU NOW, ADAPTED BY B. PRICE; THIS PAGE, LEFT: BOBBIE BROWN; MIDDLE AND RIGHT: INSTITUTE OF HUMAN ORIGINS/ARIZONA STATE UNIV.

Lucy was discovered in Ethiopia at a site called Hadar (far left) by paleoanthropologist Donald Johanson (middle) and graduate student Tom Gray in 1974. In all, the Hadar field team that year (near left) excavated hundreds of fossil fragments belonging to Lucy's skeleton.

The position of the ancient child's skull opening for the spinal cord showed that the head rested directly above the spine, a hallmark of the ability to walk upright. Though the South African skull hinted that early hominids had adopted a two-legged gait before big brains, some researchers suspected that Taung would have developed into a chimplike, knuckle-walking adult.

The Taung Child certainly deserves recognition in this centennial year of its discovery. But the fossilized Hadar female named for a trippy rock song has gained far more public acclaim than the ancient kid named after a quarry.

Lucy goes by other names. Her formal designation, rarely used outside academic journals and scientific meetings, is AL 288-1. And Ethiopians today refer to the remains as Dinknesh, a word that in a regional language means "you are marvelous." On the world stage, though, the Hadar female answers only to Lucy.

Inspire big evolutionary debates

Lucy would have appreciated the lyrics of another Beatles song that opens with: "I'm looking through you, where did you go? I thought I knew you, what did I know?"

Her partial skeleton revealed enough anatomy to reshape debates about hominid evolution without supplying easy answers. Five decades later, those disputes continue.

At the time of the Hadar find, the fossil discoveries and evolutionary ideas of Louis and Mary Leakey and their son Richard dominated anthropology. Louis Leakey regarded human evolution as having occurred solely within the *Homo* genus. Probably starting with *H. habilis*, he argued, one *Homo* species led to the next without any branching into dead-end lines. South African australopithecines, such as the Taung Child, represented extinct ape species, from his perspective.

Big brains powered the rise of the *Homo* genus and eventually people today, starting in Africa perhaps 3 million years ago, the Leakeys argued.

Lucy, with a body built for humanlike walking topped by an ape-like brain, challenged that idea. Johanson placed Lucy's kind at the center of a dramatic split in hominid evolution, with *A. afarensis* evolving in one direction into later australopithecines and in another direction into the *Homo* genus. That view is still held by Johanson and many others today.

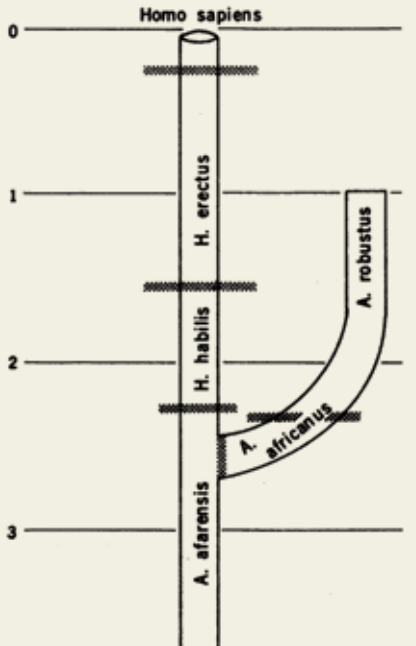
At a minimum, Lucy's partial skeleton strengthened the argument — until then based on the tiny Taung skull — that a two-legged stride arrived before the emergence of big brains in human evolution.

Lucy's lower-body design triggered a related dispute. Her spine and legs were adapted for an upright gait, which would reinforce her proposed status as a direct *Homo* ancestor. But relatively long arms and curved fingers resembled those of a tree-climbing ape. After Lucy's discovery, researchers debated whether the species divided its time between the trees and the ground, or mainly stayed on the ground despite retaining skeletal traits of tree-climbing ancestors.

Lucy's preferred mode of getting around remains a hot topic (*SN: 12/1/12, p. 16*). Frequent tree climbing, possibly linked to exceptional upper-body strength, would support a controversial proposal that she fell to her death from high up in a tree. If an efficient two-legged stance kept Lucy grounded, as suggested by another *A. afarensis* fossil find (*SN: 7/17/10, p. 5*), then she probably died from some other cause.

Crucial questions also concern her species's diet and possible stone tool use (*SN: 9/11/10, p. 8*). In 2000 at another Ethiopian site, researchers discovered the nearly complete fossil skeleton of a 3-year-old girl from Lucy's species, which they named Selam. Later evidence from that site suggests that *A. afarensis* used stone tools to obtain marrow, meat and fat

Family ties Donald Johanson and Tim White published this hominid family tree in 1979 (numbers show how many millions of years ago each species lived; hatched lines show boundaries between species). *Australopithecus afarensis* is shown as the direct ancestor of the genus *Homo* and a side branch of other australopithecines.



D.C. JOHANSON AND T.D. WHITE/*SCIENCE* 1979

from animal carcasses. If those findings hold up, then meat eating did not rapidly lead to bigger hominid brains, as many researchers have assumed.

Make the right scientific friends

Lucy attracted big-time researchers from the moment Johanson and Gray started retrieving parts of her skeleton. The evolutionary status of the ancient Hadar hominid and her kind soared thanks to her newfound admirers' collaborative efforts and publications.

Johanson, Lucy's first champion, arrived at Hadar in 1972 as part of an international fossil-hunting expedition. His colleagues included three already distinguished researchers, all now deceased: paleoanthropologist Yves Coppens, geologist Jon Kalb and geologist Maurice Taieb, who had discovered the Hadar Formation in 1968 and organized the expedition. The team became immersed in excavating more Hadar fossils, with a first wave of fieldwork running through 1977.

Johanson recruited a young paleoanthropologist who would go on to have a bright future in fossil hunting and analysis, Tim White, to help analyze the growing trove of ancient bones. It was in a 1978 paper that Johanson, White and Coppens identified Lucy and other fossil hominids at Hadar and another East African site, Laetoli, as a new species.

White added a keen eye and voluminous knowledge of bones to the early studies of Lucy and her kind. In 1991, White published *Human Osteology*, a classic book on how to analyze human skeletons that is still in print. The next year, he published an influential book on how to recognize signs of cannibalism on human bones (SN: 1/2/93, *p.* 12). He later directed excavations of a 4.4-million-year-old partial hominid skeleton known as Ardi that also shook up the human family tree (SN: 1/16/10, *p.* 22).

Johanson thrived in a role as scientific popularizer. His 1981 book *Lucy: The Beginnings of Humankind*, coauthored with writer and naturalist Maitland Edey, brought her worldwide attention. In the same year, newscaster Walter Cronkite moderated a nationally televised debate between Richard Leakey and Johanson.

Though fieldwork stopped in 1977 due to an increasingly violent Ethiopian Civil War, in 1981 Johanson met an anthropology graduate student who would direct a second wave of Hadar excavations. William Kimbel started out by analyzing braincase remains of *A. afarensis*. In the early 1980s, Kimbel worked with Johanson and White to detail why *A. afarensis* and *A. africanus* were different species.

Kimbel took charge of a new phase of fieldwork in 1990 as the civil war neared its official end the next year. He raised funds for, organized and directed *A. afarensis* excavations for the next three decades. During the 1990s, he helped lead a movement to understand different species concepts and their implications for primate evolution.

Lucy's kind had no better *Homo sapiens* friend than the paleoanthropologist everyone called Bill. Paleoanthropology suffered an enormous loss in 2022 when Kimbel, who also directed the Institute of Human Origins at Arizona State University from 2009 to 2021, died of abdominal cancer at age 68.

Kimbel, like Lucy's discoverers, had argued that she is a direct ancestor of the *Homo* genus, a proposal that remains controversial. To this day, few early *Homo* fossils exist for comparison with *A. afarensis*. Kimbel contributed to the analysis of one such find, a roughly 2.8-million-year-old *Homo* jaw found near Hadar. In his view, traits of that fossil indicate that one branch of Lucy's species evolved into the first members of the genus *Homo*, and eventually gave rise to *H. sapiens* (SN: 4/4/15, *p.* 8).

During the televised debate between Johanson and Richard Leakey, Johanson presented a drawing of his proposed hominid family tree. Leakey scrawled a question mark over it. Decades later, Lucy and her Hadar crowd still elude scientific consensus.

But no matter how this pivotal evolutionary issue plays out, Lucy's trip from a Hadar gully to an Ethiopian museum vault has been eventful for her species and anyone interested in the origins of humankind. Fifty years after stopping a couple of fossil hunters in their tracks, Lucy's star power shines bright. ■

Lucy is so renowned that then-President Barack Obama viewed the bones during a trip to Ethiopia in 2015.

WHITE HOUSE PHOTO/ALAMY STOCK PHOTO

Explore more

- Learn more about Lucy's story from the Institute of Human Origins: bit.ly/LucyAnniversary

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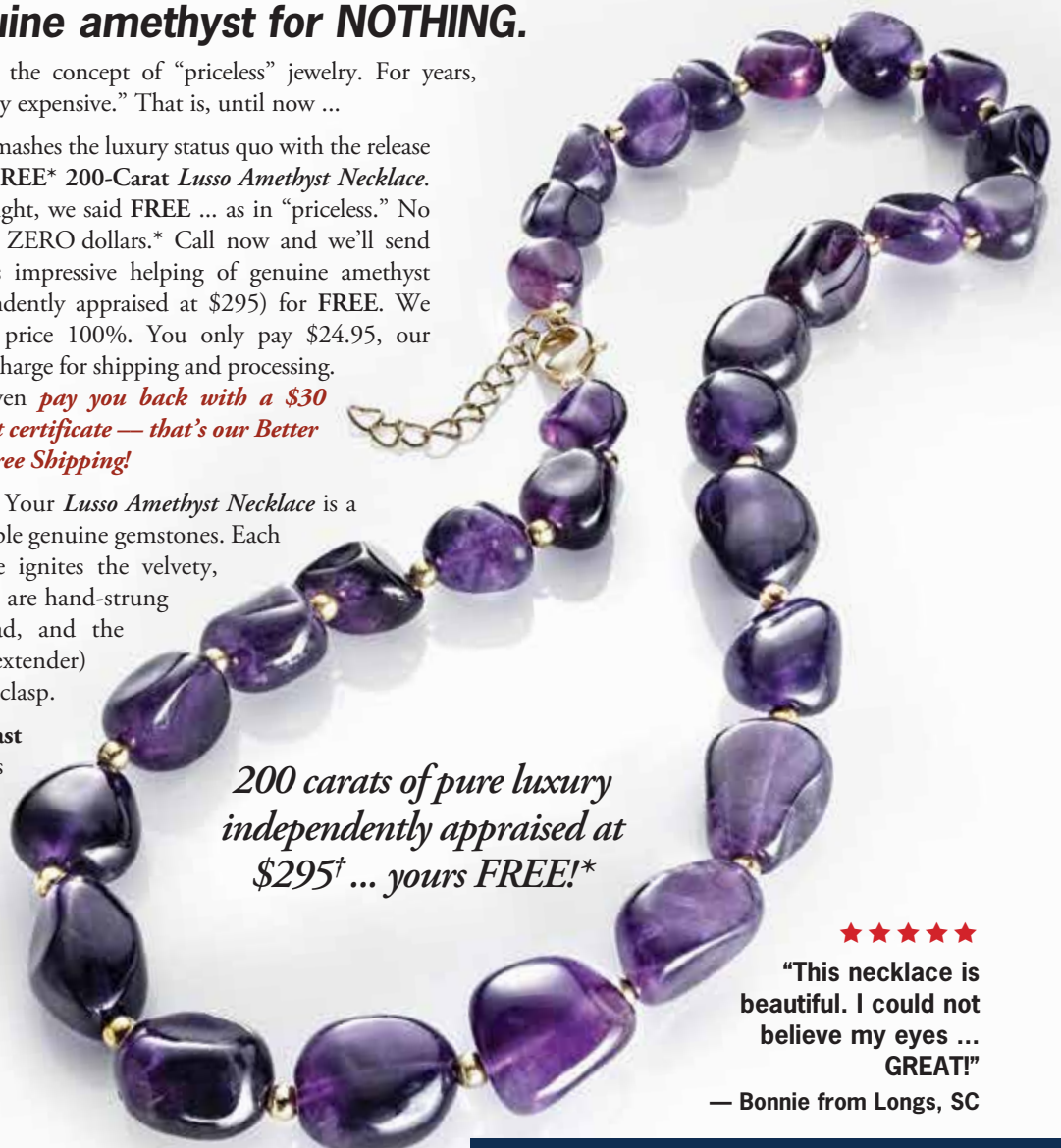

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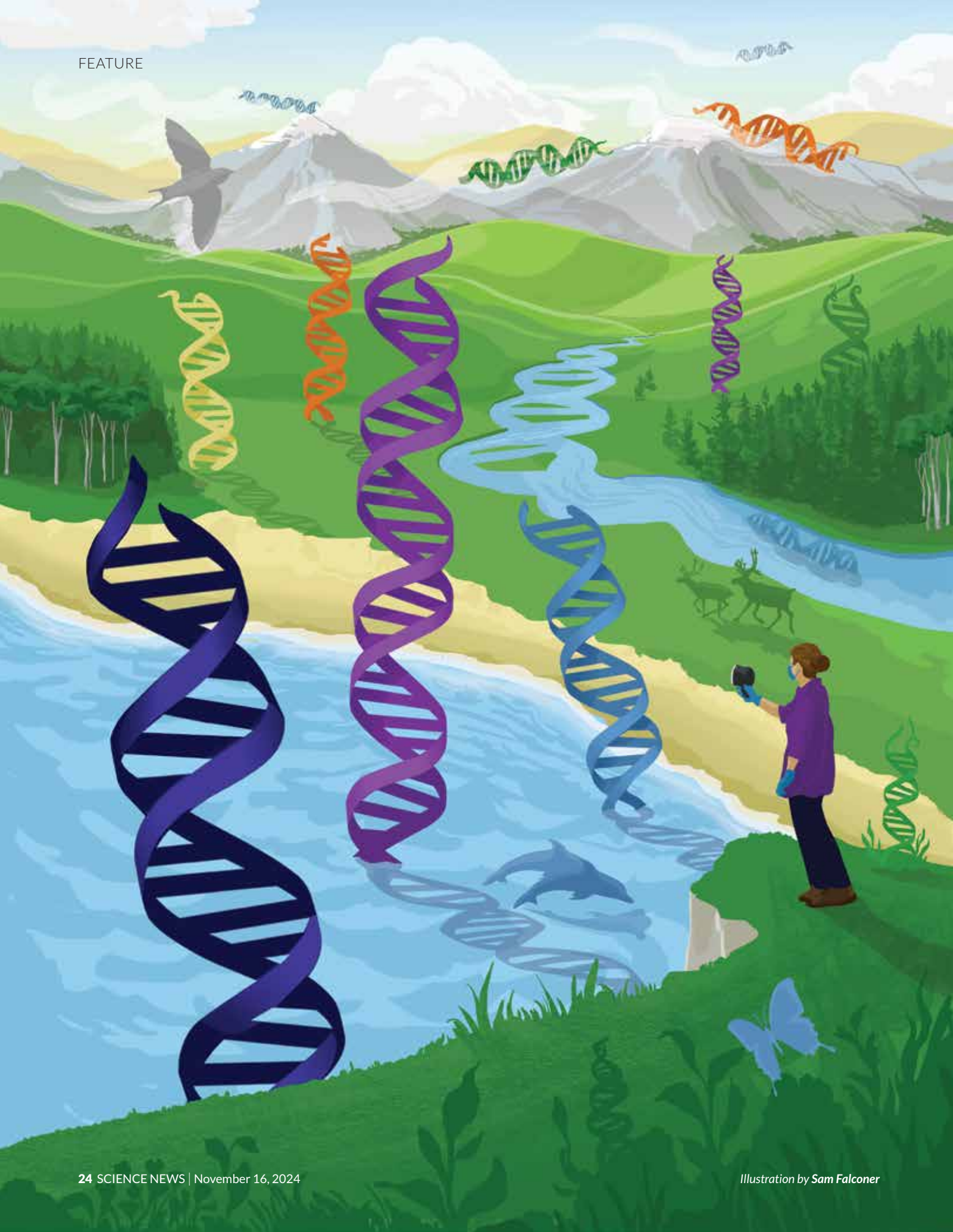


*Illustration by **Sam Falconer***

In pursuit of eDNA

DNA left behind by wildlife is revolutionizing conservation biology

By Erin Garcia de Jesús

On a warm, sunny day in April, biologists David Duffy and Jessica Farrell prepare to motor down the Matanzas River on a small boat to catalog the area's aquatic life. Ripples signal the river's lazy flow along Florida's northeastern coast. Birds fly overhead, some settling onto mangroves occupying the river's edge. The muddy-brown waters obscure most signs of any life in the river.

But then a pod of bottlenose dolphins appears. The sleek critters break through the water to take a breath as they swim against the current. The team will cross paths with many more of these cetaceans as the boat traverses the river and connecting waterways. A few dolphins toss a fish in the air, seemingly playing catch with their food. Others pass alongside the research vessel as underwater shadows.

Dolphins are hardly the river's only inhabitants. It's just that some species are harder to spot.

Sea turtles poke their heads above the water in occasional blink-and-you'll-miss-it events. Diving manatees produce swirls on the surface that only a trained eye knows to look for.

But even the rarest, hardest-to-spot fauna—and flora—leave behind molecular traces of their presence. And that's what Farrell and Duffy are searching for: DNA.

All living beings constantly shed bits of DNA, left behind from skin, scales, hair, urine, feces, pollen and more. This environmental DNA, or eDNA, has "changed everything" about how scientists study biodiversity and conservation, says molecular ecologist Elizabeth Clare of York University in Toronto.

Traditionally, conservation research and monitoring have required a physical presence, perhaps a person who keeps watch over monkeys, or a motion-sensitive camera that documents a passing mountain lion, or a light trap that collects moths. "These are excellent confirmations that something was there," Clare says. But "if the animal walks behind your camera trap, you miss it. No record."

That's not a problem with eDNA. "eDNA is more like a footprint, and footprints last longer than the animal or the plant," Clare says. "The marvelous thing about it is it widens your time window of detection.... It's like having eyes on the back of your head."

eDNA is particularly useful for biodiversity surveys, sleuthing out even elusive species that rarely cross paths with humans. Samples taken from remote areas and brought to the lab for analysis can help researchers track the spread of invasive species, say, or identify species thought to be extinct. But even as conservationists discover new ways to put eDNA to use or new places to look for it, they must overcome challenges in how to interpret the genetic material they find.

Getting a handle on uncertainties is worth it, says Melania Cristescu, an evolutionary biologist and ecologist at McGill University in Montreal. "These [genetic-monitoring] tools are going to make biodiversity programs possible at the global level, so that we have a way of monitoring biodiversity the way we monitor our weather, with consistency."

Who's there?

Farrell and Duffy, who both work at the University of Florida's Whitney Laboratory for Marine Bioscience in St. Augustine, reach their first stop of the day, Dolphin Creek, an offshoot of the Matanzas.

Into the waist-high water, Farrell slips a long,

metal pole with a 1-liter plastic bottle on the end and fills it with water. She pulls out the bottle and caps it with gloved hands — a precaution to avoid contaminating the sample — and plops it into a white cooler for transport. Back at the lab, the team will filter out any DNA for analysis and search genetic databases for potential matches to ID the species.

Duffy, meanwhile, is testing a method that could eliminate the need to lug around heavy bottles of water. On the boat's deck, he sets up a portable pump and attaches it to a tube that pulls water through a pinkie-sized filter encased in plastic and submerged in the creek. After about five minutes, the once-white filter is now tinged light brown and hopefully loaded with DNA.

The idea of trawling water for genetic material goes back to the mid-1980s, when researchers used DNA to detect bacteria inhabiting marine sediments. Then in the early 2000s, scientists discovered that some sediments could preserve DNA from extinct animals. Woolly mammoth DNA was found deep in Siberian permafrost, and sediment from a cave in Arizona contained genetic material from an ancient giant ground sloth. These discoveries showed that DNA could persist for thousands of years.

Modern signs of life were present, too. The researchers working in Siberia, led by geneticist Eske Willerslev of the University of Copenhagen, pulled DNA belonging to present-day flowering plants and mosses from surface soil.

Clare credits Willerslev for inspiring conservationists to use such molecular traces to monitor biodiversity. His work with frozen sediments "really started the field," she says, "and then it quickly went to the water." In 2008, researchers in France used eDNA to detect invasive American bullfrogs (*Lithobates catesbeianus*) in natural ponds. Then in 2011, another team pointed to eDNA to suggest that two invasive Asian carp species were swimming in waters connected to Lake Michigan.

Back in Dolphin Creek, it's not hard to guess one animal that will appear in Farrell and Duffy's samples. "We do get dolphin DNA," Duffy confirms.

With so many dolphins swimming by, some of the eDNA is guaranteed to be recent. But the Matanzas sampling illustrates one of the difficulties in interpreting eDNA. Unlike a time-stamped photo from a camera trap, it's hard to know exactly when an animal left behind its genetic calling card.

Studies show that eDNA can persist for hours to weeks in the water column, says ecologist Kristy Deiner of ETH Zurich. After that, "you'll find it sometimes and not other times." Inconsistent detections in samples collected on the same day or over a few days provide a hint that an animal is long gone, or that the DNA traveled there from somewhere else.

How long eDNA sticks around in water depends on several factors. For instance, eDNA decays faster as temperatures increase above 20° Celsius, Deiner and colleagues reported in a 2022 meta-analysis. How DNA exists in the environment could also influence its staying power.

"We know DNA exists inside a nucleus, inside of a cell, inside of a big multicellular organism," Deiner says. "But what are we actually detecting when we take a water sample? We don't know if it's the cell or coming from an organelle [a structure within a cell] or dissolved DNA floating around." It's unclear how these different states of eDNA might affect whether the molecule is detected or how it moves through a water system.

Also unknown is how water chemistry impacts eDNA degradation, or how the water it's flowing in affects it. eDNA from a fast, glacier-fed river might behave differently than eDNA from the slow-moving Amazon River. "We haven't done enough studies around the world to know that it's context dependent or if there are universal equations that would predict [eDNA's] behavior," Deiner says.

Jessica Farrell labels a water sample collected from the Matanzas River in Florida. Back in the lab, any DNA retrieved from the samples will be analyzed to determine which species are present in the river.

E. GARCIA DE JESÚS

But eDNA's movement through the water might bring benefits. For instance, river water often ends up in lakes, which might act as a "biodiversity accumulator," Deiner says. A single lake could be a repository of all the life in an entire watershed.

To test that idea, earlier this year in May, Deiner and colleagues asked citizen scientists globally to sample water from about 400 lakes, including in Africa and Southeast Asia, locations that are underrepresented in eDNA studies. By analyzing hundreds of samples, the team hopes to capture what organisms inhabit connecting waters, as well as the terrestrial species that live in the surrounding area.

Such a massive analysis of biodiversity wouldn't be possible without eDNA, Deiner says. "It just allows you to think much bigger and much larger."

Where'd you go?

In the moments before sunrise, the Florida sky is on fire. Red, orange and yellow hues blend into light blue as waves crash onto a sandy beach. Few people are out this early, but the steady growl of two utility task vehicles breaks the calm.

It's the second day of the sea turtle patrol season, when volunteers come together at Mickler's Landing, a beach north of St. Augustine, to comb for sea turtle nests. One task on this chilly April morning is to collect sand from nests to harvest DNA that turtles leave behind.

Unfortunately, it's early in the season and there are no nests. But volunteer Lucas Meers explains the sampling process if a nest were present. He would kneel down, pull out a tube about the size of a toilet paper tube from his backpack and take up short, delicate scoops of sand. If turtle tracks were present, Meers says, he would also scoop samples from where the turtle's flippers touched sand and where the turtle's body scraped across the beach (and probably left behind secretions from laying eggs). Far away from the tracks, Meers would collect a control sample that should test negative for sea turtle DNA.

As with the Matanzas River samples, eDNA pulled out of the sand helps Duffy, Farrell and colleagues identify which turtle species are present, such as green turtles (*Chelonia mydas*), loggerheads (*Caretta caretta*) or leatherbacks (*Dermochelys coriacea*). The team also checks for the presence of a tumor-causing virus that's infecting turtles around the globe, providing a window into sea turtle health.

Genetic analyses can also go beyond which species are present, Duffy says, and reveal where animals go.

By identifying the genetic fingerprint of a population and looking for that signature in eDNA, researchers may be able to pinpoint where groups of animals travel by gathering samples in multiple places. As a proof of concept, loggerhead turtle DNA found at Mickler's Landing and other Florida beaches belonged to animals known to lay their nests in the southeastern United States, Duffy, Farrell and colleagues reported in 2022 in *Molecular Ecology Resources*. Using DNA to follow paths of travel could be helpful in making decisions about which habitats to protect.

David Duffy tests a method of sampling eDNA in water. A small filter encased in plastic is placed in the water. The attached tube connects to a portable pump on the boat that pulls water over the filter. The filters, which turn brown after sampling, are easier to carry around and store than heavy bottles of river water.

E. GARCIA DE JESÚS

"If you're trying to conserve [a species] based on just protecting one portion of the habitat they need during life, that's going to have limited success," Duffy says. "If you can start to understand where those animals are coming from, then you get a much better idea of their range and what needs to be protected."

Singling out the genetic signal of a single individual in a population might even be possible, allowing researchers to forgo tagging endangered species. In a 2023 study in *eLife*, for instance, scientists could discern some of the members of a highly studied kākāpō parrot population in New Zealand that left behind traces of DNA in soil samples. But it's currently difficult to parse out specific individuals from eDNA unless their genetic material dominates the sample, giving researchers more material to work with to make a match. Most samples are a jumble of many individuals.

But an example from humans further demonstrates the possibility of tracking individuals. Duffy and colleagues have inadvertently collected snippets of human DNA in the environment that are intact enough to reveal genetic ancestry and even disease susceptibility. With targeted analyses, the collected material could be enough to identify people, the team reported in 2023 in *Nature Ecology & Evolution*.

While the possibility raises ethical concerns

about privacy, conservationists typically take active steps to avoid analyzing human DNA from field samples in favor of other species.

Still, "if you translate [the human findings] in the future out to other species," Duffy says, "that's potentially a game changer in terms of the amount of information you can obtain."

What's in the air?

Like the innumerable chunks of DNA that float in water or settle in sand, researchers are discovering that with a vacuum in hand they can suck up eDNA from a new frontier: the air.

Wind gusts haul tree pollen and fungal spores the way people get swept up in a crowd. Fur and skin cells from animals can catch rides in dust. This immense repository of DNA is all around us, just as water surrounds aquatic creatures. Analyzing airborne eDNA faces many of the same interpretation challenges that water and soil samples do, and for now, just a handful of labs worldwide, including Clare's at York University, are harvesting airborne eDNA to survey life's gamut.

In the past, researchers focused on picking up DNA from microbes, spores and pollen — obvious targets in the air. On the animal side, Clare found very little, including a report from two Japanese high school students who picked up starling and owl DNA from the air for a science project.

> "These [genetic-monitoring] tools are going to make biodiversity programs possible at the global level."
>
> **MELANIA CRISTESCU**

Then in 2022, Clare's team and a separate group independently reported experiments pulling animal DNA out of thin air at zoos — confirmation that a whiff of air could reveal the area's animal roster (SN: 2/26/22, p. 4). Thanks to those demonstrations, interest in airborne eDNA is expanding. The abundance of such DNA, Duffy says, "opens up whole new ways of measuring biodiversity."

That abundance helps scientists easily collect hundreds of air samples from the same area over and over again, says Clare, who studies both eDNA and bat ecology. "Me alone, I can sit there and watch one cave. But I can put 100 [air] samplers in 100 caves and do it every night for a week and suddenly understand neotropical roosting ecology."

Scientists might even be able to collect genetic samples from existing infrastructure. Air pollution–monitoring stations, for instance, can be hidden warehouses for eDNA, Clare and colleagues reported in 2023 in *Current Biology*. Facilities worldwide collect daily or weekly samples to keep tabs on pollution. Some facilities store the samples for decades, meaning such stations could help researchers track biodiversity at a larger scale than ever before.

"Now we found a method that fits the surveillance system we already have," Clare says.

But collecting genetic material from the air comes with uncertainties. Whether airborne DNA detects only local species or picks up ones that are many kilometers away is unclear. Also unknown is how long the signal lasts and what the overall abundance of DNA from one species in a sample means for how plentiful it is in nature.

The amount of eDNA in a sample of air — or soil or water — is roughly correlated with how many of that plant or animal are in the area, Clare says. "But there's so much that can go wrong with that, that [abundance estimates are] difficult to use in any real way."

For one, some organisms might shed more DNA than others, with furry animals perhaps popping up at higher rates than scaly critters by virtue of the "fluffiness factor." And researchers themselves sometimes influence results without even knowing it.

While studying bats in Belize, Clare and her team harvested airborne eDNA from a classroom where they had brought bats into the room in cloth bags. The aim was to figure out how well vacuumed DNA identified different bat species and if it could pick up how many there were. While much of the genetic material from the room's air matched the number of each kind of bat present, Clare says, "there were wild exceptions."

Some bats were overrepresented and others underrepresented. "It took us ages to work out why," she says. "And apparently I was quoting Taylor Swift every time I say this: The problem was me."

Clare had to identify each bat. Some species are hard to classify, and because she spent time closely examining these bats' bodies and teeth, they shed lots of DNA into the air. Vampire bats, on the other hand, made a distinct sound when someone touched the bag, so Clare didn't need to open it to know what was inside. That may be why very little vampire bat DNA turned up in the experiment, Clare's team reported in 2023 in *Environmental DNA*.

Still, airborne eDNA offers similar opportunities to monitor terrestrial species the way streams and oceans ferry DNA from water-living creatures. Depending on how far eDNA travels in the air, researchers could ask questions that encompass large

swaths of land, especially compared with soil samples from many spots over a vast landscape. For example, "if we are installing solar panel farms in New Mexico," Duffy asks, "what is the effect of that on the local biodiversity?"

What's here right now?

Repeat collections give researchers more confidence in how to interpret eDNA findings. But new methods based on DNA's molecular cousin, RNA, may help pinpoint which life-forms were most recently in a place.

RNA turns DNA's genetic instructions into proteins. Compared with DNA, RNA offers a clearer sign that an animal was recently in an area because RNA breaks down much sooner. That fragility initially prompted scientists to assume that it would degrade too quickly for sampling, but emerging research shows there is a detection window. After an organism releases RNA into the environment, most of the RNA molecules are gone within three to five hours, Cristescu says, though studies suggest that eRNA may be detectable for up to 72 hours. Any eRNA found in a sample therefore implies that the organism that left it behind was in the area within the last few days.

The molecule offers other advantages, too. "What's beautiful about RNA," Cristescu says, "is that you can get a lot of ecological information that you cannot get with DNA."

RNAs churned by individuals vary by factors like sex or environmental stress. By collecting eRNA, researchers can also largely distinguish between living and dead organisms, as well as adults and juveniles.

In a study of American bullfrog ponds in Idaho, water samples contained RNA that revealed when tadpoles were present, researchers reported in the May *Molecular Ecology Resources*.

Additional tests looking for long-toed salamander (*Ambystoma macrodactylum*) larvae came up negative in ponds when only adults were around. Adults lay their eggs in the spring and leave, so adults and offspring aren't in the ponds at the same time. Just three months later, after the eggs had hatched, the team detected larva-specific RNA.

For now, samples must make it all the way back to the lab from the field, sometimes taking weeks, and undergo hours of processing before researchers can get a glimpse of the species detected in them. But biologist Ravi Nagarajan of the University of California, Davis says that eRNA might one day be analyzed in the field.

Such technology is already in development for eDNA. Using the molecular scissors CRISPR, scientists hope to design field tests that take less than an hour to detect DNA for a single or multiple species in water samples. This real-time sampling technique, dubbed SHERLOCK, could uncover preliminary signals for species of interest, pinpointing which sites require more thorough sampling, says Nagarajan, who has used SHERLOCK to scan an estuary in California for endangered fish. It could also help allocate a lab's limited resources to spots with the most potential to answer questions.

E. CLARE

Nina Garrett, a Ph.D. student in Elizabeth Clare's lab, sets up a handheld air filter inside a bat roost to collect airborne eDNA.

SHERLOCK could be adapted to work for eRNA, Nagarajan says. By harvesting RNAs that become active in certain conditions from the environment, SHERLOCK could provide an immediate hint that an ecosystem is stressed. Such tests could also indicate the threat, whether organisms are imperiled because of chemical contaminants in the water or a massive heat wave, Nagarajan says. "There's huge potential there."

As species dwindle or go extinct amid stressors like climate change and other human influences, it has become all the more important to have a global approach to cataloging what's out there, Cristescu says. "Not having a good understanding of biodiversity puts us in a very bad position of understanding what we are losing." ■

Explore more

- Jessica A. Farrell, Liam Whitmore and David J. Duffy. "The promise and pitfalls of environmental DNA and RNA approaches for the monitoring of human and animal pathogens from aquatic sources." *BioScience*. June 2021.

CONVERSATIONS WITH MAYA

KELLY BENOIT-BIRD
Senior Scientist and Science Chair at the Monterey Bay Aquarium Research Institute

Maya Ajmera, President & CEO of Society for Science and Executive Publisher of Science News, chatted with Kelly Benoit-Bird, Senior Scientist and Science Chair at the Monterey Bay Aquarium Research Institute (MBARI). Benoit-Bird is an alumna of the 1994 International Science and Engineering Fair (ISEF), a program of Society for Science.

What are your favorite memories from ISEF? I believe your project title was "Sounds Created by Captive Female Bottlenose Dolphins."

My favorite memories were about meeting different people from around the country and the world. Up to that point, I really hadn't had the opportunity to travel. ISEF exposed me to different cultures and opportunities that I hadn't thought about previously. It was really exciting. Before attending ISEF, I had been accepted to Brown University, and I was excited to meet other finalists who would be studying there as well.

I won a special award from the Acoustical Society of America, and one of the judges I met went on to be a mentor during my undergraduate career. Today, I am on the board of the Acoustical Society of America.

ISEF provided me with opportunities that I didn't know at the time were going to be opportunities. As I look back, I see how much of a foundation ISEF helped me to build. As a first-generation college student, I didn't have connections that I could rely on. ISEF really helped.

What inspired you to pursue a career in marine biology?

When I was in fourth grade, I visited a marine park where I learned about echolocation, which is when animals locate objects through reflected sound. The idea that some animals perceive their worlds in completely different ways than we do was fascinating. That is what inspired my ISEF project and has been an important part of my career.

You have been at MBARI since 2016. What makes it unique?

MBARI's mission is to advance marine science and technology to understand our changing ocean. Our founder, Silicon Valley innovator and philanthropist David Packard, created MBARI as a new kind of research institute, one that brought together science, engineering and marine operations and access to the ocean. We work in collaborative teams to bring together different perspectives, technologies and approaches to understanding the ocean.

Many might say, "I have this tool, what can I do with it?" Instead, we can say, "I have this question, how do I address it?" Even if the tools to answer the questions aren't available yet, we work together to come up with the ways to get us there. A lot of my work involves developing new technologies and new approaches to getting sonars, cameras and other sensors into the ocean.

In your research, you've developed innovative acoustic techniques to study the behavior of deep-sea organisms. How do these methods work, and what are their advantages over traditional observation methods?

Most of my work involves using sonar—we transmit a very short pulse of sound and then listen to how it reflects off things in the environment. Because fish don't reflect sonar well, it is a difficult technology to use to figure out what is happening in the ocean. I develop tools and figure out how to get them into the ocean so that we can use sound to map life. We want to understand where food is, where predators are and how organisms interact with each other in areas that we can't see. That's the advantage. Even with a lot of light, a camera can only see about 10 feet in the ocean. By using sound, we can "see" hundreds or maybe even thousands of meters.

What is one of the most surprising findings from your work in the deep ocean?

One of the very first behavior-focused topics I studied was diel vertical migration, which is the daily movement of marine animals between the ocean's surface and its deeper layers. Ocean animals hide in deep, dark waters during the day and then go up to the surface at night where there's enough food to survive. As the sun starts to rise, they migrate back down. We tended to think about this as a totally light-driven process, where animals just move up at night and move down during the day. End of story. But we've learned that the animals aren't preprogrammed to do this. They are very sensitive to benefits and risks. If there aren't any predators around, they feed at the surface and don't go deep. If predators are present, we can see that they respond very quickly. And if there is no food at the surface, they stay deep because it's not worth taking the risk of going to the surface.

What do you feel is the most misunderstood aspect of climate change as it relates to the ocean?

I think most people don't understand how much work the ocean has already done for us, in terms of protecting the planet from the worst consequences of climate change. The planet would be much warmer and atmospheric carbon dioxide would be twice as high today if it wasn't for the ocean. It takes up about a quarter of the carbon emissions we put in the atmosphere each and every year.

From competing at ISEF to being a first-generation college student to becoming an expert and leader in your field, you are a trailblazer. What advice do you have for young people just beginning their STEM journey?

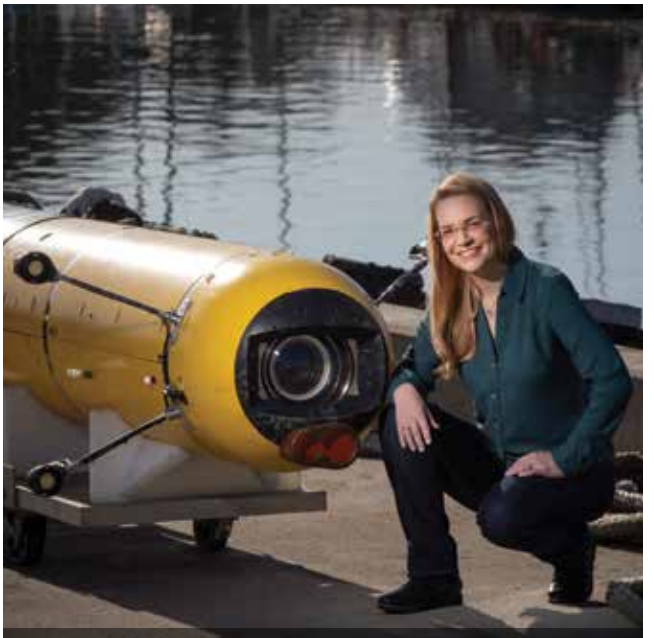
Always stay focused on what's exciting to you. It's easy to get distracted by what other people say is important, but you do better if you come back to your own curiosity. That is how I have focused my career.

A lot of folks think about STEM as a stuffy, white lab coat kind of science, right? I don't. Science is a creative pursuit, and I don't know any scientist who doesn't have a creative outlet in their life that they have incorporated into their science. I recommend that today's students bring their whole selves to their science—all of the skills and strengths that they have will be valuable to working in STEM.

You received the MacArthur Fellowship in 2010. How did that impact your life?

It was life-altering. The freedom it afforded me was transformative. For five years, they provided me with funding that was the equivalent of my salary. Instead of saying, "I have to take this project because I need the funding," I was able to follow my passion. I could decide what questions were the most interesting without the stress of failure hanging over me.

I ended up realizing how important that was for the way that I wanted to do science. I wanted to take risks. That was part of the reason that I moved to MBARI—risk-taking is part of our DNA here.



Kelly Benoit-Bird uses advanced underwater robots to learn more about the close connection between deep-sea animals and our climate.

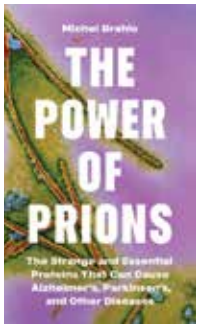
What books are you reading, and what books inspired you when you were young?

When I was young, I read absolutely everything I could get my hands on. I loved to be exposed to things I didn't even know I could be interested in. I also really loved *Nancy Drew* books. I still enjoy reading books in series and mysteries. At the moment, I am reading *An Immense World* by Ed Yong, which is all about the different ways that animals perceive their environments. It's always fun to be a consumer of science communication.

There are many challenges facing the world today. What's keeping you up at night?

I think what's keeping me up at night is inertia. Can we come up with the willpower and the desire to move forward on issues that are really threatening all of us, like climate change? Are we going to move fast enough to keep us from experiencing the absolute worst possible impacts?

It's an interesting problem because it's not something that I feel like I can do much about, and maybe that's why it keeps me up, right? This isn't a science question. The science has been answered. This is a political question. Our goal as scientists is to provide information and to share it in a way that can be understood. MBARI shares our research, technology and data outside our walls so policy makers and resource managers can make informed decisions about the ocean and our big blue planet.



The Power of Prions
Michel Brahic
PRINCETON UNIV., $24.95

BOOKSHELF

The good, the bad and the ugly of prions

A mysterious neurological disease was killing women and children in the Eastern Highlands of Papua New Guinea. Patients in the final stages experienced uncontrollable outbursts of laughter, earning the disease the macabre nickname "the laughing death."

Autopsies revealed tiny holes in the victims' brains, giving the tissue a characteristic spongy look. It was the 1950s, and scientists knew of only a few other diseases that pinprick the brain in such a way. All caused bizarre and frequently devastating symptoms in affected animals or people. And all, scientists later learned, could be blamed on infectious proteins — prions.

These malevolent molecules, first identified in 1982, are the subject of neurovirologist Michel Brahic's pint-size new book, *The Power of Prions*. Brahic, a consulting professor at Stanford University, took to writing after his wife convinced him to turn his lectures into a book. The process, he writes, "transformed a dreaded retirement into an exciting adventure."

The book jumps headfirst into the molecular biology of disease-causing prions, proteins that fold incorrectly and then force normal proteins to do the same. These misfolded proteins can arise naturally in the body or enter via consumption of infected tissue. In the brain, the abnormal proteins stack together "like a pile of soup dishes in the kitchen cabinet," Brahic writes. The buildup can cause neurological trouble, such as memory loss, trouble speaking and jerky movements. If the protein stacks break apart, the resulting pieces can seed other areas of the brain, transforming healthy proteins into misfolded ones and sprouting new stacks. That's how prions spread like an infection.

Brahic takes readers on a tour of prion diseases, with stops at scrapie (which makes sheep scrape incessantly against fence posts), mad cow disease and kuru, the illness that plagued those people in Papua New Guinea. Kuru spread via cannibalism, scientists figured out; eating brain tissue containing prions was enough to cause infection. (Some scientists think the cannibalism was a cultural ritual, others, a way to give women and children protein since animal meat was saved for men.) Once cannibalism ceased, so did new kuru cases.

At less than 200 pages, Brahic has packed his lectures into an astonishingly tiny tome. But class is clearly in session. Though he's writing for nonscientists, Brahic's book is not for the casual reader. It's for people who want to dig into prion biology.

Brahic writes succinctly about the science, and with feeling about people harmed by prion diseases. They're far less rare than one might think. Scientists now believe prions may play a role in many neurological diseases, including Alzheimer's, Parkinson's and Huntington's (SN: 10/17/15, *p.* 12; SN: 2/24/24, *p.* 6).

In Alzheimer's, some research suggests that a buildup of prion proteins in the brain may contribute to the devastating loss of short- and long-term memory. "Long-term memory shapes our personality, makes us who we are," Brahic writes. "By erasing the past it robs us of our identity."

By this point in the story, you'd be forgiven for thinking all prions are mutinous molecules of disease. But Brahic touches on "good" prions too — noninfectious proteins that stack up just like the bad ones but perform necessary jobs in the body, like helping preserve long-term memories.

An efficient vehicle for delivering science, *The Power of Prions* also includes bits of narrative that help propel the story. But prion-curious readers may want more information about the people affected by these diseases and the scientists studying them.

Either way, with its CliffsNotes-style chapter summaries and glossary of biological terms, Brahic's book may find a place on people's shelves as a quick reference guide to a field he calls "young, fast-moving and not devoid of controversy."
— *Meghan Rosen*

Bovine spongiform encephalopathy, commonly known as mad cow disease, is a fatal disease caused by prions. The infectious proteins are the subject of a new book.

SEAN GALLUP/GETTY IMAGES

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It was a warm summer afternoon and my wife and I were mingling with the best of them. The occasion was a 1920s-themed party, and everyone was dressed to the nines. Parked on the manse's circular driveway was a beautiful classic convertible. It was here that I got the idea for our new 1920s Retrograde Watch.

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Move over, Simone Biles!

A globular springtail can backflip (shown below) at a rate of 368 spins per second, **Jonathan Lambert** reported in "How an arthropod does the world's fastest backflip" (*SN: 10/5/24, p. 4*). X user **@FluronaVirus** wrote: "That's incredible! The agility of globular springtails is truly remarkable. High-speed camera footage capturing their spin rate is a fascinating insight into their aerial abilities. Nature never ceases to amaze with its wonders."

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Experimenting with food

Mayonnaise's texture is perfect for mimicking what a fuel capsule goes through when it's blasted with lasers to ignite nuclear fusion, ***Emily Conover*** *reported in "Mayonnaise may shed light on nuclear fusion experiments"* (SN: 10/5/24, p. 5). Reader **Linda Ferrazzara** wondered if mayo qualifies as a non-Newtonian fluid, one whose viscosity changes depending on the stress applied to it. If so, could researchers instead use oobleck—a non-Newtonian fluid made from cornstarch and water—as a stand-in for nuclear fuel capsules in experiments? **Ferrazzara** asked. Oobleck might be easier to keep consistent between experiments than mayo, which has different formulations depending on the brand.

Mayonnaise is a non-Newtonian fluid, says mechanical engineer **Arindam Banerjee** of Lehigh University in Bethlehem, Pa. But oobleck would not work for fusion experiments. The substance gets thicker, or more viscous, when hit by an outside force—a phenomenon called shear thickening. So it "would freeze up when we spin our experiment," **Banerjee** says. Mayo is the opposite: It gets less viscous.

Repeatability is crucial to the team's scientific process, so the materials used in each experiment need to be well-characterized and consistent, **Banerjee** says. "We have used Hellmann's Real Mayonnaise for the last 12 years. We measure properties of each batch and have found them to be remarkably consistent. We do not make our own mayonnaise," he says. "Prior to picking mayonnaise, we tried yogurt. But my students at that time were not able to replicate the yogurt consistency and thus the properties were different, leading to large variations in observed behavior."

Machines make mistakes

A quantum computer improved its results by repeatedly correcting its mistakes mid-calculation, ***Emily Conover*** *reported in "A quantum computer fixes its errors"* (SN: 10/5/24, p. 6). X user **@Lightning456243** asked how a quantum computer can identify its own errors.

"Quantum computers correct their own errors by inserting some redundancy in their data and periodically checking whether the information is still self-consistent," **Conover** says.

Classical computers do this too by copying bits, which have a value of either 0 or 1. For instance, 1 can be copied three times to become 111. If one of those bits gets unintentionally flipped (say, 111 becomes 110), the mismatch between the three bits would indicate an error. By looking at which value is the majority, the computer can identify which bit needs fixing.

The complexities of quantum physics complicate this process, but quantum computers likewise encode information redundantly, **Conover** says. Rather than directly copying individual quantum bits, however, the computers spread the information between multiple quantum bits that are entangled, or linked (*SN: 6/20/20, p. 18*).

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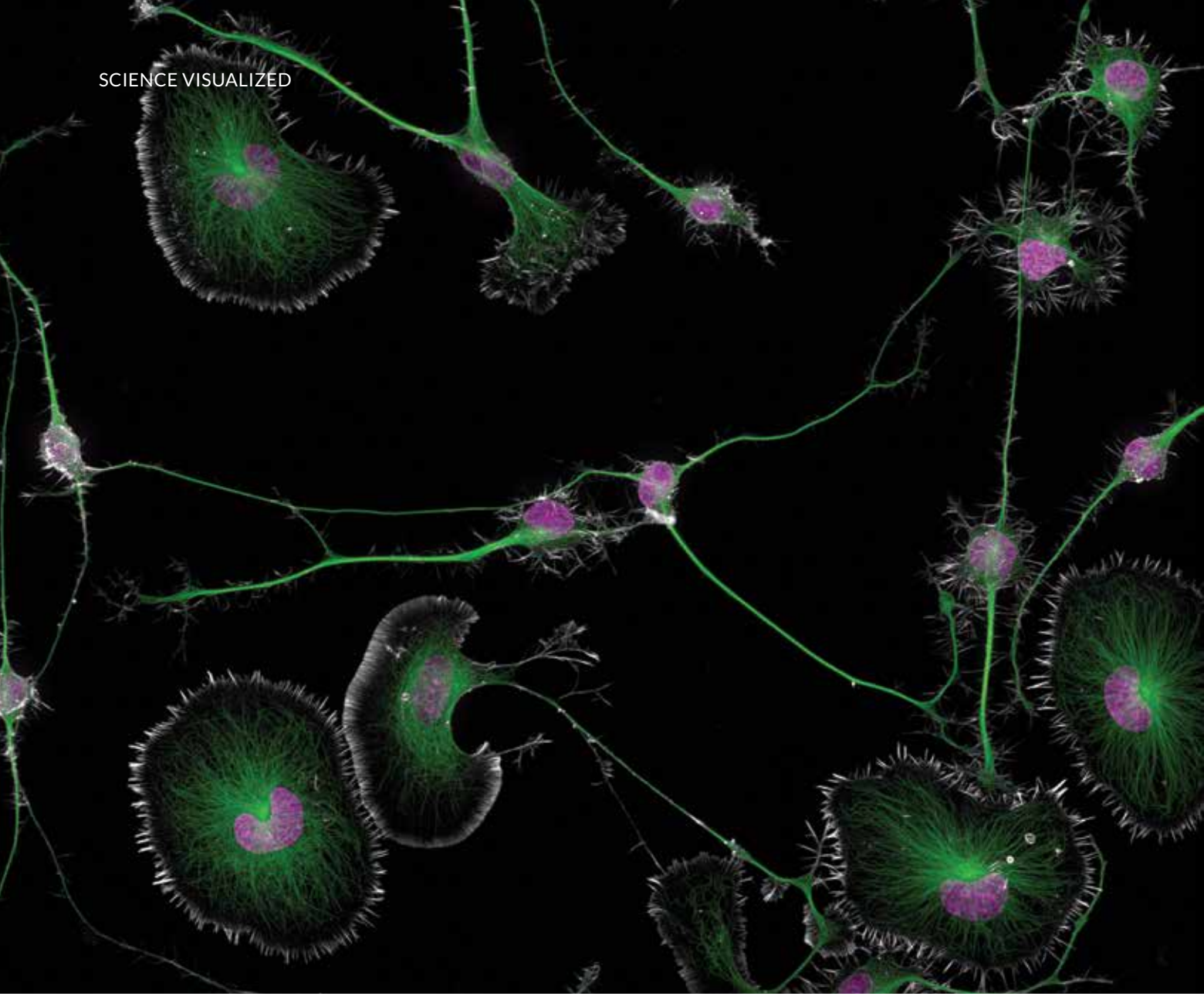

Zooming in on mouse brain tumor cells

With the snap of a camera shutter—and a microscope—what was once small can become grand.

A closeup peek at mouse brain tumor cells won first place in the 2024 Nikon Small World photomicrography contest. Neuroscientist Bruno Cisterna of Augusta University in Georgia snapped the photo (above) using a high-resolution microscopy technique as part of research to understand how neurodegenerative diseases such as Alzheimer's and ALS develop.

These tumor cells, shown at 100 times magnification, are nerve cells that are growing uncontrollably. The nucleus (magenta) of each cell is surrounded by actin proteins (white) that give the cell shape. Rodlike microtubules (green) connect some cells and also transport organelles within cells such as mitochondria, which generate much of a cell's energy.

Earlier this year, Cisterna and colleagues included similar images of individual cells in a study that found that the protein PFN1 helps the microtubules function properly. Without enough PFN1, the team reported, the cell's microtubules transport more mitochondria faster around the cell, causing it to die.

There's a "delicate equilibrium" to how fast mitochondria can move around a cell and how many get transported, Cisterna says. Using images like the winning photo to track cellular structures can help reveal abnormalities that might be linked to cell death and neurodegeneration.

Cisterna says his favorite thing about this image is that it shows both mature, spindly nerve cells and their round, immature precursors before they've morphed into full-fledged neurons. It's not easy to find both, he says. Once he found the cells under the microscope, he spent two hours taking images. "They look beautiful."

The resulting photo is one of 88 recognized October 17 in the 50th year of this annual contest. —*Erin Garcia de Jesús*

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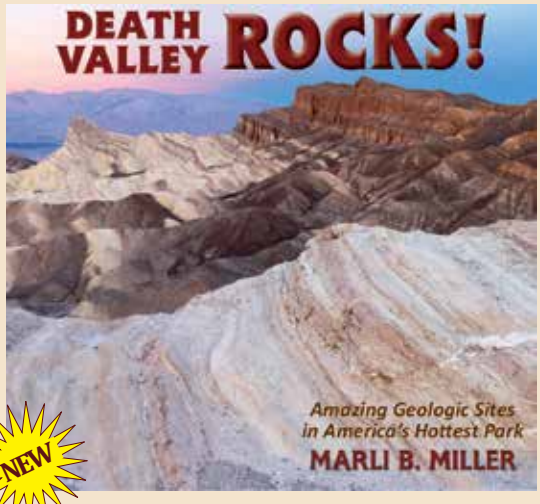

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MARLI B. MILLER

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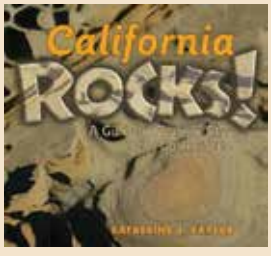

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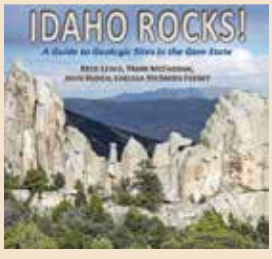

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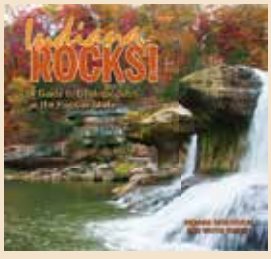

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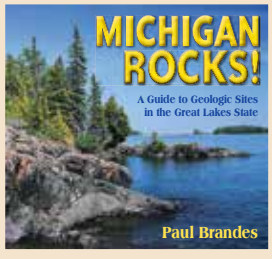

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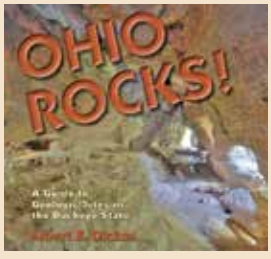

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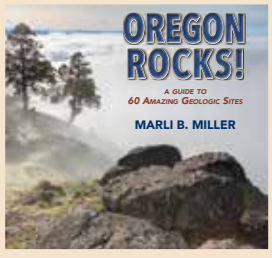

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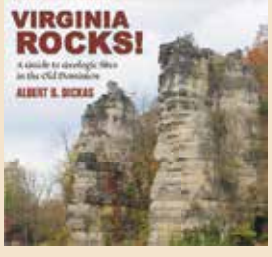

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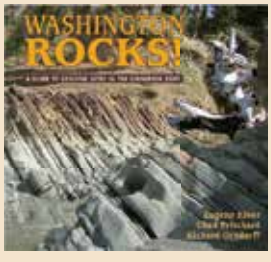

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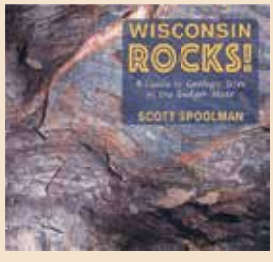

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