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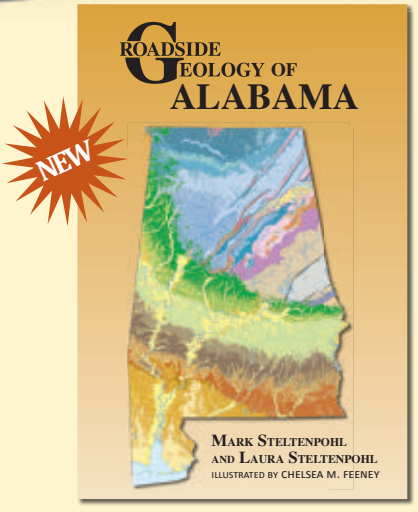

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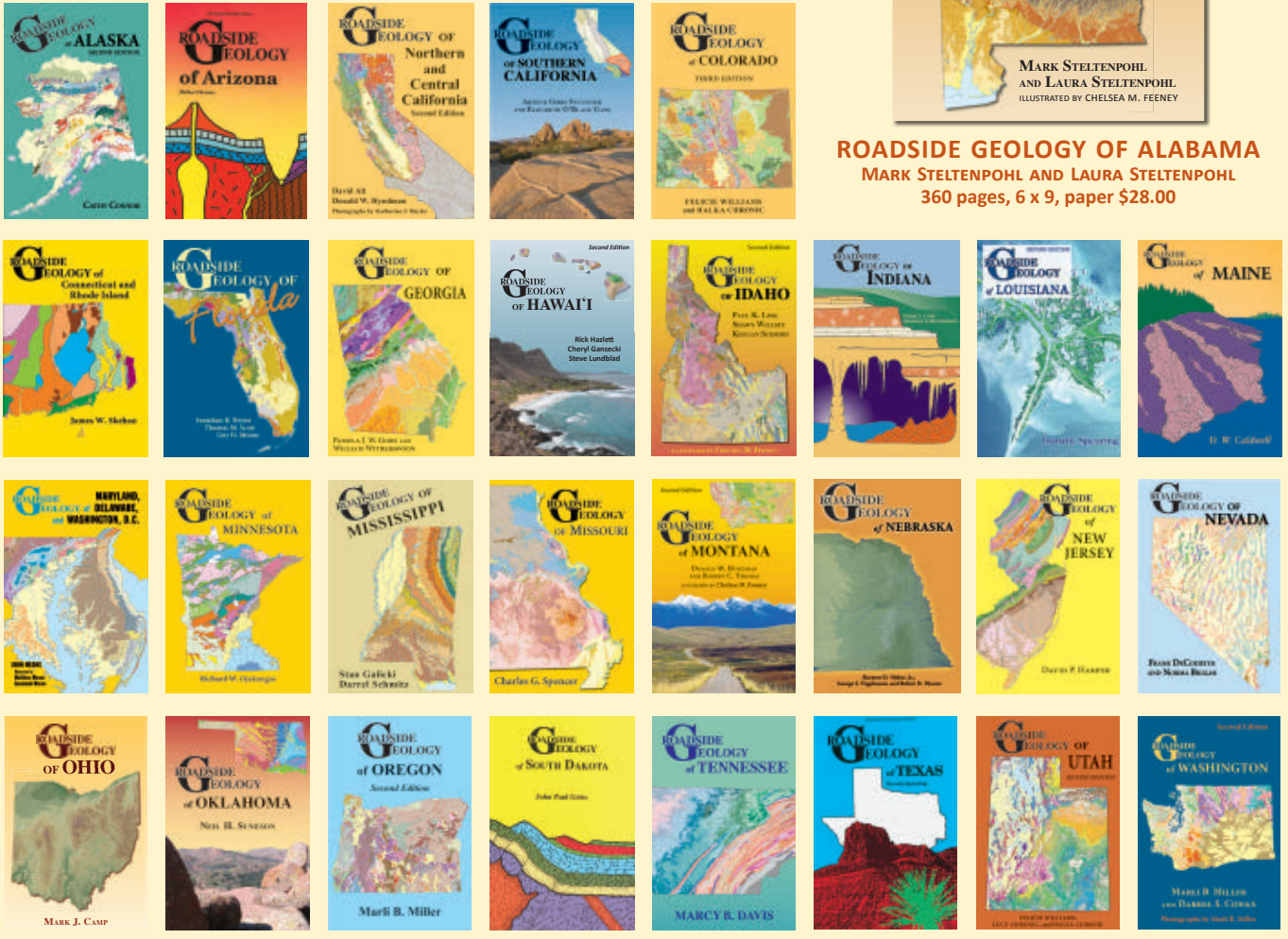

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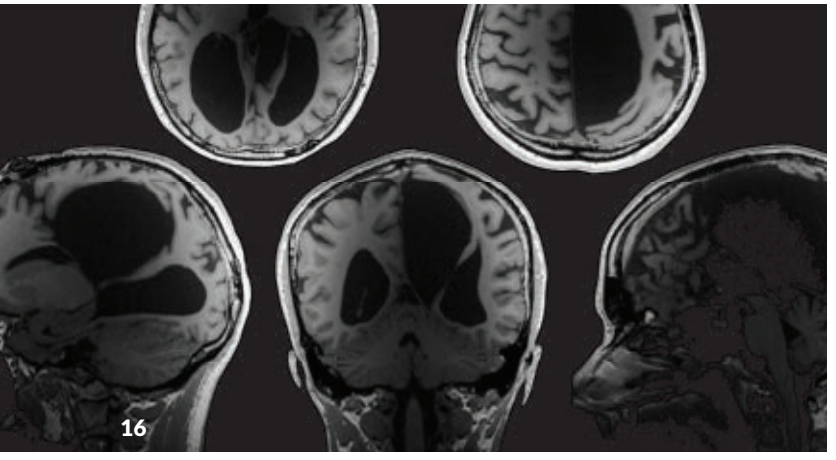
16

Features

News


8

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4

Departments

COVER Big G, known formally as Newton's gravitational constant, describes the strength of gravity. *Neil Webb*

From our brains to gravity, how science surprises us

In this era of precision medical imaging, it's not uncommon to get a CT scan or MRI for one thing and have the radiologist find something altogether different. These incidental findings usually don't reveal anything major. But what if the doctor said, "Hey, did you know you're missing a big chunk of your brain?"

That surreal experience is recounted in the story of Elyse G. (Page 16). She is one of a number of people recently discovered to be missing significant chunks of brain, with no apparent health impact, staff writer Meghan Rosen reports. Elyse is lacking most of her left temporal lobe, which is generally believed to be essential for language. But her interview with Rosen makes clear that Elyse has no difficulty expressing her thoughts. "I could have probably taken over the world if I had my entire brain," Elyse jokes.

Researchers at MIT are now studying Elyse and other people with "interesting" brains. Those tested have all scored at or above average on language and thinking tests. Researchers speculate that these people might have suffered a stroke or other brain injury while in utero or in infancy. Other parts of the brain then took on the roles of the missing chunks. Gaining a better understanding of how Elyse and others thrive could lead to better treatments for people suffering debilitating brain injuries.

The researchers' excitement at exploring this mystery is palpable, as is that of scientists trying to solve an enduring puzzle of physics: exactly how strong gravity is. Freelance writer James R. Riordon explains how physicists around the world are trying to make exceedingly precise measurements of Newton's gravitational constant, also known as big G (Page 28). The goal: to resolve discrepancies in measurements from around the world. If the discrepancies are real, rather than experimental flukes, they could point to physics that we don't yet understand. But the tests are exceedingly difficult.

Riordon visits a researcher at the U.S. National Institute of Standards and Technology who changes into a dedicated pair of shoes before stepping into his subterranean laboratory. He knows that random specks of dust could be enough to skew the experiment's results.

Precise measurements can also be vital when unraveling the past, as news about the Vikings demonstrates. Rather than getting their start as boorish pillagers, the intrepid voyagers may have focused instead on establishing trade routes—an eighth century version of Amazon.

Researchers found this out by tracing patterns of trade to and from a medieval town in Denmark. Interpreting patterns at this site required dating archaeological layers with a greater precision than radiocarbon dating, archaeology's go-to method, allows. Data on an ancient solar flare helped researchers overcome this limitation, freelance writer Martin J. Kernan reports (Page 22).

This is our summer double issue; each year we seek out stories that make for a great vacation read. We hope you'll put up your feet and enjoy these articles, wherever you happen to be. The next issue of the magazine will be in your mailbox in August. —*Nancy Shute, Editor in Chief*

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50 YEARS AGO

Oldest rocks

Until recently, Greenland possessed the oldest known rocks in the world. They date back 3.7 billion years (*SN: 12/9/72, p. 374*). Now granite and crystalline schist specimens … suggest that the Antarctic Continent is older. These specimens date back 4 billion years.

UPDATE: At about 4.3 billion years old, bedrock in northeastern Canada currently holds the title of oldest known rock on Earth (*SN: 4/15/17, p. 8*). In Western Australia, scientists have found zircon crystals in bedrock that are even older, dating to about 4.4 billion years ago. For comparison, Earth is only about 4.5 billion years old. Since these ancient materials preserve information about early Earth, they have fueled ongoing debates about when and how Earth's crust formed, when plate tectonics started and even when life on the planet first arose. Additional clues that could help resolve the debates might lie on the moon. Lunar samples collected by Apollo 14 astronauts contain 4-billion-year-old zircons that may have been delivered via an Earth meteor, scientists reported in 2019.

IT'S ALIVE

Polyester bees brew beer-scented baby food in plastic cribs

Female *Ptiloglossa* bees are single moms with a lot to do and little time. Fortunately, they can use a feathery tongue to make infant-care plastics and then brew up batches of baby food.

"We jokingly call them polyester bees," says pollination ecologist Stephen Buchmann of the University of Arizona in Tucson.

The bee-made plastic is a cousin of human-made polyesters. A gland on a female's abdomen secretes molecules of repeating lactones, each with its "ester" structural bit that gives polyester its name. The stuff makes the finishing touch for little nursery chambers that mother bees dig underground. They use their tongues to lick up the gland secretion and slather it on nursery walls.

The plastic is tough and "can be kind of crunchy," Buchmann says. It's thought to keep the brood chamber "nice and cozy … and also to keep out the bad guys."

Buchmann studies *P. arizonensis* bees. Females of this species have just weeks to fill plastic retreats with all the food each youngster needs for much of a year underground. Each generation grows up floating in, and feeding on, mom's brew of fermented nectar and pollen — which smells like beer.

Many other bee species mix pollen and nectar to "a kind of Play-Doh consistency," Buchmann says. Food stored in a polyester bee nest, however, is runny. That's probably because of the nectar these polyester bees collect. Much of it comes from the bloom spikes of agave plants, watery enough for easy slurping by bats.

To see what's in the beer-scented brew, Buchmann recruited bee microbiome researcher Tobin Hammer of the University of California, Irvine. The researchers gathered and analyzed *P. arizonensis* bees and their relatives in Arizona as well as the bees' food-filled brood cells and source flowers.

Despite the beery smell of *P. arizonensis* baby food, Buchmann says, "lo and behold, no yeast!" The bees' microbial fermenters are mostly lactic acid bacteria, Hammer, Buchmann and colleagues report April 5 in *Frontiers in Microbiology*. The glop is closer to yogurt or sauerkraut than it is to beer.

Buchmann doubts that young bees take along moms' bacterial culture when they leave home. Youngsters go through much of their early growth without pooping. Then they defecate "all at once," Buchmann says, which clears the gut of the microbes.

The aboveground world that new generations eventually join offers plenty of replacement bacteria. Somehow the variety of microbes that bees encounter gets winnowed down for baby food, lab analyses suggest. Just how is an open question. But that great coming-of-age poop at least spares human fans the image of diaperless baby bees feeding for months on excrement stew.

— *Susan Milius*

A *Ptiloglossa arizonensis* bee (inset) will dig a nursery (illustrated lower right) and fill the cribs with pollen from nightshade flowers (middle), nectar from agave (left) and bacteria.

SCIENCE STATS

What's behind record-shattering heat in the North Atlantic Ocean?

Sea-surface temperatures in some parts of the North Atlantic Ocean have soared to new heights. The anomalous warming is occurring in a large swath that stretches almost one-third of the way across the Atlantic from Africa's northwestern coast. Some surface waters in this vast area are almost 4 degrees Celsius above normal for this time of the year, says meteorologist Brian McNoldy of the University of Miami in Coral Gables, Fla.

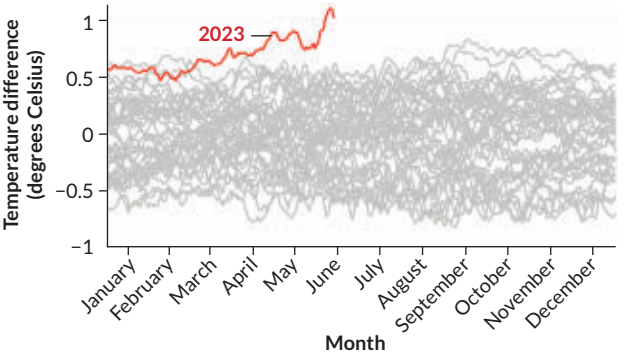
"There's been record-breaking warmth since March, but even more so now," McNoldy says. On June 10, for instance, the North Atlantic's average sea-surface temperature was 22.7° C. That's about 1 degree C higher than the average recorded for this date from 1991 through 2020. The previous record, 22.1° C, occurred in 2010. (The graph at right shows the change in the daily average sea-surface temperature for 2023 up to June in red and the last 41 years in gray. The 1982–2022 daily mean temperatures have been subtracted from this year's temperatures as well of those from 1982 to 2022.)

What's causing the unusual warm-up isn't clear. But several factors might be at play.

Winds that transport Sahara Desert dust over the North Atlantic have been calmer and largely dust free lately, says climate scientist Michael Mann of the University of Pennsylvania. As a result, solar radiation that the dust would normally scatter back into space reaches the ocean surface.

The return of El Niño this year means warmer-than-normal sea-surface temperatures. In the North Atlantic, the extra warmth may strengthen storm systems that can later develop into hurricanes. But El Niño may strengthen globe-circling winds that can shear the tops off nascent hurricanes. How the 2023 hurricane season plays out depends on which force prevails (SN: 7/1/23, p. 9). —*Sid Perkins*

Change in the North Atlantic Ocean's daily average sea-surface temperature, January 1982–June 2023



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MYSTERY SOLVED

DNA reveals origins of the largest known gecko

A lizard called Delcourt's giant gecko has long been one of herpetology's biggest mysteries—literally. Measuring more than half a meter from snout to tail tip, the presumably extinct animal is by far the largest gecko known to have crawled on Earth. The only example scientists have of the gecko, however, is a single museum specimen from the 19th century with no notes as to its origin or identity.

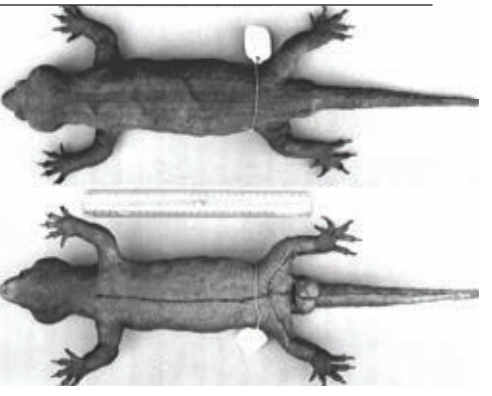
Now, DNA from one of the specimen's leg bones reveals that the colossal lizard belongs to a group of geckos called diplodactylids in New Caledonia, researchers report June 19 in *Scientific Reports*. Geckos in this lineage repeatedly evolved extreme body sizes throughout history.

Previously dubbed *Hoplodactylus delcourti*, the gecko has been renamed *Gigarcanum delcourti*, or "giant mystery." The lizard is about 50 percent longer and several times heavier than the largest living gecko species (*Rhacodactylus leachianus*), which also belongs to the New Caledonian group. Compared with all other geckos, *G. delcourti* was "monstrous," says evolutionary biologist Matthew Heinicke of the University of Michigan-Dearborn.

The reptile was big enough to prey on birds and lizards, including other geckos, Heinicke says. Its toe pads and long claws suggest it lived in trees, though it was probably the maximum size a gecko can be and still adhere to vertical surfaces with its hallmark sticky grip.

The specimen (shown above right) came to scientists' attention in the 1980s after collections manager Alain Delcourt found it at the Natural History Museum of Marseille in France. The stuffed lizard sports a thick trunk, bulbous head and red-banded brown skin. Herpetologist Aaron Bauer of Villanova University in Pennsylvania cowrote the first description of the species in 1986. He placed the reptile with diplodactylids in New Zealand based on its physical traits.

Since methods for retrieving and analyzing archival DNA have improved, Heinicke, Bauer and colleagues revisited the gecko. Their analysis shows that the lizard is not even closely related to New Zealand's geckos. About 45 million years of evolution separate New Caledonia's diplodactylids from New Zealand's.



The finding "turns things on their head," says herpetologist Paul Doughty of the Western Australian Museum in Perth. Gecko geeks have long associated *G. delcourti* with New Zealand, he says. "But this is the thing about these precious museum specimens. With new technology, they can give up new secrets." —*Natalie van Hoose*

OPPOSITE PAGE: BILL SINGLETON; INSET: T. HAMMER; THIS PAGE, FROM TOP: C. CROCKETT; A. BAUER

PALEONTOLOGY

Ancient molecules tied to complex life

Billion-year-old fossil residues shed light on eukaryote evolution

Geochemist Jochen Brocks examines a portion of the Barney Creek rock formation in northern Australia. He and colleagues discovered molecular footprints of early eukaryotes in the formation.

BY SOUMYA SAGAR

Molecular fossils in ancient sedimentary rocks have unveiled a lost world of some of the earliest complex life-forms, which dominated aquatic ecosystems from about 1.6 billion to 800 million years ago.

The findings, published in the June 22 *Nature*, come from laboratory analyses of rock samples from around the world that reveal remnants of primitive biological compounds called protosteroids. The majority of these molecules, which form in the process of creating modern steroids, were probably produced by eukaryotes, a group that includes animals, plants, protists and fungi, researchers say.

Almost all living eukaryotes — organisms whose cells have a nucleus — make steroids, such as cholesterol, which are crucial components of cell membranes. Steroids don't degrade easily and their remnants can be detected in sedimentary rocks as molecular fossils.

The last common ancestor of all modern eukaryotes is thought to have lived roughly 1.8 billion to 1.2 billion years ago, but the oldest eukaryote fossils found so far date to only 800 million years ago.

A dearth of older eukaryote fossils had led scientists to speculate that bacteria dominated ecosystems at that time. Primordial eukaryotes may have lacked strength in numbers to leave behind enough steroid remnants for them to be detectable today.

Alternatively, maybe some intermediate molecule in the chemical pathway that produces modern steroids was actually the end product in primordial eukaryotes. This theory had been proposed by biochemist Konrad Bloch, who shared the 1964 Nobel Prize in physiology or medicine with biochemist Feodor Lynen for their discovery of cholesterol's biosynthetic pathway.

But it was unclear what those early end products would look like — or if they could even be detected — until scientists found a way to re-create the molecular footprints.

A team led by geochemist Jochen Brocks of the Australian National University in Canberra matured lanosterol and cycloartenol, which are products of the first steps of steroid biosynthesis. With an idea of what those compounds would look like as fossils, the team searched for them in tarlike bitumens and oils extracted from ancient rocks from all over the world.

The researchers discovered a deluge of protosteroid fossils in samples ranging from deep to shallow water environments. The oldest sample, dating to 1.6 billion years ago, came from the Barney Creek Formation in Australia.

"This study explains why we don't see footprints of these guys in the rocks, as researchers were looking for the wrong thing," says Laura Katz, a biologist at Smith College in Northampton, Mass., who was not involved in the work. "It fills a void in the fossil records."

The findings also solve one of the greatest puzzles of early evolution, says study coauthor Benjamin Nettersheim, a geobiologist at the University of Bremen in Germany. "Why didn't our highly capable eukaryotic ancestors come to dominate the world's ancient waterways?" he says. "We show that the protosteroid-producing microorganisms were hiding in plain sight and were in fact abundant in the world's ancient oceans and lakes all along."

Bacteria could have contributed a small amount to the protosteroid fossils that the team found. For most bacteria, their version of protosteroids are molecules called hopanoids. Some bacteria also have the tools to make protosteroids, but they exist in niche environments, such as hydrothermal vents. And their footprints haven't been found in sediments older than 800 million years, indicating that eukaryotes did dominate ancient aquatic ecosystems, Brocks' team contends.

"Konrad Bloch would have been delighted had he lived to see this," says MIT geobiologist Roger Summons. "This paper has elegantly confirmed his prediction that biosynthetic precursors to cholesterol reflect ancient life's quest for improvement."

Making steroid precursors requires less oxygen and energy than making steroids, which may have let primordial eukaryotes thrive in early Earth's low-oxygen conditions, Brocks and colleagues propose. Eventually shifting to making steroids probably helped eukaryotes dominate new ecosystems, since the molecules are better at protecting cells than protosteroids.

If true, the study suggests "we may be able to examine the stepwise evolution of eukaryotes at [an] unprecedented level of detail," says evolutionary biologist Yosuke Hoshino of the GFZ German Research Centre for Geosciences in Potsdam. It would be "a great opportunity to understand the evolution of complex life, which biologists have always dreamed of." ■

THE AUSTRALIAN NATIONAL UNIV.

ASTRONOMY

Scientists rezone the Milky Way

Its life-friendly area may reach the galaxy's edge, a cloud hints

BY BAS DEN HOND

Phosphorus discovered in a cloud at the edge of the Milky Way may extend the region in our galaxy where life might be found.

The element is one of six that are essential for life on Earth, along with nitrogen, carbon, hydrogen, oxygen and sulfur (SN: *1/28/23, p. 11*). Scientists use the presence of those elements to help define the Milky Way's habitable zone. Until now, phosphorus had been the only one missing from the farthest reaches of our galaxy. Finding the element that far out could extend the distance of the habitable zone by roughly 22,000 light-years, researchers reported June 8 in Albuquerque at a meeting of the American Astronomical Society. That in turn could motivate astronomers to look in the hinterlands of the Milky Way for planets and any life they might harbor.

Using two radio telescopes, the team studied a cool, dusty gas cloud at the edge of the galaxy, which is about 74,000 light-years from the Milky Way's core. The cloud is a frigid −248° Celsius, a mere 25 degrees above absolute zero. And it emits radiation at wavelengths consistent with phosphorus monoxide and phosphorus mononitride, astrochemist Lilia Koelemay of the University of Arizona in Tucson said at the meeting.

Finding phosphorus in that distant cloud was a long shot, says Lucy Ziurys, a University of Arizona astrochemist and Koelemay's collaborator. Phosphorus is produced only in massive stars that end their lives in element-spewing supernovas (SN: *12/4/21, p. 15*). Since there isn't a lot of material in the outer Milky Way, it is hard to build such stars there. Beyond 49,000 light-years from the galaxy's center, there is only one known supernova remnant, Ziurys says.

One way phosphorus could have ended up in the outer galaxy is through a supernova closer to the center that launched what researchers call a galactic fountain. "A supernova explodes, the material gets thrown out of the galactic plane, then settles back down near the galactic edge," Ziurys says. The concentration of material would get diluted, but "if there are different supernovae going off, they're going to keep polluting the outer galaxy," she says.

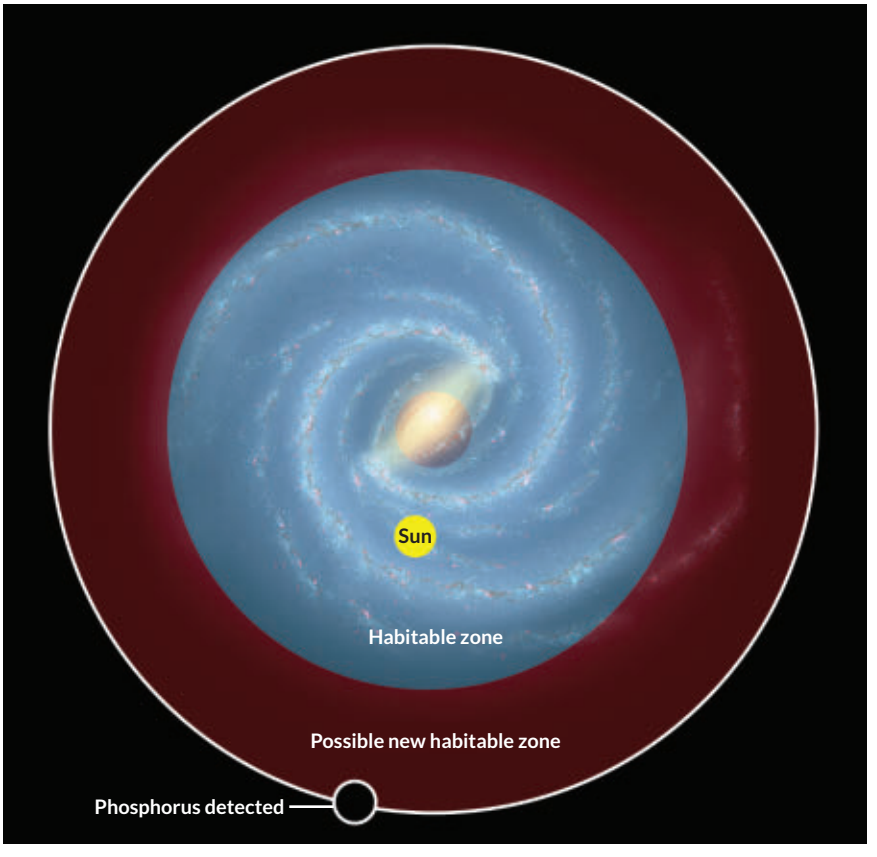
Based on where all six elements essential for life had previously been found, astronomers assumed that the Milky Way's habitable zone extended from about 6,500 light-years beyond the galactic center to the farthest known supernova remnant, which is about 52,000 light-years from the center. While the zone's outer region has very few supernovas, the inner edge has so many that any planets in the area would be exposed to intense ultraviolet and X-ray radiation, making it difficult for life to last for long.

The new finding seems clear and compelling, says Francesco Fontani, an astrophysicist at the Italian Institute for Astrophysics in Florence who was not involved in the work. Fontani has observed some of the other essential elements for life in the outer Milky Way, but never phosphorus.

"This detection, together with previous detections of organic molecules at similar large distances from the galactic center, supports the idea that the outer boundaries of the galactic habitable zone could be wider than what we previously thought," he says.

But no planets are known to exist so far from the galaxy's center. All known exoplanets are relatively close to our solar system — most within a few thousand light-years.

"I don't think we know right now whether [planets] can form at larger galactic-central distances," Ziurys says. The knowledge that these six elements exist at our galaxy's edge will hopefully spur the search for the most distant places where life could thrive, she says. ■



Phosphorus found in a cloud at the edge of the Milky Way suggests that the galaxy's habitable zone (blue in this illustration) extends (red) far beyond our solar system.

JPL-CALTECH/NASA, R. HURT/SSC/CALTECH, L. KOELEMAY, ADAPTED BY C. CHANG

ASTRONOMY

Early black holes get home inspections

Small but hefty galaxies may help solve a cosmic mystery

BY LISA GROSSMAN

CAMBRIDGE, MASS. — For the first time, astronomers have detected starlight from distant galaxies that host extremely bright supermassive black holes called quasars.

Data from NASA's James Webb Space Telescope reveal that four such galaxies are massive, compact and possibly disk-shaped, researchers reported June 12 at the JWST First Light Conference. Studying the galaxies could help solve the mystery of how black holes in the early universe grew so big so fast (SN: 2/13/21, p. 4).

"Since the discovery of [distant] quasars, there have been studies trying to detect their host galaxies," said MIT astrophysicist Minghao Yue. But until JWST's sharp infrared eyes came along, it wasn't possible.

Quasars are black holes that feed so furiously that the material they gobble gets white-hot, making them shine brighter than the stars in the galaxies around them. Quasars are so bright and distant that each appears as a single point of light.

Two independent groups used that starlike quality to erase the black hole glow from images of their galaxies, like a sculptor coaxing a figure out of marble.

Yue and colleagues observed six quasar galaxies. Around the same time, a team led by astrophysicist Xuheng Ding of the Kavli Institute for the Physics and Mathematics of the Universe near Tokyo looked at another two. The light from all eight quasars was emitted more than 12.8 billion years ago, less than a billion years after the Big Bang.

Distant galaxies with superbright, supermassive black holes called quasars (one illustrated) could help scientists figure out how black holes in the early universe grew so big so fast.

Stars in the galaxy images helped each team simulate the quasars' starlike shapes. Subtracting the simulated quasars from the images gave researchers a direct peek at four of the eight galaxies.

Each of these galaxies appear to be less than a sixth as wide as the Milky Way, yet their individual masses are comparable to the combined mass of all the Milky Way's stars. The two galaxies that Yue's team observed contain enough stars to make up between 10 billion and 100 billion times the mass of the sun. The pair that Ding and colleagues looked at weigh about 25 billion to 63 billion solar masses, the team reported at the conference and in a study to appear in *Nature*.

What's more, the galaxies' black holes appear more massive than the amount of stars should allow. Typically, the more massive a galaxy's central supermassive black hole, the more stars the galaxy has. "For these luminous quasars, they really are over-massive," Yue said.

Astrophysicist Paul Shapiro of the University of Texas at Austin questions the mass estimates. Converting the light that JWST can see into stars rests on assumptions about how many stars of various masses a galaxy has. Modern galaxies have a lot more dim, puny stars than bright, hefty ones, so scientists typically assume that the brightest stars they see are just the tip of the iceberg. But that might not have been the case soon after the Big Bang. "If there were a mass distribution that favors high-mass stars, you could be significantly overestimating the mass associated with the light," Shapiro says.

JWST is slated to watch 10 more quasar hosts. Those data may shed light on how black holes in the early universe are so massive. "You need to understand the environment of this monster, how it can collect so much matter," Ding says. By figuring out the mass of host galaxies, "at least then you can say how their local environment is." ■

CHEMISTRY

One photon kicks off photosynthesis

Laboratory experiments confirm a long-held hypothesis

BY EMILY CONOVER

For photosynthesis, one photon is all it takes.

Only a single particle of light is required to spark the first steps of the biological process that converts light into chemical energy, scientists report June 14 in *Nature*.

Researchers have long assumed that the reactions of photosynthesis begin upon the absorption of just one photon, but it had never been demonstrated, says physical chemist Graham Fleming of the University of California, Berkeley. He and colleagues decided "we would just look to see was it really true that one photon was enough to start the whole thing off."

The sunlight that falls on Earth's surface seems brilliant to human eyes. But on small scales, that light translates to a dribble of photons. Every second, only a few tens of photons of the appropriate wavelengths of sunlight fall on a square nanometer, the scale of the tiny chlorophyll and bacteriochlorophyll molecules that are central to photosynthesis in plants and bacteria.

Many experiments on photosynthesis use lasers, much more powerful light sources, to kick off the reactions. Instead, Graham and colleagues used a source of light that produces just two photons at a time. One photon served as a herald, going off to a detector to let researchers know when the photons were released. The other photon went into a solution containing light-absorbing structures from the bacterium *Rhodobacter sphaeroides*. These structures — called light-harvesting 2 complexes, or LH2 — are made up of two rings of bacteriochlorophyll and other molecules.

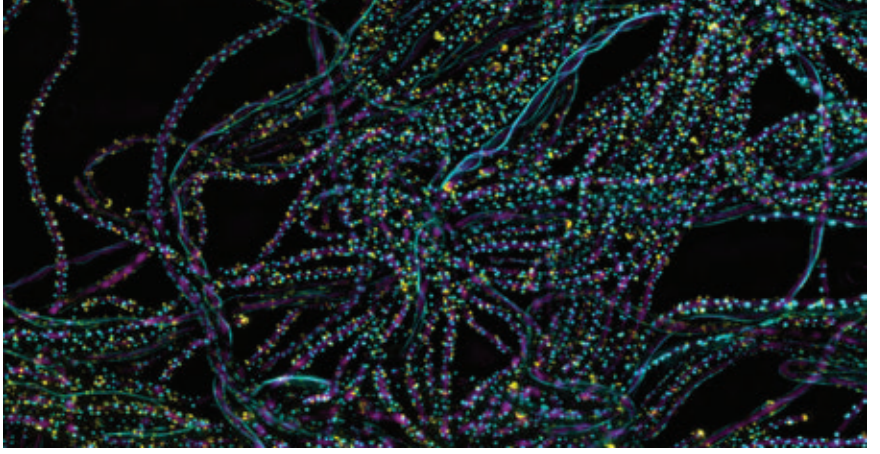
In a normal photosynthesis reaction, it's thought that LH2 absorbs a photon and passes its energy to another LH2 complex, and then another, like a game

NASA, ESA AND J. OLMSTED/STSCI

of hot potato. Eventually, the energy reaches another type of ring, LH1, which then passes the energy to the reaction center where it is finally converted into a form that the bacterium can use.

In the experiment, the solution contained no LH1, so LH2 emitted a photon instead of passing its energy on to LH1. The emitted photon had a different wavelength than the absorbed photon, a sign that energy had been transferred between LH2's two rings, a first step of photosynthesis. The team detected that second photon and, by comparing the detection time with that of the initial herald photon, confirmed that LH2 needed to absorb only one photon to kick things off.

Though plants and bacteria use different processes for photosynthesis, the initial steps are similar enough that a single photon would kick off the process in plants as well, Fleming says. However, plants require multiple independently absorbed photons to complete the reactions.



In *Rhodobacter sphaeroides* bacteria (shown fluorescing in this microscope image), one particle of light can initiate photosynthesis.

The role of single photons isn't surprising, says Richard Cogdell, a biochemist at the University of Glasgow in Scotland who was not involved in the research. The important thing, he says, is the new technique. With it, "you're able to essentially interrogate what will be happening in nature," Cogdell says.

Some researchers suspect that photosynthesis relies on quantum physics (SN: 2/27/10, p. 10). While it's not clear whether the new technique could resolve the role of quantum effects, it could help researchers disentangle natural effects from artifacts of using intense sources of light in studies of photosynthesis.

"You can really work out what's happening in the early reactions," Cogdell says, "[as if] you could shrink yourself down and watch these photons moving around." ■

ASTRONOMY

Red dwarfs may be light on Jupiters

Very few of the Milky Way's most common stars have gas giants

BY KEN CROSWELL

Whether you're looking to visit a gas giant planet in another solar system or you're a science fiction writer who needs such a planet for your story, you'd better steer clear of little red stars.

A search for planets like Jupiter around low-mass red dwarf stars has come up empty, researchers report in the July *Astronomical Journal*. "Around 200 stars, we did not detect a single one of these planets," says Emily Pass, an astronomer at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass.

The find — or lack thereof — lends support to a theory of giant-planet building called core accretion. In this theory, gas giants like Jupiter and Saturn form by gradually piecing together a solid core out of debris orbiting a young star. That core eventually gets massive enough to attract lots of gas. But low-mass red dwarf stars shouldn't host much solid material to begin with, so a paucity of gas giants is in line with that theory.

About three out of every four stars in the Milky Way are red dwarfs, a type of star that is much fainter, cooler and smaller than the sun (SN: 9/25/21, p. 13). Red dwarfs glow dimly because they were born with little mass, about 8 to 60 percent of the sun's. Previous planet searches have found that a few red dwarfs have gas giants. But the new search targeted red dwarfs with only 10 to 30 percent of the sun's mass, which are the most common such stars.

Pass and colleagues spent about six years searching for the shift in starlight caused by an orbiting planet tugging on its sun with telescopes in Arizona, Hawaii and Chile. All of the observed stars are nearby, within 50 light-years of Earth. The closest is Barnard's Star, which is just six light-years away and was once thought to possess two planets as massive as Jupiter.

But no gas giants turned up around that star or any of the others. Extrapolating to the rest of the galaxy, the team concludes that less than 2 percent of low-mass red dwarfs have Jupiter-sized planets.

The finding "is very consistent with the expectations from core accretion," says astronomer Edward Bryant of University College London. Forming a Jupiter around the lowest-mass stars is very difficult, he says. Since disks of gas and dust around infant low-mass red dwarfs are small, there's less material to work with.

But smaller, rocky worlds stand a much better chance. In fact, many red dwarfs have Earth-sized planets, some at the right distances from their suns to sport life-friendly temperatures. Even so, "we are talking about strange new worlds, not an Earth 2.0," Pass says.

In our solar system, Jupiter's gravity may have prevented lots of ice from reaching Earth, Pass says. As a result, our world didn't end up completely underwater. In a planetary system without a massive gas giant, an Earth-sized planet could turn into a water world that might still give rise to a highly intelligent species that would live underwater — think dolphins. "Those planets are just going to be so different than our own experiences," Pass says. ■

SHENG-WEN CHUI/UNIV. OF OXFORD

These cats were part of a study of an experimental feline contraception. Betty and Jacque (right), received a gene therapy injection. Rosalyn and Michelle (left) got a placebo.

CINCINNATI ZOO & BOTANICAL GARDEN

ANIMALS

Gene therapy prevents cat pregnancy

A single shot has kept females kitten-free for at least two years

BY ERIN GARCIA DE JESÚS

Invasive surgeries to spay cats could one day be a thing of the past, replaced instead with a single shot.

An injected gene therapy given to female cats prevented them from getting pregnant, researchers report June 6 in *Nature Communications*. None gave birth to a litter of kittens after mating with a fertile male. The tactic, if it holds up in further testing, could offer a more efficient way to control a global population of feral cats that numbers in the hundreds of millions.

"We love domestic cats, but they are killers out in the environment," says conservation biologist Bill Swanson of the Cincinnati Zoo & Botanical Garden. Free-roaming cats around the world are thought to kill billions of birds and small mammals every year (SN: 2/23/13, p. 14). Spaying feral and pet cats can help control feline populations and reduce their casualties.

The experimental gene therapy targets anti-Müllerian hormone, a protein that helps fetal sex organs develop. After injection, a modified virus introduces the gene that instructs the body to make the hormone into the cats' cells. The cells then make more anti-Müllerian hormone than normal. High levels of the protein may prevent a cat's ovaries from releasing eggs by keeping follicles — the structures that house and release eggs — in a dormant state.

Swanson and colleagues treated six female cats with the gene therapy. Three cats received a high dose and another three received a lower dose. An additional three cats in a control group got a placebo. None had any severe side effects.

The team housed all nine cats together with a fertile male in two four-month-long trials. One trial took place eight months after treatment; the second, with a different male, happened nearly two years after the injection. In both trials, the control cats gave birth to litters after mating with males only once. Of the six treated cats, two mated with males and neither became pregnant.

The proof-of-concept study is "the first real sign of hope that we could do something besides spaying cats," says veterinarian Julie Levy of the University of Florida in Gainesville. The single-dose injection is especially promising to control feral populations, eliminating the need to bring wild-living cats into a clinic for surgery or trap animals more than once to administer multiple doses.

The therapy appears to be long-lasting because of where the gene is delivered — muscle cells — says coauthor David Pépin, a reproductive biologist at Massachusetts General Hospital and Harvard Medical School. There, the cell makes the hormone using small, circular strings of DNA. Since muscle cells generally don't die, the DNA can stick around for a lifetime.

The study reports results after two years, Pépin says, but to date the team has followed the cats for more than four. Because gene therapy can last a lifetime in other animals, including people, it's likely that the same would be true for cats.

Of the two treated cats that mated with males, one mated nine times yet still never got pregnant. Zooming in on all the cats' hormones revealed that the treated females didn't ovulate, but other hormones involved in reproduction and estrus — also known as heat, a time when female cats are ready to mate — remained intact.

The four treated cats that never mated with males had spikes in estrogen levels, one sign of estrus. But the females didn't allow the males to mate, a sign those females weren't actually in heat.

Males pursuing a female in heat are persistent, Swanson says. A male will endlessly follow a female and attempt to mount her if he thinks it's possible to breed. "It's like velociraptors in *Jurassic Park* testing the fence. All the time they're testing these cats if they're in estrus."

That kind of behavior makes some people not want cats in their neighborhoods, Levy says. Her ideal cat contraception would keep females from allowing males to mate with them, something that the new shot does for some females but not others. Hopefully that would pacify fertile males.

Studies with more cats are required to verify the injection's safety. If the U.S. Food and Drug Administration and similar agencies around the world approve the therapy, it will still be years before it appears in veterinary offices. The team is tweaking the gene and method of delivery, exploring how to make it as effective as possible as well as cost-effective to manufacture. ■

PALEONTOLOGY

Fossils may revise duck-billed history

One dinosaur lineage wasn't so widespread, scientists contend

BY JAKE BUEHLER

Fossils from the southern tip of Chile are adding a wrinkle to researchers' understanding of how duck-billed dinosaurs conquered the Cretaceous world.

Duck-billed dinosaurs known as hadrosaurids were highly successful, living on most continents by the end of the Cretaceous Period about 66 million years ago. Now, a study shows that a different duck-billed lineage appears to have thrived some 72 million years ago in subantarctic South America, potentially millions of years before hadrosaurids reached the continent, researchers report in the June 16 *Science Advances*.

"It's yet another chapter in the dispersion of these dinosaurs that we did not know about," says paleontologist Jhonatan Alarcón-Muñoz of the University of Chile in Santiago.

About a decade ago, paleobiologist Marcelo Leppe of the Chilean Antarctic Institute in Punta Arenas was searching for plant fossils in the Río de las Chinas Valley in Chile when he spotted fossilized bones. After bringing the finding to the attention of Alexander Vargas, a paleontologist at the University of Chile, researchers extracted the bones for a more detailed examination.

Alarcón-Muñoz, Vargas, Leppe and their colleagues determined that the bones belonged to a type of duck-billed dinosaur — herbivorous giants that had flattened, waterfowl-like snouts — that had never been found before. The recovered remains include pieces of hip, limbs, ribs, vertebrae and skull.

The researchers named the animal *Gonkoken nanoi*. *Gon* and *koken* are words that mean "similar to" and "wild duck or swan" in the language of the Indigenous Aónikenk people from the part of southern Patagonia where the bones were found.

In all, the researchers suspect that they found four *Gonkoken* individuals. No fossils of other animals were found with the remains, Vargas says, which suggests the dinosaurs were probably moving in a herd (SN: 8/9/14, p. 20).

Gonkoken isn't like other known duck-billed dinosaurs from South America nor the former supercontinent of Gondwana, which included South America, Antarctica, Africa, Australia and India. Until now, all known duck-billed dinosaurs from Gondwana were hadrosaurids, which had their heyday in the Late Cretaceous. Their efficient, stacked, plant-pulverizing teeth helped them chew their way to nearly global dominance, outcompeting other herbivorous dinosaur groups. *Gonkoken* appears to be part of an older, less specialized lineage that diverged from other duck-billed dinosaurs around 91 million years ago, before the first hadrosaurids evolved, the team says.

Gonkoken's ducklike snout had a simpler construction than that of hadrosaurids, Alarcón-Muñoz says, and the dino had fewer rows of teeth in its chewing surface. *Gonkoken* was also relatively small — about 4 meters long — whereas some hadrosaurids were true titans, reaching up to about 15 meters long.

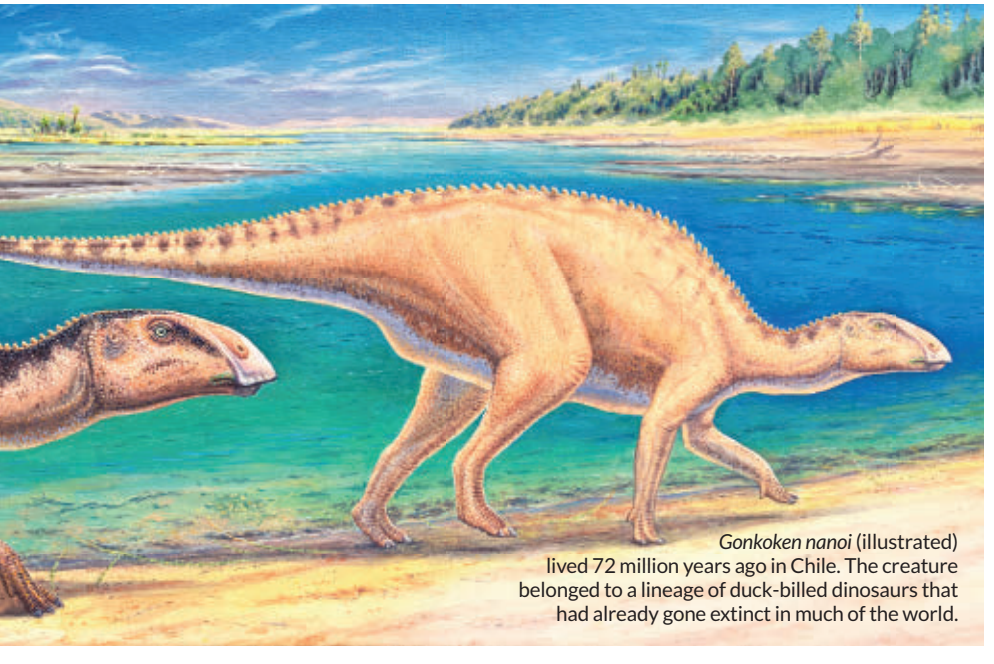
Finding a non-hadrosaurid duck-billed dinosaur like *Gonkoken* in South America is "somewhat unexpected," says David Evans, a vertebrate paleontologist at the University of Toronto who wasn't involved in the research. The discovery "makes us rethink their biogeographic history in the Americas in interesting ways."

For example, rather than colonizing the continent just once, duck-billed dinos moved from North America to South America in two distinct waves, the team contends. "We suspect our kind of duck-billed dinosaur arrived earlier into South America and reached farther south than the hadrosaurids," Alarcón-Muñoz says.

What's more, *Gonkoken* probably was a relict during its lifetime. "In most other places of the world, [members of this older lineage] had already gone extinct by this time," Alarcón-Muñoz says.

The findings may also mean that hadrosaurids were not quite as widespread as previously thought. Fragmentary remains unearthed in southern Patagonia and Antarctica that were thought to belong to hadrosaurids may actually be *Gonkoken* or its close relatives.

Many other outcrops along the Río de las Chinas Valley are studded with dinosaur bones. The team wants to examine these remains to see if they belong to *Gonkoken* as well. Finding more skull bones of *Gonkoken*, Evans says, could be key to figuring out exactly how it was related to other duck-billed dinosaurs. ■



MAURICIO ÁLVAREZ ABEL

Gonkoken nanoi (illustrated) lived 72 million years ago in Chile. The creature belonged to a lineage of duck-billed dinosaurs that had already gone extinct in much of the world.

CLIMATE

Shrinkage predicted for boreal forest

One of nature's woody behemoths — the North American snow forest, spanning much of subarctic Alaska and Canada — may soon shrink.

Scientists have suggested that this boreal forest might shift northward as the climate warms, helping maintain its expansive breadth. But for two decades, the ecosystem's northern tree line has held fast, while its southerly tree cover has thinned, researchers report June 8 in *Nature Communications*. Human activities and climate change could push the prodigious forest to contract.

North America's boreal forest is thought to contain about 25 percent of Earth's remaining intact forest, and millions of people's lives depend on it. In addition to climate change, logging and wildfires threaten the forest (a stretch in Alberta, Canada, burned by wildfires in May is shown at left).

Environmental scientist Ronny Rotbarth of Wageningen University in the Netherlands and colleagues assessed how those pressures were impacting the forest's range. Using satellite observations, the researchers tracked tree-cover changes from 2000 to 2019. They then analyzed how those changes corresponded with temperature, precipitation and disturbances like wildfires and logging.

Overall, tree cover increased, mostly within the northern half of the forest. But its northern boundary showed little to no expansion, while its southern boundary thinned, largely due to wildfires and logging. The researchers also found that the southerly reaches didn't fully recover from these disturbances during the study period, potentially hindered by climate warming.

The changes may foreshadow a long-term forest contraction, though it's unclear when exactly that could start. — *Nikk Ogasa*

EARTH

Irrigation nudges the North Pole

Groundwater removal can alter Earth's rotational axis

BY SID PERKINS

Runoff from irrigation has moved so much water from land to sea that Earth's rotation might have measurably shifted.

Computer simulations suggest that from 1993 through 2010, irrigation alone nudged the North Pole by about 78 centimeters, scientists report in the June 28 *Geophysical Research Letters*. That would make irrigation the second largest contributor to polar drift after the ongoing rebound of Earth's surface following the retreat of glaciers since the last ice age.

The North Pole wanders across the Arctic seascape in a circle a few meters in diameter. Seasonal weather patterns cause part of this cyclical drift, and long-term variations in the temperature and salinity of ocean water help drive a 14-month oscillation dubbed the Chandler wobble.

There's also a more subtle, noncyclic drift caused by the movement of land-based water to the sea, says Clark Wilson, a geophysicist at the University of Texas at Austin. In the first study to try and tease out the contributions of these water movements, Wilson and colleagues used computer simulations to assess how the impoundment of water behind dams, the melting of glaciers and ice sheets, irrigation and other factors affect polar drift.

Previous studies have suggested that irrigation shifted about 2 trillion metric tons of water from aquifers to the oceans from 1993 through 2010 — enough to raise global sea level by over six millimeters.

Although seemingly minuscule, that redistribution of water was enough to shift the North Pole just over four centimeters each year on average during that period, the team found.

When all sources of water movement are considered, the North Pole drifted about 1.6 meters toward the east coast of Greenland in that time, the simulations showed. The impact of irrigation was mostly to nudge the pole generally east of where it would have gone otherwise.

"The team's findings all make sense," says Jay Famiglietti, a hydrologist at Arizona State University in Tempe. "It's important to realize that water is heavy, and when it moves around, it's going to affect Earth's rotation."

Large-scale irrigation can also affect local and regional climate. Studies have shown, for instance, that irrigation lowers temperatures and boosts humidity in California's Central Valley and increases rainfall in the Four Corners area of the American Southwest. ■

MEGAN ALBU/AFP/GETTY IMAGES

ENVIRONMENT

Rising waters threaten Superfund sites

Groundwater could spread pollution in U.S. coastal communities

BY NIKK OGASA

Hidden flows of water are poised to flush toxic contamination into U.S. coastal communities.

Sea level rise from climate change won't just force shorelines to retreat — in nearby inland areas, it will lift groundwater into shallower soils. That rising water could infiltrate hundreds of Superfund sites, severely polluted locations identified by the U.S. Environmental Protection Agency for cleanup, researchers report in a study posted online May 25 to the preprint server *ESS Open Archive*.

These sites and thousands of other polluted areas could be at risk of releasing heavy metals, radioactive elements, pesticides and industrial chemicals associated with human health problems. People of color and low-income communities would be disproportionately affected, the researchers say.

"The sheer number of Superfund sites where there are these dangerous contaminants that could be liberated — it's astonishing," says Patrick Barnard, a coastal geologist at the U.S. Geological Survey who is based in Santa Cruz, Calif., and who wasn't involved in the study. Many of the polluted areas have been managed without regard for groundwater rise, Barnard says. "We need to think about what the future holds for these sites."

The link between climate change, the sea and underground water may not be obvious, but it is intimate. At the beach, seawater can seep into the ground and move inland, permeating layers of earth under coastal communities. Meanwhile, rain and runoff can also trickle down from above. In the ground, this freshwater often sits atop the denser saltwater from the sea. And when the sea level rises, it pushes all this groundwater up through the earth.

Rising sea levels can push up groundwater in coastal areas like San Leandro, Calif.

As the top of the groundwater, known as the water table, nears the surface, it can damage human infrastructure. It can also spread hazardous substances in the soil, exposing people and ecosystems nearby.

Environmental planner and geologist Kristina Hill found motivation for the study while investigating groundwater conditions at a former Superfund site in the San Francisco Bay Area. There, groundwater was touching pollutants in the soil. "I started wondering, what is the scale of this problem?" says Hill, of the University of California, Berkeley.

Of the roughly 1,800 Superfund sites, Hill and colleagues identifed 326 that are in low-lying coastal areas — less than 10 meters above average sea level.

If the sea surface rose by a meter — a possibility by 2100 — then groundwater could potentially infiltrate contaminated soils at all of those sites, the team found. With 54 at-risk Superfund sites, New Jersey has the most of any state. Florida comes in second place with 51.

Not every polluted site in the United States is a Superfund site, but that doesn't make them less hazardous, Hill says. Her team assessed the potential impact on such sites by using the Bay Area as a case study.

The scientists flagged 15 Superfund sites and nearly 5,300 contaminated areas managed by the state that are vulnerable to a meter of sea level rise. There could be thousands more such at-risk sites along U.S. coastlines, Hill says.

People from socially vulnerable communities — those whose circumstances limit their ability to prevent suffering or loss in the face of a disaster — bear a disproportionate risk of exposure, the team's analysis of U.S. Census data revealed.

Though the findings are not surprising, the study takes the first step in addressing the hazard by calling out where it could arise, says Holly Michael, a hydrogeologist at the University of Delaware in Newark. More localized research will be needed to thoroughly assess each site's risk and determine next steps, Michael says, whether they be treating contaminated soils or removing the soils altogether.

As the ocean encroaches on coastal communities, helping people move inland won't be enough unless we also clean up our mess, Hill says. "Otherwise, there will be a toxic area that we leave behind, and that will spread." ■

The Halaco Engineering Company site in Oxnard, Calif., is one of hundreds of Superfund sites on U.S. coastlines where rising groundwater could spread pollution to nearby communities.

FROM TOP: K. HILL; STEVE OSMAN/*LOS ANGELES TIMES* VIA GETTY IMAGES

ANIMALS

Snow flies lose a leg to survive the cold

When limbs freeze, amputation can keep the insects alive

BY MEGHAN ROSEN

A few years ago, John Tuthill was trail running in the Cascade mountains in Washington state when he spotted something dark skittering across the snow.

It was about the size of a wild blueberry, with an elongated body and six legs that moved in a blur.

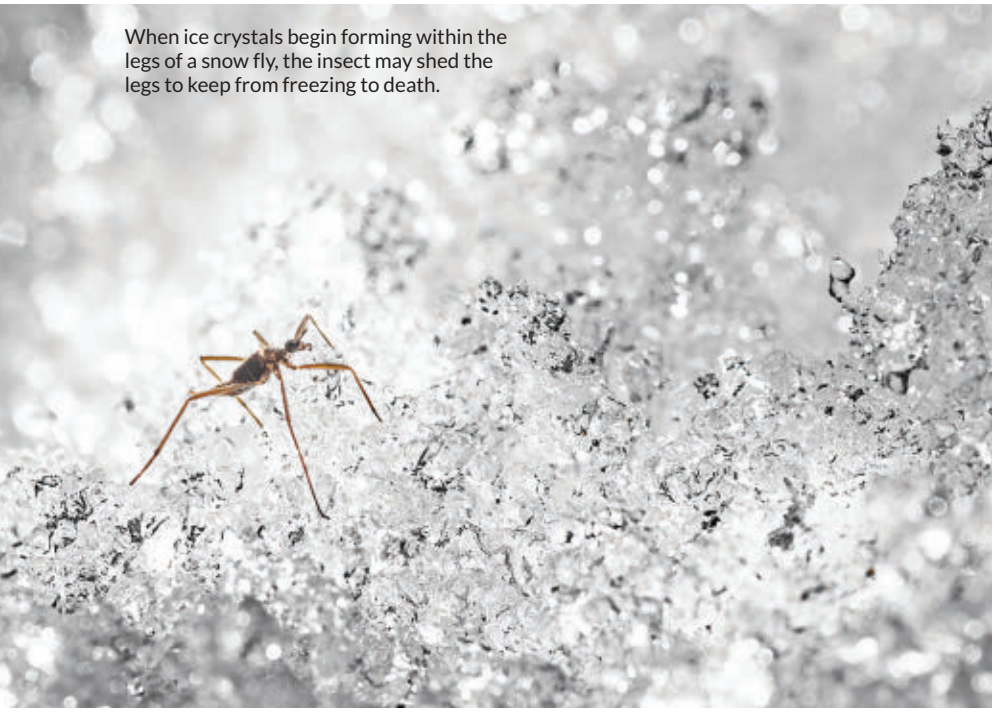
Tuthill was surprised to see an insect out and about on that cold October day. "I was kind of blown away that there was this animal out running around," says Tuthill, a neuroscientist at the University of Washington in Seattle. It was a snow fly, he later learned. Also known as *Chionea* flies, they can somehow walk around at temperatures well below what most other insects can tolerate.

Now, Tuthill and colleagues have shown that a grisly trick helps snow flies survive sub-zero conditions. When a leg begins to freeze, the insects can rapidly self-amputate it, preventing ice crystals from creeping up into their bodies, the team reports in a paper posted online May 30 at bioRxiv.org.

Many animal species, including spiders, lizards and crabs, can drop a limb or tail to escape a predator (SN: 3/26/22, *p.* 32). But the new work is the first to show an animal using this life-saving measure in response to the cold, says Christine Miller, an evolutionary biologist at the University of Florida in Gainesville who was not involved in the work.

Snow flies are a type of flightless crane fly, relatives of the "big, spindly, goofy-looking flies that you see bumbling around in your house," Tuthill says. Snow flies, which can live for two months, aren't easy to study: The insects can't be bred in the lab, and they're tough to collect from the wild. Snow flies can live in alpine areas that are difficult for people to reach and where the threat of avalanche looms.

The best way to find these flies, Tuthill says, is to spend a lot of time wandering around, looking at snow. Backcountry skiing fit the bill. In an eight-hour trip, he says, "probably seven hours of that is walking slowly uphill." From 2020 to 2022, Tuthill, his wife, and some friends and volunteers collected hundreds of snow flies, scooping them into plastic tubes brought back or mailed to Tuthill's lab. Most of the snow flies that arrived alive came from excursions in Washington.



When ice crystals begin forming within the legs of a snow fly, the insect may shed the legs to keep from freezing to death.

TRASROID/FLICKR (CC BY-NC 2.0)

Tuthill's team used a thermal camera to record 77 snow flies as they walked on cold plates. The insects kept trekking even when their body temperature fell to an average of –7° Celsius, the researchers found. More than half of the snow flies tested dropped at least one leg during the experiments.

A sharp-eyed research tech, Dominic Golding, noticed a temperature spike in the flies' legs just before they fell off. That spike is a sign of ice formation, Tuthill says. Liquid water releases heat as it crystallizes into ice. Neurons in the leg may sense this temperature shift and trigger amputation, preventing the icy crystals from spreading, the team suggests. The flies "have about half a second to get rid of their leg before that wave of ice crashes into their body and then freezes all of their internal organs," Tuthill says.

Snow flies didn't lose their limbs when the researchers tugged on them — only in response to freezing.

Other animals have devised different strategies to fend off frost, says entomologist Katie Marshall of the University of British Columbia in Vancouver. Some insects pump out antifreeze proteins; certain snails and frogs simply withstand ice forming in their bodies.

"The cool thing about snow flies is that they don't actually follow either strategy," says Marshall, who provided feedback on the team's manuscript, which has not yet been published in a peer-reviewed journal. They let ice form in their legs, she says, and "self-amputate to get rid of it, which is just completely strange to me."

Snow flies that amputated their gelid limbs survived more than a minute longer than flies that didn't, the team found. That extra time may not seem like much. But in the wild, when night is falling and the temperature is dropping and the insects are "looking furiously for a place to hunker down," Tuthill says, it could be the difference between life and death. ■

Urgent: Special Summer Driving Notice

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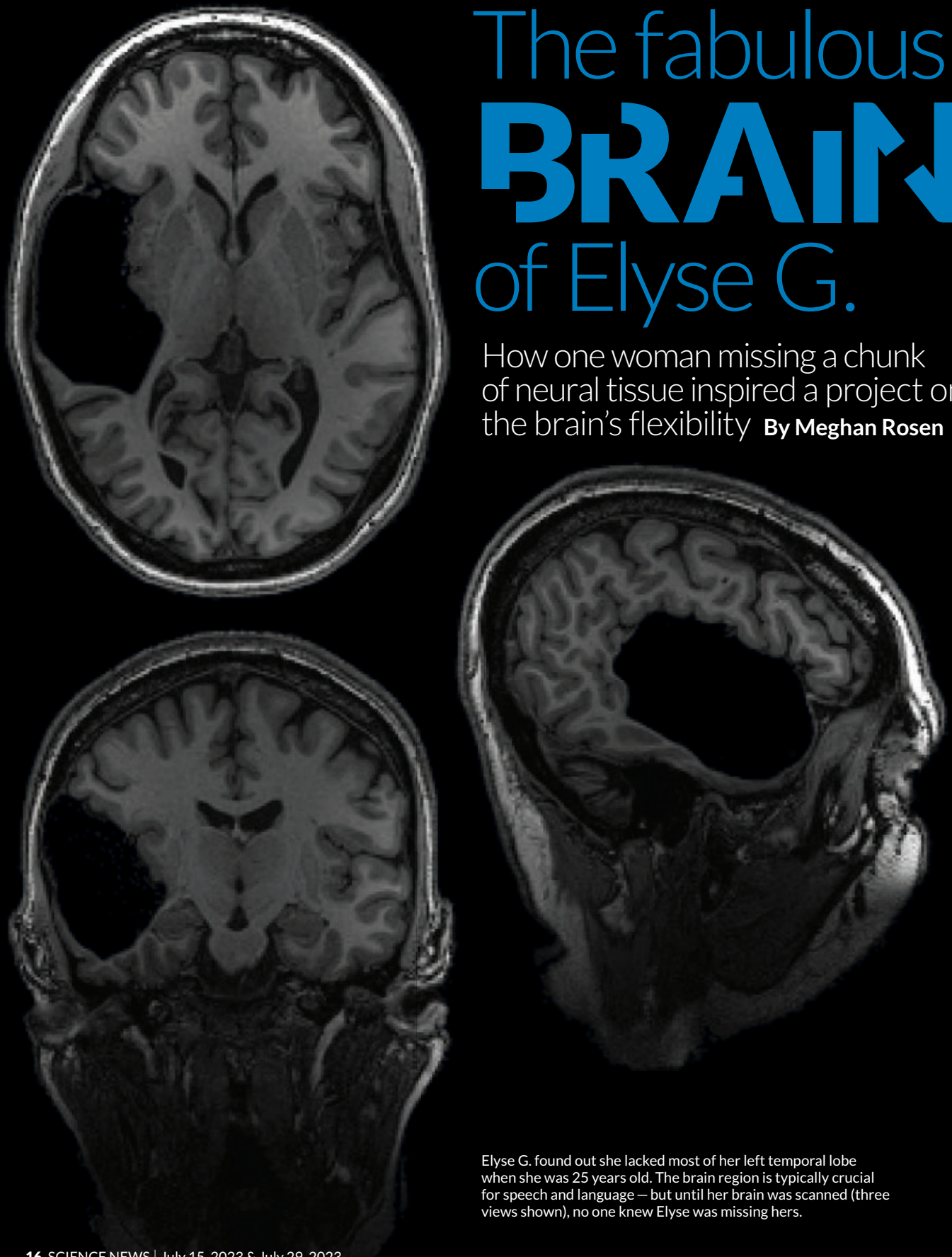
The fabulous BRAIN of Elyse G.

How one woman missing a chunk of neural tissue inspired a project on the brain's flexibility **By Meghan Rosen**



Elyse G. found out she lacked most of her left temporal lobe when she was 25 years old. The brain region is typically crucial for speech and language — but until her brain was scanned (three views shown), no one knew Elyse was missing hers.

COURTESY OF THE FEDORENKO LAB

You'd never guess that Elyse G. has a black hole in her brain.

Meet her on the street, and it'd be impossible to tell she's lacking a chunk of neural tissue about the size of a small fist.

Looking at her brain scans is a different story. It's as if someone has knocked over a bottle of ink. The darkness pools inside her skull near her left ear, a puddle of fuliginous black. Inside the splotch, there's no white matter or gray matter, no blood vessels or tissue at all.

Elyse says you don't have to be a neurosurgeon to spot what's different about her brain: "There's a big honking piece missing!"

Scientists can't say exactly how it happened. It's possible that sometime long ago, perhaps due to a stroke before or shortly after birth, a portion of Elyse's brain died and then ultimately disappeared, leaving behind only liquid—brain tissue swapped for a fluid-filled void. Her sister has one too.

Elyse and her sister, Martha M., who are not using their full names to maintain their anonymity, look and act perfectly ordinary. But each lacks most of a temporal lobe, and each in a different hemisphere. Elyse is also missing part of her brain stem. The women are two of who knows how many people living their lives without brain structures generally thought to be crucial.

Martha, now age 59, didn't know her brain was different until she was a teenager. Elyse, who will turn 61 this year, found out in graduate school. Two sisters. Two brains. Two black holes. When MIT cognitive neuroscientist Evelina Fedorenko's team first learned about the duo, "we were all kind of blown away," she says.

Elyse emailed Fedorenko her brain images in 2016, decades after the void was discovered. She had read an article about neuroscience research at MIT and was curious if scientists would be interested. "She said, 'I'm missing my left temporal lobe. Do you want to study me?'" Fedorenko remembers.

The left temporal lobe is generally thought to be essential for speech and language, and Fedorenko, who trained as a language researcher, was intrigued. Her lab hadn't studied people like Elyse before, but "I'm a very adventurous scientist," she says. So her team brought Elyse to the lab for tests.

Fedorenko didn't know it at the time, but those first studies would set in motion a whirlwind that would alter the course of her research. Her team's findings would ignite media attention, prompting even more people to send along their brain scans. What started as a single case study has now snowballed into the Interesting Brains Project.

By the end of this fall, the project will likely have scanned more than 40 people with atypical brains. In many cases, participants are missing entire brain regions, and like Elyse, they didn't find out until they were adults.

That may be a tribute to the brain's flexibility—its ability to change and adapt—including its redundancies, Fedorenko says. Like backup generators, some brain areas can kick into gear if others get injured. A close look at cases like Elyse's could help scientists better understand how our brains cope with damage and why some kinds are worse than others.

For now, Fedorenko's team is focusing on language and aspects of high-level cognition, such as a person's capacity for general reasoning. But the effort could also offer insights into the workings of the brain more broadly and might one day give doctors a better sense of what outcomes a person with a brain injury might expect.

> "I felt like my brain was something that needed to be 'cured' rather than celebrated."
>
> ELYSE G.

That's what Elyse and Fedorenko hope, anyway. Before she started working with the MIT team, Elyse says, "I felt like my brain was something that needed to be 'cured' rather than celebrated." Not anymore. These days, there's a different word that comes to Elyse's mind when she thinks about her brain. "It's fabulous," she says.

The power of MRI

Elyse first learned about her atypical brain after an MRI scan in the fall of 1987. She was 25 years old and in her first year of grad school in Washington, D.C., an avid reader and a whiz with a needle and thread.

At an appointment with a neurologist at the George Washington University Hospital, Elyse—who had been previously diagnosed with epilepsy despite never having a seizure—sensed mostly boredom from the doctor and an accompanying resident. They didn't pay her much notice, she says.

That feeling evaporated when Elyse came back for her results. Now she had the doctors' full attention. They leaned forward in their chairs, elbows on knees, chins in hands, eyes laser-focused on Elyse. "How do you feel?" she remembers them asking. She felt like a lab specimen—like a frog they were zapping with electrodes, she says.

What the doctors had seen in her brain scan, of course, was that blatant black hole. When detected

EDITOR'S NOTE:

Most of the Interesting Brains Project participants featured in this story are using shortened forms of their names and/or pseudonyms to protect their privacy.

A matching lesion Martha M., Elyse G.'s younger sister, is also missing most of a temporal lobe, but on the right side of the brain — a near–mirror image of Elyse's lesion. Martha may have had a stroke while she was in the womb. Later, fluid buildup in the brain pressed against the nerves of her eyes, hindering her sight. Like all of the Interesting Brains Project participants tested so far, Martha scores at or above average on language and cognitive tasks.

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in babies, it's the kind of lesion that makes parents fear the worst. In adults, strokes in the left hemisphere can steal people's ability to read and write and jumble their speech. The meaning of words can slip suddenly from the mind, as if an eraser has scrubbed away a person's mental dictionary. Elyse's doctors, she remembers, were surprised she had more than a fifth-grade vocabulary.

At the time, Elyse felt sickened and scared. She didn't know if the lesion was growing, if it foreshadowed early Alzheimer's disease or if it was going to "explode in my head," she says. A follow-up scan six months later eased her fears. The scan looked the same as the first. Her brain's black hole wasn't expanding.

Elyse never returned to those doctors, but she did get a second opinion that summer from her sister's neurosurgeon. He had operated on Martha when she was 17, after she had noticed vision problems. The bulk of her right temporal lobe was gone, possibly due to a stroke in the womb. Fluid buildup in the brain was pressing against the nerves of her eyes, hindering her sight. "They drained it, and I went on my merry way," Martha says. She hasn't had the area drained since.

Martha's doctor looked at Elyse's scan and told her that as MRIs were becoming more common, doctors were finding other people with brains that diverged from the norm. "He said, 'We're seeing more and more deviations, and you've got one,'" she remembers.

Birth of a project

When Elyse and Fedorenko first met, Fedorenko was interested in how language areas wire up when a chunk of crucial tissue is missing. Her plan was to peek inside Elyse's head using functional MRI, a technique that tracks blood flow in the brain. Functional MRI lets scientists see which parts of the brain are active while a person performs a specific task.

For Elyse, that means lying statue-still inside the giant tube of an MRI machine while equipment whirs around her. Depending on the task, Elyse may look at or listen to words, sentences and stories or see math problems or spatial puzzles. Occasionally, she'll press a button so the team knows she's staying alert.

Outside the tube, the researchers have also tested Elyse's vocabulary, reading and writing skills, and intelligence. She scored near the top of every language test she took. "I could have probably taken over the world if I had my entire brain," Elyse jokes.

Elyse's first scan with Fedorenko's team revealed language activity in the right side of the brain, the team reported in 2022 in *Neuropsychologia*. Shifting functions to the right is one trick our brains use to deal with damage on the left, something other scientists have reported previously, Fedorenko says.

The team wondered if Elyse's left frontal lobe might chip in too. Yes, Elyse lacks her left temporal lobe, Fedorenko says, but her left frontal

lobe — where language also typically resides — is perfectly intact. "Is there any language going on there?" Fedorenko asked.

But that lobe showed no language-responsive areas at all. The findings hint at a neural order of operations for language development: Without Elyse's left temporal lobe, language areas in her left frontal lobe couldn't wire up.

> "I could have probably taken over the world if I had my entire brain."
>
> ELYSE G.

Fedorenko's team also revealed that Elyse completely lacks a typical region for reading words. The team thought such a region might show up in Elyse's right temporal lobe. Instead, she appears to tap into a network of neurons across the visual cortex, the team reported this year in *Cognitive Neuropsychology*.

"It turns out you can have perfectly functional reading visual machinery in your brain that's implemented in a different way," Fedorenko says. Elyse may be the first reported example of this.

The findings from Elyse's brain caught the attention of a reporter at *Wired* who wrote an article last year with an eyeball-grabbing headline: "She Was Missing a Chunk of Her Brain. It Didn't Matter." Then the emails started pouring in.

The morning after the *Wired* story published, Fedorenko's inbox was "filled with cool brain pictures — brains missing all sorts of big parts," she says. In many cases, people found out about their atypical brains accidentally. Fedorenko heard stories about people with neck tension going in for an MRI and finding out they're missing most of their right frontal lobe. Others, like Helen Santoro, have known about their brain lesions since they were little.

Santoro, a science journalist who reached out to Fedorenko after reading the *Wired* story, had a stroke before birth and was missing her left temporal lobe, like Elyse. Doctors said Santoro would never speak and would need to be institutionalized. "But month after month, I surprised the experts, meeting all of the typical milestones of children my age," she wrote last September in an article about her experience for the *New York Times*.

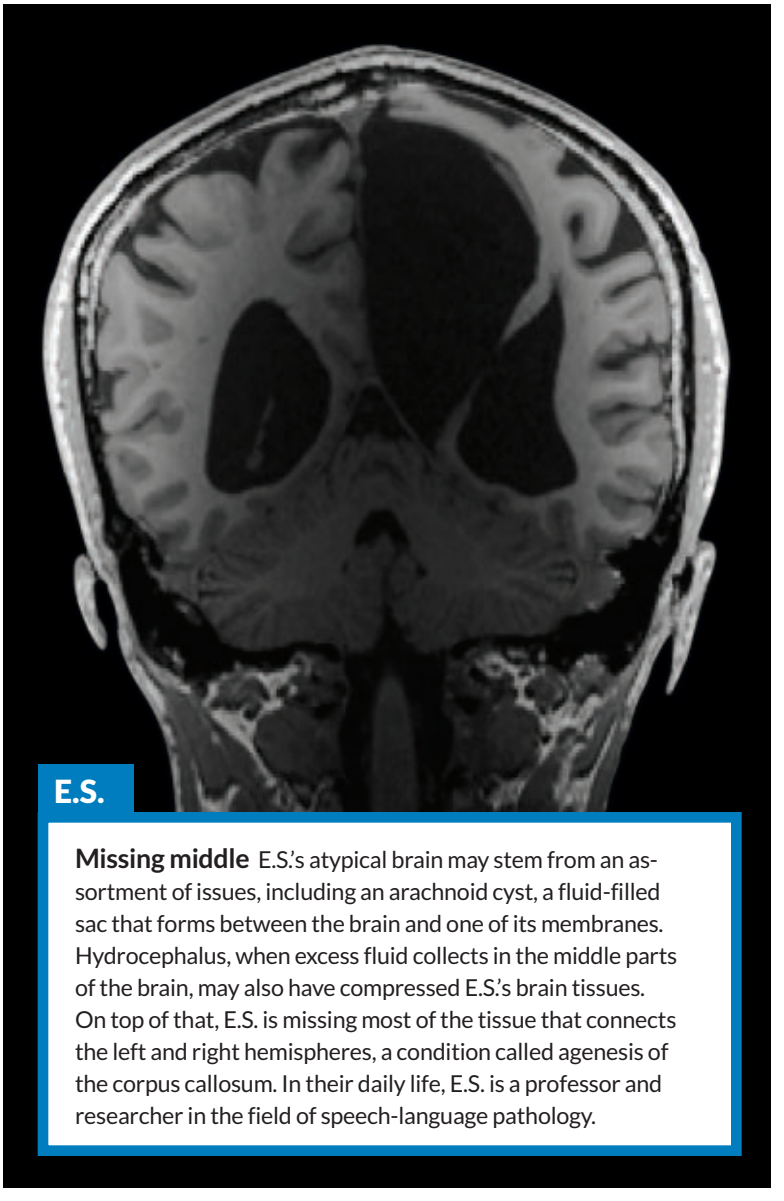
It's still not clear why some brain injuries slide by unnoticed while others demand attention, says neuroimaging scientist Helen Carlson. Her team at the University of Calgary in Canada has worked with kids who've had early strokes in the motor cortex, the brain region responsible for movement.

Some kids with large brain injuries have only minor weakness on one side of their body. Others with just "a little whisper of a smudge on their MRI ... have quite profound disabilities for their entire life," Carlson says.

That mismatch can be true of other difficulties too, including problems with language and general reasoning — and it's one of several mysteries the Interesting Brains Project is pursuing.

Brain region rearrangement

As of May 30, the Interesting Brains Project had scanned the brains of 30 people. Some have holes in their frontal or temporal lobes; others are missing parts of their cerebellum, a brain structure involved in balance and movement. Still other participants have brain matter



E.S.

Missing middle E.S.'s atypical brain may stem from an assortment of issues, including an arachnoid cyst, a fluid-filled sac that forms between the brain and one of its membranes. Hydrocephalus, when excess fluid collects in the middle parts of the brain, may also have compressed E.S.'s brain tissues. On top of that, E.S. is missing most of the tissue that connects the left and right hemispheres, a condition called agenesis of the corpus callosum. In their daily life, E.S. is a professor and researcher in the field of speech-language pathology.

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that's squished up against the sides of their skull; scans show voids that appear to have ballooned from the brain's center.

These atypical arrangements can stem from cysts, surgery, strokes or excess fluid buildup in the brain. Some can result in a brain with much less neural tissue than usual—and sometimes the change can be abrupt. What happens when the brain needs to perform its same jobs but in a much smaller space, Fedorenko asks. "What are the solutions that our brains come up with when suddenly there's a lot less turf to work with?"

> "My brain is special, unique and interesting."
>
> **ELYSE G.**

A community of scientists has already dug up some answers by studying kids who have had perinatal strokes. In some of these cases, during a baby's birth, or the weeks before and after, blood flow in the brain can cut off altogether, starving tissues of oxygen.

The brain can adapt to this injury, but it's not a lump of clay with infinite potential. "Everybody thinks, 'Oh, the brain is endlessly plastic,'" says Elissa Newport, a cognitive neuroscientist at Georgetown University in Washington, D.C. But it tends to deal with damage in set ways.

Newport worked recently with a group of 15 kids and young adults who all had perinatal strokes that resulted in left hemisphere damage in an area that processes words and sentences. In nearly every case, the participants' brains shifted language over to the same spots in the right hemisphere, Newport and colleagues reported in 2022 in the *Proceedings of the National Academy of Sciences*.

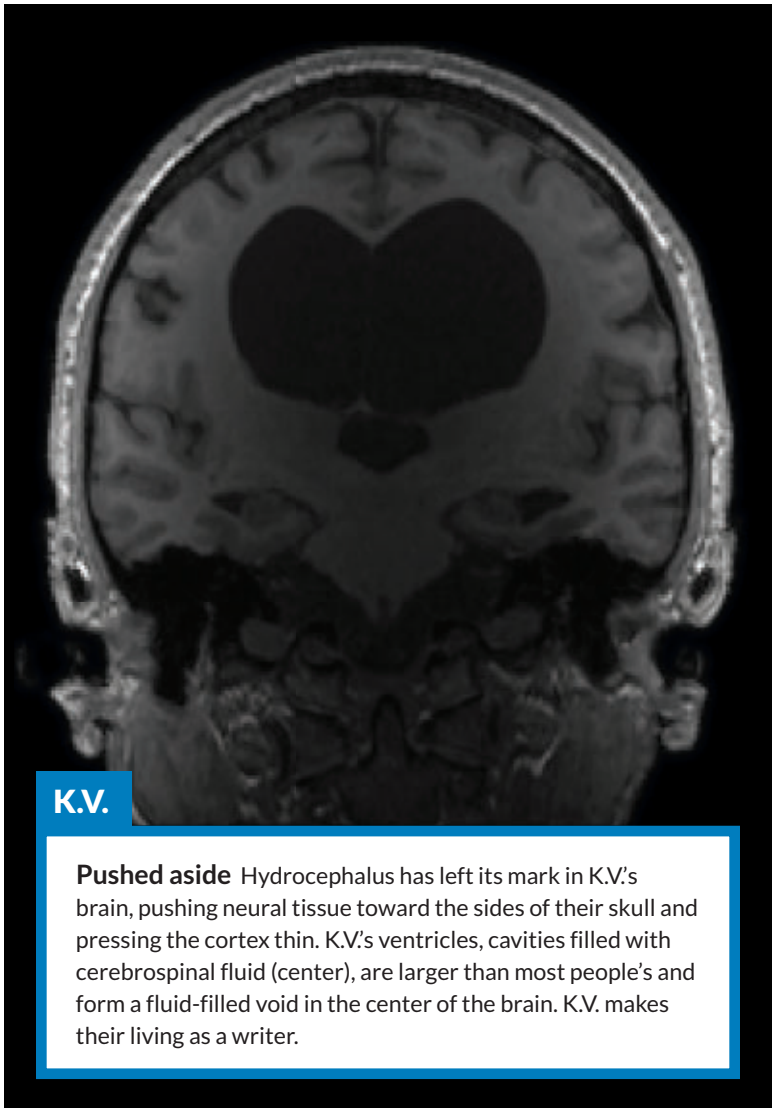
It's as if the language region has flip-flopped from left to right, "exactly the mirror image of what ordinary, typical brains look like," she says. This pattern suggests that certain brain areas can serve as pinch hitters for language function.

But there's still a universe of more questions, Fedorenko says. She's curious if brain functions can overlap, sharing the same cortical machinery in an atypical brain when they might otherwise have set up shop in different locations. And a damaged left hemisphere doesn't always mean language moves to the right. Sometimes language function stays behind, surviving on the fringes of the damaged region, Fedorenko says. "Nobody knows why that happens."

Carlson and colleagues reported this kind of adaptation in 2020 in *Pediatric Neurology*. The team was studying young stroke patients who had perinatal strokes that hit the motor cortex. Carlson says the Interesting Brains Project is valuable because it could tell scientists more about plasticity in the brain at the individual level—how a specific person's brain has adapted to injury.

Not every person's brain is able to bounce back. What scientists learn from the project, along with individualized neuroimaging, could help with prognosis, and potentially rehabilitation. "Perhaps if we can tailor intervention options to an individual brain, they might be more effective," Carlson says.

Getting results will take time. Fedorenko's team is currently juggling experimental logistics, including scanning a new participant every one to two weeks, performing behavioral tests and analyzing data. Still, they're seeing some interesting results, Fedorenko says, and hope to submit a paper this summer.



Pushed aside Hydrocephalus has left its mark in K.V.'s brain, pushing neural tissue toward the sides of their skull and pressing the cortex thin. K.V.'s ventricles, cavities filled with cerebrospinal fluid (center), are larger than most people's and form a fluid-filled void in the center of the brain. K.V. makes their living as a writer.

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She hopes the project can showcase the range of solutions our brains can, in some cases, employ to deal with a slow or sudden loss of neural real estate. Maybe, she says, the project's findings will help more people understand "how different you can be and still grow up and do amazing things."

What is normal?

In an opening note in Fedorenko's 2022 paper in *Neuropsychologia*, Elyse wrote about how her brain's structure doesn't define her. "Please do not call my brain abnormal, that creeps me out," she wrote. "My brain is atypical. If not for accidently finding these differences, no one would pick me out of a crowd as likely to have these, or any other differences that make me unique."

Elyse hopes the message comes through for doctors and research scientists. "I want them to understand that this is a person they're reading a paper about, not a disembodied brain in a jar," she says.

One thing Elyse likes about working with Fedorenko's team is that the research feels collaborative. Scientists rely on close partnerships like this to understand how the brain works under typical situations and how it may recover from injury, says Lesley Fellows, a neurologist at McGill University in Montreal who studies how brain damage affects decision making. People with atypical brains "can give us all kinds of great ideas we might not have thought about," she says. "They have a unique vantage point."

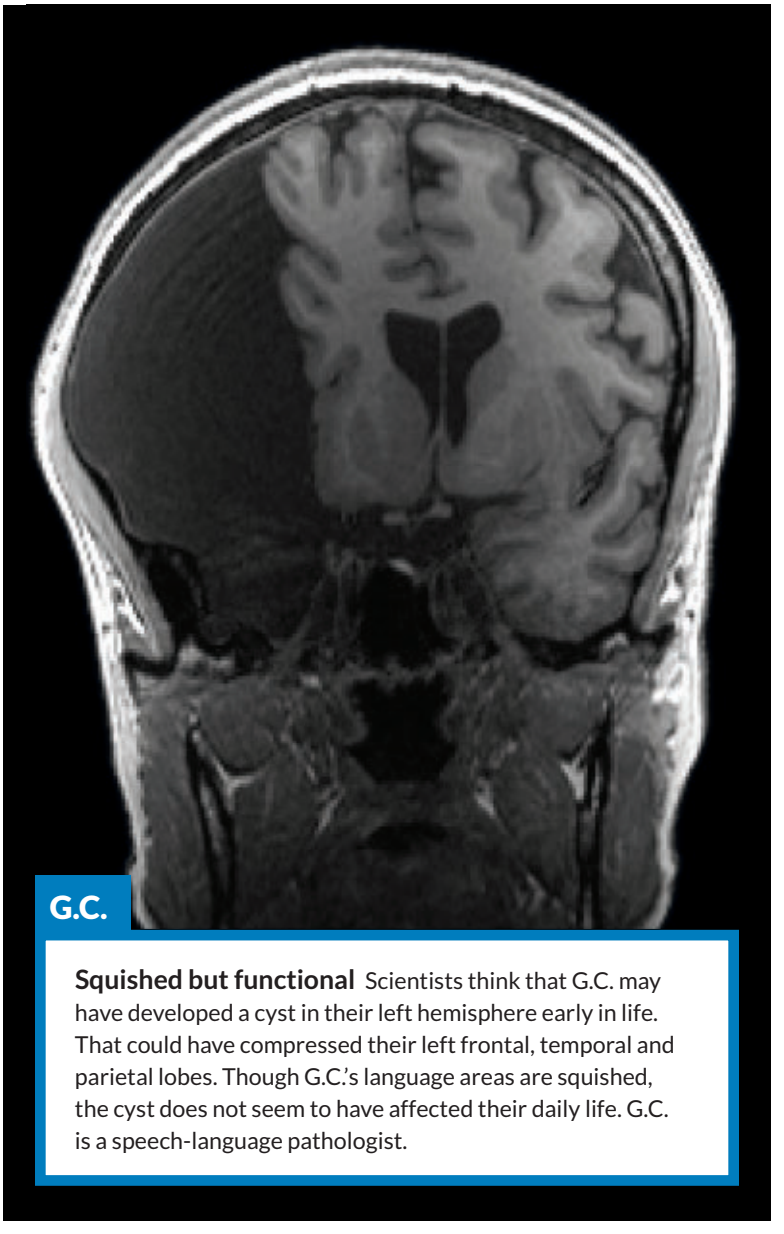
Elyse, for example, experiences smell hallucinations. She picks up whiffs of electrical fires whenever she's under a lot of stress. "When I was in grad school, I would smell electrical fires three times a week," she says. Elyse hasn't yet explored this brain quirk with Fedorenko and her colleagues, but she's open to their ideas for future investigations.

For the team's most recent study, reported in a preprint this year, Elyse, Martha and another sister (one with an "ordinary" brain) participated in hearing tasks inside the MRI tube. Fedorenko's team wanted to find out how the left or right auditory cortex works when the other side is missing.

You might think that the remaining auditory cortex would have to be enhanced somehow to pull double duty, perhaps taking up extra space, says Tamar Regev, a cognitive neuroscientist in Fedorenko's lab. But that's not what the team found.

In both Elyse's and Martha's brains, "activity looks completely neurotypical," Regev says. That suggests there's some redundancy to the brain's auditory system, and that the development of one auditory cortex does not depend on the existence of the other.

Elyse is curious what other insights Fedorenko's team will glean from her brain, and the brains of fellow Interesting Brains Project participants. "My brain is special, unique and interesting," she wrote in the 2022 paper, "and I am excited that it can help neuroscientists understand the plasticity of the human brain." ■



G.C.

Squished but functional Scientists think that G.C. may have developed a cyst in their left hemisphere early in life. That could have compressed their left frontal, temporal and parietal lobes. Though G.C.'s language areas are squished, the cyst does not seem to have affected their daily life. G.C. is a speech-language pathologist.

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> "I want them to understand that this is a person they're reading a paper about, not a disembodied brain in a jar."
>
> ELYSE G.

Explore more

- To find out more about the Interesting Brains Project and the team members, visit web.mit.edu/~interestingbrains/

The early Vikings set sail from the Scandinavian Peninsula to participate in regional trading, research suggests.

VLASTAS/ISTOCK/GETTY IMAGES PLUS

THE DAWN OF THE VIKING AGE

An ancient solar flare sheds light on global trade in early medieval times

By Martin J. Kernan

Calamity after calamity befell Europe at the beginning of the so-called Dark Ages. The Roman Empire collapsed in the late fifth century. Volcanic eruptions in the mid-sixth century blocked out the sun, causing crop failure and famine across the Northern Hemisphere. Meanwhile, the Justinian Plague arrived, killing, by some estimates, nearly half of everybody in Constantinople, the capital of the Byzantine Empire, and scores of others elsewhere.

And then, on June 8, 793, a group of marauders attacked a small island off the northeastern coast of Great Britain. As Christian monks noted in the *Anglo-Saxon Chronicle*, "heathen men destroyed God's church in Lindisfarne island by fierce robbery and slaughter."

With that description, the Vikings entered the annals of medieval history as merciless raiders, having also killed a local official in southern Great Britain in 789. From today's perspective, these Norse seafarers burst into existence seemingly out of nowhere.

Exactly when and why the Vikings first turned their boats away from shore to sail south over the horizon and into the unknown is hotly debated. According to some historians, another development in the late eighth century offers a clue: Silver coins known as dirhams made their way to Europe from the Islamic world in the Middle East. Around this time, Viking men in what is now Norway and Sweden became obsessed with silver as a means to purchase brides made scarce by female infanticide, or so a popular theory holds. A desperate need for silver, it was thought, motivated the Vikings' initial trips across the North and Baltic seas and somehow precipitated their infamous raids.

Other historians, however, suspect the Vikings' first forays into the outside world long preceded their violent raids and had nothing to do with a quest for silver.

"Our understanding of the chronology of the early Viking Age is really patchy because our best accounts are sometimes written 100 years later," says Matthew Delvaux, a medieval historian at Princeton University. That includes the description of the Lindisfarne raid in the *Anglo-Saxon Chronicle*.

Fortunately, medieval scholars have recently found another aid to turn to: a solar storm. Archaeologist Søren Sindbæk and his colleagues at Aarhus University in Denmark have reconstructed the timing of the Vikings' early voyages by harnessing the power of what was likely a supermassive solar flare that erupted in 775. The flare has helped the team improve radiocarbon dating and thus more precisely date artifacts excavated at Ribe, Denmark, the site of an early medieval trading post.

The chronology of events at Ribe reveals a less violent start for Viking voyages, at least 50 years before the Lindisfarne raid. The secret of Viking success, Sindbæk believes, is best explained by skillful trading, not fearsome raiding.

More precise radiocarbon dating has the potential to reveal other aspects of the medieval world once thought lost to history.

Going global

Since the 1970s, archaeologists have been probing Ribe, on the North Sea, for artifacts that could help explain one of the deepest mysteries in medieval history: how, within the span of mere decades, hardscrabble farmers wedged between dangerous seas and impenetrable forests became the Vikings who dominated Europe for nearly 300 years — a period known as the Viking Age.

At some point, a few highly motivated seafarers from the Scandinavian Peninsula made it across

The secret of Viking success is best explained by skillful trading, not fearsome raiding.

Early medieval trade routes in northern Europe

In the early medieval period, Ribe was a hub of international trade, with trade routes bringing goods from across northern Europe and the Middle East. Dashed lines show routes where goods probably passed through intermediaries before heading to Ribe.

the treacherous 100-kilometer Skagerrak strait to Ribe. There, among a cluster of thatched single-story houses on a sandy outcrop rising above a tidal marsh, the Vikings left clues to why they had come.

Sindbæk imagines how Ribe, already a marketplace for settlements to the south, would've looked to those early Vikings. "What would impress you at first sight would be all those masts," he says. "There would be more ships than you've ever seen in your life."

Ribe, Denmark's oldest town, eventually linked trade routes crisscrossing across northern Europe. The artifacts excavated along its narrow streets reveal when the early Vikings first arrived and where they spread next, expanding their influence around the region.

Starting in June 2017 for 15 consecutive months, Sindbæk's group uncovered extensive evidence of trade in Ribe, starting around the year 700. In clay floors of houses that had functioned as both residences and workshops, the Aarhus team found glass beads, including a kaleidoscopic array of colorful Middle Eastern beads, embedded among debris from prolific metalworking, hide preparation, weaving and bone carving. These were all telltale remains of a Viking Age trading town, where a variety of people met, mingled and hawked their wares.

And they did so peacefully. There is virtually no archeological evidence of violent conflict in Ribe, contrary to the popular myth of Vikings as bloodthirsty barbarians.

"From the beginning Ribe seems to have been a sort of safe haven. You can land here, you'll be safe. We're not going to plunder you. We'll try to outsmart you," Sindbæk says.

In all, he and his colleagues unearthed more than 100,000 artifacts—tools, accessories and trinkets that would come to define Viking Age culture. In many cases, these objects were made with materials sourced from the Scandinavian Peninsula inhabited by the early Vikings. Some beauties stand out. A magnificent amber battle axe pendant hints at the Vikings' warrior ethos. Combs carved from reindeer antlers display intricate designs. Terrifying beasts adorn oval brooches. The face of the Viking god Odin graces coins. The artifacts had value beyond their utility or inherent beauty. Back home on the Scandinavian Peninsula, these prestige items gave social status to those who delivered or received them.

"You can kind of show off your ability to participate in these interregional networks the same way that we might show off our ability to purchase a foreign car," Delvaux says.

Digging down through the centuries, there were many generations of workshops. Twenty shop floors strewn with artifacts. Two hundred years of continuous manufacturing activity compressed into 2½ vertical meters.

Richard Hodges, an archaeologist and past president of the American University of Rome, visited the site in 2018. It's "a layer cake of superimposed workshops, one on top of another," he says. "Some burned down. Some of them were just demolished. Every one of them was producing huge amounts of material culture."

With the layers often bleeding together, the Aarhus team needed to radiocarbon-date each one to put the artifacts in a clear chronological order and reveal the timing of events that produced them.

Radiocarbon limitations

For decades, radiocarbon dating has been a go-to technique for archaeologists. It takes advantage of the fact that when living organisms take in carbon and incorporate it into their tissues, some fraction of the carbon is a radioactive version of the element. It takes 5,730 years for half of that radiocarbon to decay into a form of nitrogen. Knowing that half-life and the amount of radiocarbon in, say, a bone or piece of charcoal helps scientists calculate the age of that organic matter.

But the amount of radiocarbon in the

T. TIBBITTS, ADAPTED FROM B. PHILIPPSEN *ET AL*/*NATURE* 2022

atmosphere—and thus taken up by plants during photosynthesis and then by the animals that eat them—fluctuates over time, so scientists must calibrate their measurements to estimate a true calendar date. Tree rings are handy for this purpose; each one records the atmospheric radiocarbon content in the year it formed. Experts have used trees of known ages from around the world to compile a curve called IntCal20 that plots fluctuations in radiocarbon over the last 55,000 years to help researchers calibrate radiocarbon dates.

But IntCal20's annual tree ring data are sparse for parts of the eighth and ninth centuries. So archaeologists haven't been able to date Viking-era artifacts precisely enough to explain the Vikings' emergence on the global stage.

To fill the gap, physicist Bente Philippsen, a member of the Aarhus team, performed her own calibration using oak tree specimens from the National Museum of Denmark—one of which befittingly had been part of a bridge built by Viking King Harald Bluetooth (the great unifier of people in Denmark and Norway in the 10th century after whom the eponymous device-linking technology is named).

But even with the extra calibration, Philippsen couldn't narrow the possible age range of a given layer enough to know exactly when Vikings first arrived or when long-distance trading networks reached the town.

Help from the sun

To zero in on the timing of these events, the Aarhus team looked to see if signs of an ancient solar flare were recorded at the site. In 775, a few literate observers in western Europe reported seeing the impact of a solar storm. Celestial phenomena streaking across the sky were described in various ways: a red cross, inflamed shields, fire from heaven. Some people saw "snakes" slither with the same movements as the aurora borealis.

At the atomic level, solar particles streaming into Earth's atmosphere kicked off nuclear reactions that transformed some nitrogen atoms into an unstable variant of carbon with six protons and eight neutrons: the isotope carbon-14, or radiocarbon.

Typically, 99 percent of atmospheric carbon is carbon-12, which has six protons and six neutrons. Only one in a trillion atoms of the remaining 1 percent is carbon-14; the rest is carbon-13. But these ratios vary ever-so-slightly over time due to carbon-14's unstable nature. In 775, the solar storm created 1.2 percent more carbon-14 than usual. That ratio of carbon isotopes became imprinted on any organisms alive at the time.

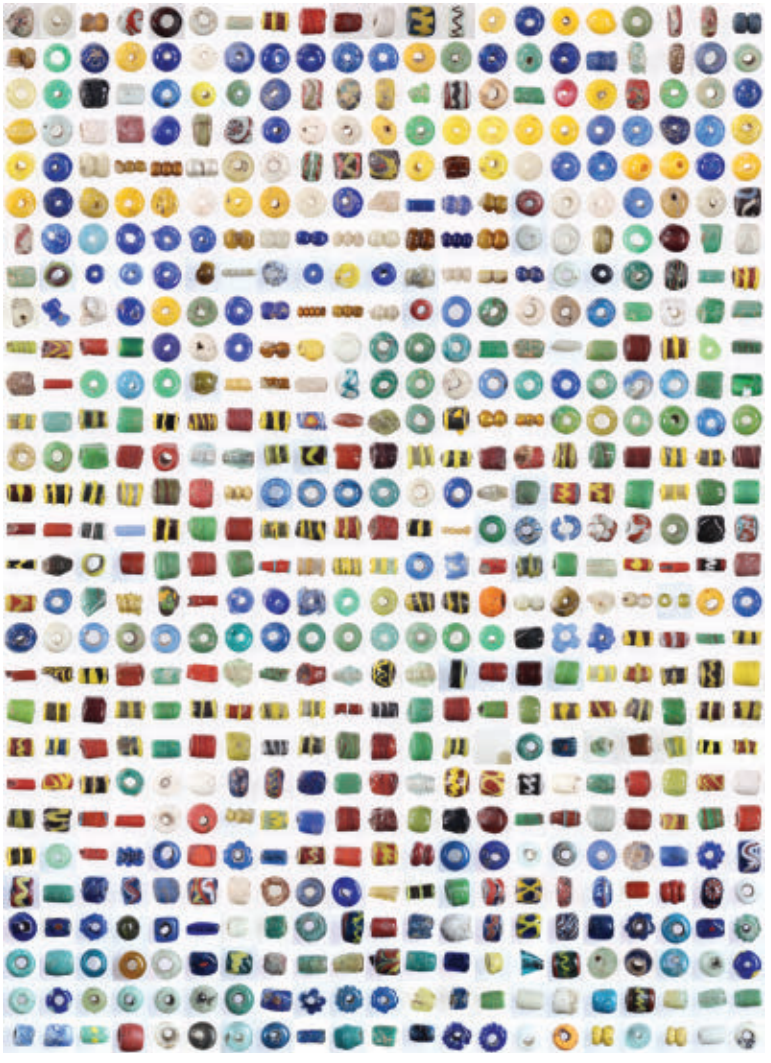
Physicist Fusa Miyake of Nagoya University in Japan and colleagues first discovered this 775 spike in radiocarbon about a decade ago, in the rings of Japanese cedar trees. Counting the annual rings, she was able to pinpoint the year of the solar storm. It turns out that the sun has on several occasions, about once every millennium and a half or so it appears, sent flares in our direction with enough energy to make measurably more carbon-14.

So while the Aarhus team peeled back layer upon layer of wet clay and sand along one of Ribe's ancient streets, Philippsen set out to see if any of those layers might date to 775. Up to her elbows in mud and clay at the site, she searched for the right bits of organic material to date.

"I've been trained in all the [excavation] methods,

Archaeologist Søren Sindbæk (left) kneels in an excavation trench that reveals the many archaeological layers at Ribe. Physicist Bente Philippsen (right) led radiocarbon dating of the site.

BOTH: MUSEUM OF SOUTHWEST JUTLAND



These glass beads found at Ribe are in chronological order, from the newest, dating to around 900 (top), to the oldest, from around 700 (bottom). Segmented beads from the Middle East appear after 790 (middle rows and above). After the introduction of those beads, black-and-yellow-striped beads made in Ribe disappear.

so it's safe for them to let me be in the trench and work, and you get a really good understanding of the samples," Philippsen says.

Of all the startling finds in Ribe, the site's trash held the most potential to shed light on the origins of Viking Age trade. Twigs, rye, barley, oats, nutshells and other refuse still lying around more than 1,000 years later possibly bore the time stamp of the supermassive flare.

Philippsen shuttled between her lab at Aarhus and the dig at Ribe with 140 samples plucked from different workshop layers. Trading her trowel for a scalpel, she diced up her bits of ancient oak and ran them along with samples from the site through the lab's accelerator mass spectrometer, which counts carbon-12 and carbon-14 atoms by sorting them according to mass. Two pieces of charcoal and a hazelnut shell from a combmaker's workshop turned out to have the same ratio of carbon-12 to carbon-14 as the oak tree rings dated to 775.

A time capsule of trade

Once Philippsen identified a workshop layer dated to 775, every other workshop and its artifacts above and below fell into a decade-by-decade chronological order. And with that sequence, Sindbæk and colleagues pieced together the evolution of trade at Ribe, reporting the findings in 2022 in *Nature*.

Around the year 700, ceramics and repurposed Roman glass appear at Ribe, indicating trade with the Franks of the Rhine Valley in what's now Germany. By the 740s, early Vikings were arriving in ships large enough to carry blocks of Swedish and Norwegian stone. In the 750s, reindeer antler appears from a species not found outside of Norway's hinterlands—more signs of a Viking presence. Craftspeople in town turned those bulk items into sought-after combs and sharpening stones. In exchange, vendors probably offered the early Vikings beads and brooches that would become the ubiquitous hallmarks of the Viking Age. These items also show up later in other Viking trading towns, such as Birka in Sweden. Finally, around 790, a cache of beautiful beads arrived in Ribe, likely via Russia, indicating new Middle Eastern trade connections.

This scenario strongly suggests, if not proves, that Viking explorations began as regional trading expeditions, not as a desperate bid for Middle Eastern silver, Sindbæk's team argues.

Given the similar timing, the possibility that the raids somehow relate to Middle Eastern trade goods just then finding their way into northern Europe raises important questions.

"We're seeing this intensification of [Middle] Eastern trade on the Scandinavian periphery of the North Sea, and that precedes the intensification of Viking raiding in the British Isles," Delvaux says. "Did this trade stimulate the raids? Were they raiding so they would pick up things to engage in Eastern trade? Did the raids start because people wanted to compete with Eastern trade? I could trade with the Muslims for silver or else I can raid the English for it, right?" Delvaux asks rhetorically.

Regardless, the solar flare clearly demarcates a moment of first contact between emerging civilizations. Sindbæk can imagine how it happened.

The Middle Eastern beads, he says, probably traveled north from the Mesopotamian heartland in several-pound bags before being handed over to

MUSEUM OF SOUTHWEST JUTLAND

The Vikings briefly lived in Newfoundland, Canada, at L'Anse aux Meadows (reconstructed settlement shown). Recent dating suggests the Vikings arrived there by 1021.

DYLAN KERELUK/WIKIMEDIA COMMONS (CC BY 2.0)

a merchant in present-day Turkey, who probably followed nomadic trails north to the forest steppe somewhere in northern Ukraine. There, the merchant may have met Vikings who had come east across the Baltic Sea and exchanged the beads for furs or enslaved people. The beads dispersed through Scandinavian markets, ultimately arriving in Ribe.

Ribe is awash in these imported beads after 790, while the locally made black-and-yellow-striped "wasp beads" individually crafted exclusively in Ribe disappear from the archaeological record. The reason, the Aarhus team concludes, is competition.

Craftspeople living several thousand kilometers away mass-produced beads by dicing up long rods of glass. People now had to ask themselves: "Do I want the beads that are made by Sven on the corner, or do I want the beads Olaf is bringing in from God-knows-where, but he could give me 30 of them for the same price that Sven can make me one?" Delvaux says.

More to illuminate

The solar flare in 775 and a slightly weaker one in 993 with a distinct carbon spike have revealed how Vikings were trying to touch every corner of the globe. Using that 993 solar flare, another group of archaeologists finally confirmed when Vikings lived in North America. Wooden objects at the L'Anse aux Meadows site in Newfoundland, Canada, hold the signature of the 993 flare. Counting tree rings revealed when the timbers to make those objects had been cut — in the year 1021, the team reported in 2022 in *Nature*.

Vikings weren't the only ones reaching beyond their horizons at the time. A diverse set of trader-explorers in Afro-Eurasia also survived perilous sea crossings and found each other in towns akin to Ribe. Solar flare–aided radiocarbon dating could bring their stories to light as well.

"We can put different cultures and regions on the same timeline, no matter whether they had a tradition of history writing or not," Philippsen says. "This makes it much easier to study contacts and the causes and effects of developments in different parts of the world. Environmental and climate records are also dated by radiocarbon … we can also check how societies responded to climate change, and how cultural developments are connected with changes in the environment."

Archaeologist Mark Horton of the Royal Agricultural University in Cirencester, England, agrees that solar flares "enable us to create a much more precise timetable for history." But in trading towns around the Indian Ocean where he works, for example, dead trees decay out of existence very quickly, leaving huge gaps in the radiocarbon calibration curve for the Southern Hemisphere, SHCal20, making it more difficult to fill them in as Philippsen did.

Next up for Philippsen is helping Aarhus archaeologist Sarah Croix radiocarbon-date early Christian graves to test King Harald Bluetooth's claim that he converted Denmark to Christianity. If the graves predate his rule, then Bluetooth would've been, let's say, exaggerating.

"Radiocarbon dating now approaches the precision of traditional historical sources, so it becomes relevant for studying 'recent' history, not only prehistory," Philippsen says. "We can thus study the lives of individuals who are not mentioned in historical sources, i.e., 'normal people,' with the same chronological precision as those of the rulers, the literate, or whoever wrote or was written about." ■

Explore more

- Bente Philippsen *et al*. "Single-year radiocarbon dating anchors Viking Age trade cycles in time." *Nature*. January 20, 2022.

Martin J. Kernan is a freelance science and history writer based in central New York.

What is big G?

Newton's gravitational constant has proved tough to pin down

By James R. Riordon

In a lab at the National Institute of Standards and Technology, scientists are using an updated version (shown) of a centuries-old experiment to try to determine the precise value of Newton's gravitational constant.

JENNIFER LAUREN LEE/NIST

There was a secret inside the envelope in the hands of Stephan Schlamminger, one of the world's leading experts in experimental tests of gravity. He appeared to be on the verge of opening the envelope during a presentation at the April 2022 meeting of the American Physical Society, to read a number that would reveal whether his latest efforts in a lifelong passion had been a success.

Schlamminger, of the National Institute of Standards and Technology in Gaithersburg, Md., sought to measure Newton's gravitational constant. The secret number in the envelope was a kind of code — an intentional and specific error inserted into his NIST experiment to obscure the measurement as it progressed. Only one person knew the number. And that person was not Schlamminger.

Without access to it, he couldn't know what the

experiment had found. Schlamminger had imposed the secrecy on himself to protect against bias in the experiment, including the unconscious bias that can beset even the best experimentalists. It was extra precaution to ensure the integrity of an experiment that could help untangle mysterious discrepancies in measurements of the constant, known as G, that have crept up over the last few decades.

G, often called "big G" (to distinguish it from "g," which depends on G and is the special case of the acceleration of gravity near the surface of the Earth), reflects the strength of gravity between any things with mass. It determines the orbits of planets and galaxies, and describes the force that pulls you to the ground. Nobody knows how to predict from theory what the actual value of G should be, says Clive Speake, a physicist at the University of Birmingham in England who developed the instrument that Schlamminger is using at NIST.

It's also very difficult to measure. After two centuries of improved precision, recent measurements of G are troubling. A handful of labs around the world have turned up values that disagree. The scattered values could be a sign of trouble with the measurement techniques among various groups, or there might be a more intriguing aspect.

"There's this haunting elephant in the room which suggests that maybe there's something going on that we don't understand," Speake says. "If the measurements are right, then it could be the greatest discovery since Newton."

Like so many science presentations in the time of COVID-19, Schlamminger's reveal was set to be virtual. Presumably other physicists and science reporters around the world were, like me, hunched over screens waiting to see what the secret number would tell us about G.

The time had come to tear open the envelope. But the video feed stopped. The big reveal had been canceled. Puzzling discrepancies in the measurements meant the numbers could not be trusted. The envelope would remain sealed for at least another year as Schlamminger went back to the lab to take another shot at one of the most challenging measurements in physics.

Gee-whiz

Newton's gravitational constant is a misnomer. Though Isaac Newton developed his theory of gravity in the 17th century, he didn't think in terms of G. He was primarily interested in how the force moved objects. Apples falling, planets in orbit and the surprisingly squashed shape of the Earth are just a few of the countless phenomena that Newton's theory explained, all without explicitly mentioning G. The constant, named for Newton two centuries later, was instead wrapped into the masses involved.

We now know that Newton's theory is only an approximation of Einstein's more encompassing version of gravity, the general theory of relativity. It took Einstein's theory to explain the intense gravity of black holes and the warping of space and time. Still, back here on Earth, it's Newton's theory of gravity that concerns Schlamminger and others wanting to measure G.

The force of gravity depends on three factors: the masses involved, the distances between the masses and G. While the masses and distances differ depending on whether you're considering the forces between you and the Earth, for example, or a planet orbiting the sun, G is always the same. Along with the masses of elementary particles, the charge on an electron and the speed of light, G is one of dozens of constants crucial to science today (SN: *11/12/16, p. 24*).

G, though, stands out from the rest. It's one of the oldest recorded constants — only the speed of light was measured earlier. Yet despite hundreds of elegant experiments since British physicist Henry Cavendish first measured it 225 years ago, G remains among the least precisely known of the fundamental constants.

And in a way, our understanding of G has only worsened in recent decades as new, incompatible measurements have come in.

The measure of G

When Cavendish performed his first measurements of the force of gravity in a lab, he relied on a set of lead spheres. Two of them were hanging at either end of a rod 6 feet (about 2 meters) long, and the whole contraption was dangled from a wire. He then placed larger lead balls nearby and measured the forces between the spheres by tracking how the hanging rod twisted on the wire. Although Cavendish was primarily interested in figuring out the Earth's density, a little manipulation of his results shows that he effectively measured G for the first time. He got a value about 1 percent higher than today's generally accepted value.

Many of the modern-day G experiments are refined versions of Cavendish's setup. That includes the one Schlamminger uses. Instead of lead spheres, Schlamminger's system has precisely machined copper cylinders. Four 1.2-kilogram cylinders, known as test masses, rest on a disk that hangs from a metallic ribbon. The gravitational attraction between the suspended cylinders and four larger,

JENNIFER LAUREN LEE/NIST

Stephan Schlamminger, of the National Institute of Standards and Technology in Maryland, is leading an effort to measure Newton's gravitational constant, or G, using an experiment that previously tested the value in Sèvres, France. Schlamminger wants to settle discrepancies in recent measurements from labs around the globe.

roughly 11-kilogram copper cylinders nearby causes the disk to rotate on the ribbon. Schlamminger calls the heavy cylinders source masses. He's also done the experiment with a set of source masses made of sapphire crystal to see if G depends on the materials involved (it shouldn't). Where Cavendish used a large wooden box to protect his apparatus from stray breezes, Schlamminger relies on a vacuum chamber to eliminate the air almost entirely.

Conceptually, the experiment running at NIST is the same as the one Cavendish used. But modern experiments offer much higher precision.

Cavendish's experiments returned a value of 6.74×10^{-11} cubic meters per kilogram-second squared. The number is correct to about one part in 100. These days, the accepted value is 6.67430×10^{-11} with an uncertainty of about a part in 50,000, which means an error of plus or minus 0.00002×10^{-11}. Some experiments have reached similar precision by relying on pendulums swinging near heavy masses instead of twisting wires.

"Testing G to higher precision allows us to understand how constant and universal G really is."

CLAUDIA DE RHAM

But as precision increased, a new problem came along. Measurements over the last 20 years from various groups don't agree. It's as if G is slightly different in different places and at different times in a way that experimental error can't account for. Schlamminger's apparatus is on loan to NIST from the International Bureau of Weights and Measures, or BIPM, in Sèvres, France, where researchers came up with a value of 6.67554×10^{-11}, a clear deviance from the accepted value.

The most likely reason for the discrepancies is that there's something about each experimental system that's unique. Researchers are keen to track down these sorts of systematic errors. But measuring gravity is tough, both because it's the weakest of the fundamental forces (gravity is so weak that some modern experiments use tons of material to home in on G) and because everything with mass has gravity. There's no way to shield the experiments from other sources of gravity, so researchers must attempt to account for the outside influences.

Alternatively, the discrepancies in G could have something to do with where the experiments are taking place. Perhaps the value of G in Sèvres really is 0.04 percent higher than the value of G recently measured in Boulder, Colo., for example. None of the experts contacted for this story think that's a likely scenario. But in borrowing the BIPM gravity experiment and moving it to NIST's campus in Maryland, Schlamminger's efforts should help confirm that G doesn't vary from place to place. That's assuming he can work out whatever threw a wrench in his April 2022 reveal.

The trouble with G

Why do scientists need to measure G to perpetually higher precision anyway?

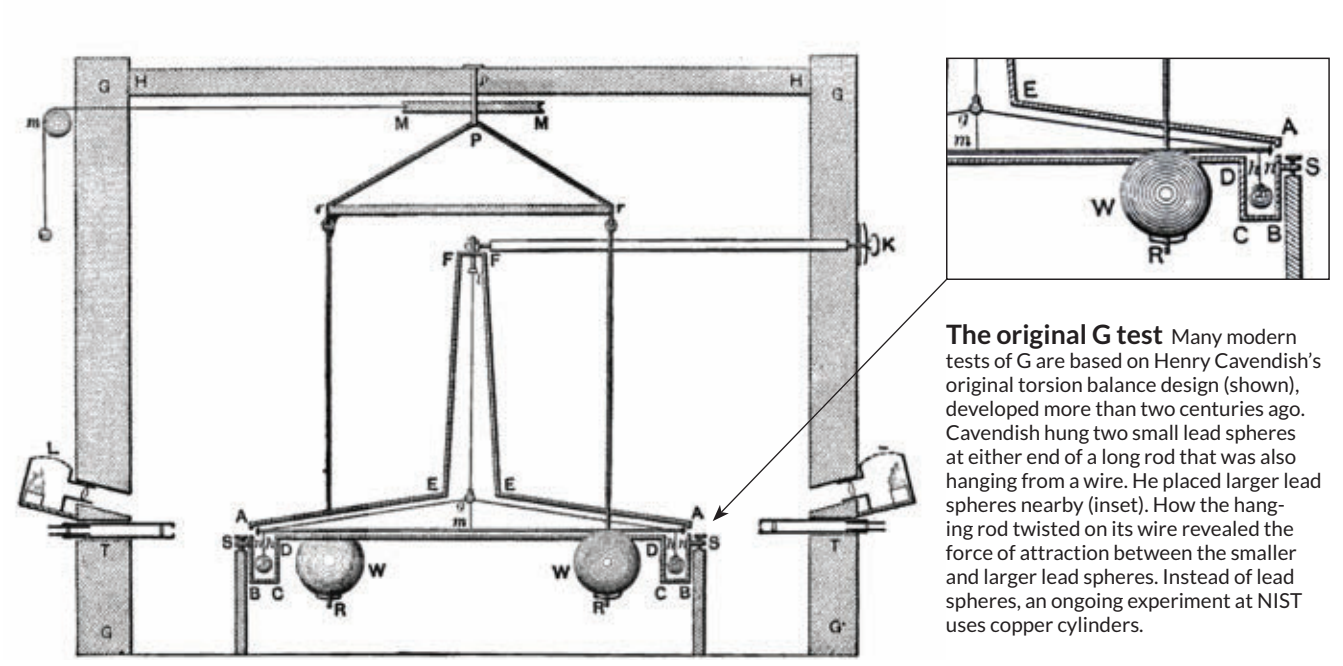
According to some experts, they don't. "From a practical point of view, there isn't a huge benefit to be derived from knowing G better," says physicist Clifford Will of the University of Florida in Gainesville. Other constants, like the charge on an electron and the speed of light, "play a huge role in all kinds of important technology, whereas G doesn't, because gravity is so darn weak," Will says. "By the time gravity matters, on scales ranging from planets to the universe, what matters is G times mass."

Physicist Claudia de Rham of Imperial College London has a different view. "G governs the strength of the gravitational force. In Newtonian gravity, it tells us how two massive bodies are gravitationally attracted to one another, but in Einstein's theory of general relativity, this constant communicates how anything in our universe curves the fabric of spacetime." Getting a better handle on G, she says, might help explain why gravity is so much weaker than electromagnetic forces or the strong nuclear force, which holds the parts of atoms together.

Although general relativity has proved to be one of the most successful and revolutionary theories in history, de Rham points out that its description of gravity may not be complete (SN: 2/13/21, *p.* 16). "Testing G to higher precision allows us to understand how constant and universal G really is and if there couldn't be something else beyond Einstein's theory of general relativity," de Rham says.

Some researchers speculate that precise measures of G might one day help uncover the solution to one of the deepest mysteries in science: Why doesn't gravity fit in with quantum physics? The standard model of particle physics is a quantum theory that describes just about everything in the universe, except gravity. Understanding G better, de Rham says, might lead to a quantum version of gravity, which is necessary to blend gravity into the standard model. Such a "theory of everything" has been a dream of physicists since at least Einstein.

For Schlamminger, the motivation is multifaceted. "It's mostly pure curiosity. And right now, there's salt in the wounds that the agreement [between experimental groups] is so bad." The thrill of pushing an extraordinarily difficult experiment just a bit further drives him too. "Why do people climb Mount Everest?" Schlamminger says. "Because it's there."



The original G test Many modern tests of G are based on Henry Cavendish's original torsion balance design (shown), developed more than two centuries ago. Cavendish hung two small lead spheres at either end of a long rod that was also hanging from a wire. He placed larger lead spheres nearby (inset). How the hanging rod twisted on its wire revealed the force of attraction between the smaller and larger lead spheres. Instead of lead spheres, an ongoing experiment at NIST uses copper cylinders.

Beyond Cavendish

One perennial challenge with Cavendish-style experiments is the wires. To interpret what's going on with G, researchers have to know how the suspending wires respond to twisting or swaying, and how they change as they age.

Some researchers choose to do away with the pesky wires altogether, instead dropping or tossing things to see how they respond to the pull of nearby masses. The most precise versions of those experiments so far toss supercooled clouds of atoms up in a tower and then allow them to fall back down again. By doing the tossing with various configurations of heavy objects nearby, researchers can see how the gravitational force exerted by those objects affects the atoms' trajectories. So far, the experiments have come up short of the most precise suspended-mass experiments by a factor of around 10, achieving a precision of one part in 5,000.

A recent experiment designed with other purposes in mind also dispensed with wires. The Laser Interferometer Space Antenna, or LISA, Pathfinder mission was a proof-of-principle test for a different type of gravity experiment. It was designed to show that it's possible to precisely measure the distance between objects in space — key to building a space-based gravitational wave detector.

LISA Pathfinder managed to measure the distance between objects well enough to find G to within about one part in 15. That's crude compared with Cavendish's precision of one in 100, and much worse than other modern measurements. But it shows that an experiment in space, free of the complication of wires and nearby massive objects like the Earth, has potential to measure G in an entirely new way.

Another shortcoming of Cavendish-like experiments is that they measure forces between objects that are either moving slowly or standing completely still. These experiments can't say much about whether G stays constant when things are moving quickly.

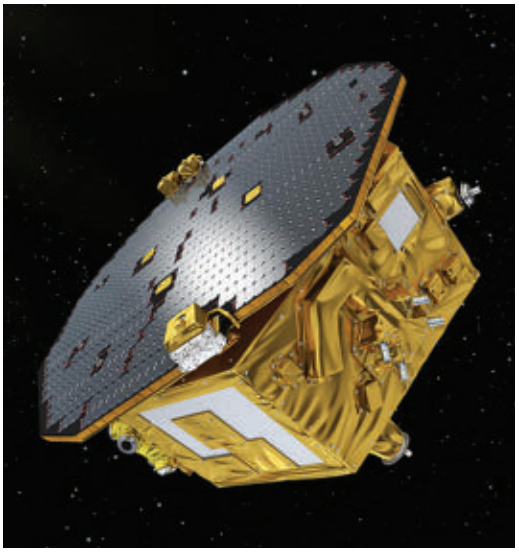
In experiments deep inside a mountain in Switzerland, mechanical engineering researcher Jürg Dual of ETH Zurich is replacing static masses with vibrating beams or rods rotating like helicopter blades. The motions result in changes in distance between the moving parts and a beam that acts as a detector, which in turn changes the gravitational forces the detector beam feels. The detector beam vibrates like a tuning fork, and the size of those vibrations offers a measure of G.

Unlike conventional experiments, this one could detect whether G depends on motion, which "might be something quite spectacular actually," Dual says. As for how likely that is, "I'm completely open," he says.

For now, though, Schlamminger and others using hanging masses much as Cavendish did 225 years ago are still providing the most precise measurements.

Going underground for G

Schlamminger's lab on the NIST campus is well below his office. "It's about four stories underground," he says. "There is less vibration, it's easier



Though designed and launched for other purposes, the LISA Pathfinder mission measured the distance between two objects in free fall in a spacecraft (illustrated) well enough to find G to within about one part in 15. This proof of concept suggests G can be measured without the interference of Earth's gravity.

ESA

to stabilize the temperature and the lab floor does not tilt as much. Usually buildings tilt with varying wind load. That is not a problem underground."

On my visit to NIST a month after the canceled reveal, we head down several flights of stairs and take a walk through a vacant hall before entering a room that has a sticky mat just inside. It's there to clean dust from your shoes as you go in. Even so, Schlamminger switches to a dedicated pair of shoes he stashes in the lab and gives me covers to slip over the soles of my shoes. Then we pass through another, airtight door to see the gravity experiment on loan to NIST. Things must be tidy when you're trying to do something as difficult as measuring G.

Dust interfering with the tips of measurement probes could throw off readings of the positions of the cylinders. "A second concern, albeit smaller," Schlamminger says, "is that dust settling on the source masses will change their mass."

The G experiment is smaller than Cavendish's pioneering design. You could fit it on a modest dining table. Here, it sits on a massive slab that minimizes the vibrations that manage to make it down to the lab. The vacuum chamber hides some of the moving parts of the apparatus from view.

Schlamminger is between runs at the moment, but four copper source masses, each about the diameter of a 2-liter soda bottle, are at the ready for the next G measurement. The source masses ride on a carousel outside the vacuum chamber, while the test masses sit on the disk suspended inside the chamber.

In the experimental mode that most closely mimics Cavendish's experiment, tracking the rotation of the disk as it twists on the suspending ribbon offers a measure of the force between the source and test masses, revealing G. In another mode, Schlamminger determines G by finding the force it takes to prevent the disk from rotating.

A set of sapphire crystal source masses that are the same size as the copper ones are in a case nearby. They can take the place of the copper ones on the carousel to confirm that G is a true constant that doesn't depend on the materials involved. At roughly twice the mass of the sapphire cylinders, the copper versions provide a better measure of G. Precisely how much each of the source masses weigh, though, Schlamminger doesn't know. That's because of the secret number tucked away in the sealed envelope.

"The big M, which is the masses of my big copper masses," he says, "I have basically asked this mass group at NIST who has measured them to add a random factor." Any studies he makes of G will be slightly off due to the random factor added to the true masses. Just how far off the measurement is won't be clear until he opens the envelope. So why didn't he open it in April 2022?

"I measured big G for like three months solid," Schlamminger says, before popping open the vacuum chamber to check the placement of the cylinders. "Then I did another big G run, and the number was different. And that's why I did not open the envelope, because I figured there's something that I don't understand."

It turns out he had prerecorded his talk and expected to reveal the answer in real time at the meeting. He changed his mind before the presentation streamed, which is why the audience was left wondering.

There are hints that changes in the quality of the vacuum that come with opening and closing the experimental chamber are related to the measurement shifts. It's another factor that Schlamminger says researchers will have to keep in mind if they're to understand the discrepancies in measurements of Newton's gravitational constant.

These days, Schlamminger is back at it with another experimental run. But one year on, at the 2023 American Physical Society meeting in Minneapolis, he still wasn't ready to open the envelope. "I'm very, very careful with it because you can't unopen the envelope." ■

Explore more

- Morris H. Shamos. *Great Experiments in Physics*. Henry Holt & Co., 1959.

James R. Riordon is a freelance science writer based in Clarksville, Md.

Eight Bears
Gloria Dickie
W.W. NORTON & CO., $30

BOOKSHELF

Visit the fabled past and fuzzy future of bears

Bears have long been considered family. "Stories of a familial bear exist in almost every human culture that shares territory with the animal," writes journalist Gloria Dickie in her new book, *Eight Bears*. The Yakut people of eastern Siberia call brown bears "grandfather" and "uncle." Shepherds in the French Pyrenees call the brown bear *la va-nu-pieds*, the "barefooted one," a reference to its humanlike footprints. In Peru, the Ukuku is an Andes-traipsing man-bear hybrid in Quechua lore that steals away young women.

The ancient and recurrent history of humans recognizing bears as either spiritual or biological brethren sets the tone for the book, which provides rich lessons for understanding our ursine neighbors and how their lives have intertwined with our own.

That bears have had such a cultural grip on our species is impressive given their dearth of global diversity. As you might have guessed, there are only eight bear species: brown, black, sun, moon, polar, spectacled, sloth and giant panda. Dickie explores each in vivid detail, traveling across three continents to some of the places where they amble.

The settings Dickie presents — some remote, some urban — are marvelously rendered. She transports readers to the perilously steep ridgelines of the Andes, perpetually misty and buzzing with hummingbirds, and to Churchill, Canada, a subarctic town on an icy seashore sitting square in the path of migrating polar bears. Through these travels, Dickie weaves in each species's unique stories — of decline, recovery and an uncertain future — and how humans have roped their own desires and ambitions to the bears, for better or worse.

Dickie expertly peppers her "ursine odyssey" with dry humor, augmenting the experience of encountering the bears, which oscillates from dopey to truly dangerous. One moment that stands out is when Dickie is preparing to visit the forest homes of Indian sloth bears and describes digesting jarringly matter-of-fact stories and photos of the aftereffects of maulings. But not to worry, a local biologist assures her "in a way that was meant to be comforting," she will see more injuries like this where she is set to travel.

Such engaging insights into Dickie's experiences elevate *Eight Bears* well above a patchwork of bear facts.

Though, there are facts aplenty. Dickie provides ample context on each species's biology, ecology and historical (and sometimes prehistorical) relationship with humans. The robust accounting of so much about these animals is fascinating, though some forays into the evolutionary history of each branch of the bear family tree and the taxonomic identity of Paddington Bear and Baloo from *The Jungle Book* can feel meandering. Still, Dickie excels in crafting a captivating and carefully considered mosaic of stories that will engross any reader interested in wildlife and wilderness.

The spectacled bear of South America faces an uncertain future as climate change threatens to destroy its forest home in the Andes.

One primary theme in *Eight Bears* is that many species inhabit woefully shrinking natural spaces. In the Andes, spectacled bears' cloud forests risk ascending upslope into oblivion due to a warming climate. Polar bears are caught between rapidly dwindling sea ice and a genetic tidal wave from hybridizing with brown bears that have started wandering poleward. Sloth bears are squeezed into smaller and smaller pockets of forest as human populations expand, leading to violent, tragic conflicts with people.

These eight bear species, Dickie shows, manage to capture the full range of people's attitudes toward wilderness, from awe to exploitation, neglect to reverence. She illuminates radically varied consequences of humans placing political, social or economic value on bears. For instance, circumstances aligned for giant pandas to be useful in "panda diplomacy" as a political bargaining chip for China, thus feeding a cultural status and conservation investment the seven other bear species lack. Dickie's honest and bleak accounts of moon and sun bears languishing on farms in Vietnam that collect bear bile to treat inflammation and high cholesterol present a far darker reality for some species.

There are relative success stories in which bears have bounced back into abundance, but that can present ongoing tension. In the United States, humans and black bears navigate coexistence at the wildland-urban interface (and national park trash cans). On the eastern flanks of the Rockies, brown bears lollop into territories gone bearless for decades due to intentional extermination, now saturated with farms and people.

In the end, Dickie warns that only three species — black, brown and panda bears — seem well-positioned to persist in the wild in the future. Losing animals whose lives have so closely paralleled our own would be like losing family, she writes. "And in some ways, we would lose a part of our own wildness. Without bears, the woods, and our stories, would be empty." — *Jake Buehler*

SLOWMOTIONGLI/ISTOCK/GETTY IMAGES PLUS

WHY I GIVE

Virginia Steel has read Science News for decades and has donated to Society for Science since 2019. She lives in a Bedford, Mass., retirement community where she edits a weekly newsletter and presents monthly nature education programs to fellow residents. "I look to Science News for inspiration as I create my monthly presentations," she says.

Steel is a Catalyst Circle donor who gives at least $10,000 annually. Her contributions support the Society's Advocate Program, which provides training, stipends and year-round support to mentors helping students from traditionally underrepresented backgrounds and low-income households enter science research competitions.

"I've known of Society for Science and Science News since I was 12 years old, getting Things of Science [science kits once sold by the Society] in blue boxes and doing all the experiments," Steel says.

"The Society still does crucially valuable work. I give to Society for Science in support of science literacy and science education outreach in underserved communities."

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JUNE 3, 2023

Magnetic muck-ups

A study of fragments from a Martian meteorite shows that the common practice of using magnets to identify meteorites can overwrite records of magnetic fields stored within the space rocks, ***Katherine Kornei*** *reported in "Searching for meteorites? Ditch the magnets"* (SN: 6/3/23, p. 5). Reader **C. R. Prahl** asked how scientists can know precisely a meteorite's source.

Scientists can determine a meteorite's origins by looking at the space rock's chemical makeup, **Kornei** says. As rocks form, tiny air bubbles often get trapped within them. Those air pockets sometimes chemically look nothing like Earth's atmosphere. For example, the chemical composition of the air pockets in the meteorite fragments used in this study was a great match for Mars' atmosphere. That's good evidence that the rocks originally formed on Mars, **Kornei** says.

Prahl also wondered whether the magnetic field records of the Martian meteorite could have been wiped instead by Earth's magnetic field as the rock entered the atmosphere.

Earth's magnetic field does rearrange the spins of electrons in a meteorite. But only a small fraction of those electrons are typically affected, **Kornei** says. That's because Earth's magnetic field is relatively weak. Magnets, however, typically produce much stronger magnetic fields that can rearrange the spins of most of the electrons within a meteorite. By studying a meteorite's magnetic properties, researchers can tell the difference between a meteorite that's simply been sitting on Earth's surface and one that's been exposed to a magnet, **Kornei** says.

Screwworm story time

In the 1970s, a "fly factory" that produced sterile screwworm flies was built to eradicate screwworms, a major livestock pest. Such efforts have helped North and Central America keep screwworms in check for decades, ***Nikk Ogasa*** *reported in an update to the 1973* Science News *article "Fly factory planned"* (SN: 6/3/23, p. 4). Reader **Howard Schneeberger** reminisced about playing a part in the screwworm eradication efforts 50 years ago. As the captain of a cargo plane, **Schneeberger** delivered sterile screwworm fly larvae to Puerto Rico. "The trip was timed so the larvae would hatch on our arrival," **Schneeberger** wrote.

"Each small cardboard box was about the size of a takeout hamburger box and had a cup of coagulated blood in the center surrounded by hundreds of maggots," **Schneeberger** recounted. "We had to keep the cargo compartment full cold to prevent them from hatching en route. Needless to say, many ... did hatch and we were grateful to arrive in San Juan." Upon touching down in Puerto Rico, the boxes of sterile larvae were transferred to helicopters and dumped throughout the countryside, **Schneeberger** wrote.

In the brain

In a clinical trial, microscopic bubbles and ultrasound waves opened the nearly impenetrable blood-brain barrier to help deliver a powerful chemotherapy drug directly into the brain. The method could lead to new treatments for people with brain cancer, ***McKenzie Prillaman*** *reported in "Ultrasound lets chemo into the brain"* (SN: 6/3/23, p. 10). Reader **Phil Chubb** asked if the method could help treat other brain diseases.

Researchers are looking into that question now, **Prillaman** says. Indeed, scientists are investigating whether the method could be used to deliver drugs in people with neurodegenerative diseases, including Alzheimer's and Parkinson's.

Clarification

"The original highfliers" stated that more than 75 percent of all life on Earth was extinguished by the asteroid that killed the dinosaurs (SN: 5/6/23 & 5/20/23, p. 26). It would have been clearer to say that more than 75 percent of species were extinguished.

Correction

"Oddball black holes" incorrectly stated that dwarf galaxies are about a trillionth the mass of the Milky Way (SN: 6/3/23, p. 24). Dwarf galaxies are about a hundred-thousandth to a millionth the mass of the Milky Way.

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These ancient flutes may have been used to lure birds of prey

Perforated bones excavated at an ancient settlement in northern Israel are the oldest known wind instruments found in the region. The small flutes could have been used to make music, call birds or even communicate over short distances, researchers suggest June 9 in *Scientific Reports*.

The seven instruments (five shown above, each from three viewpoints) were unearthed from the remains of stone dwellings at a lakeside site called Eynan-Mallaha, which was home to hunter-gatherers until about 12,000 years ago, says Laurent Davin, an archaeologist at the Hebrew University of Jerusalem. That suggests the flutes are at least that old as well.

All the flutes were made from the wing bones of waterfowl that spent winter months at the lake, Davin and colleagues determined. The largest (right) appears to be intact and is about 63 millimeters long. Microscopic analyses show that the finger holes were carved by humans and were not the result of gnawing by rodents or tooth marks left by predators.

The researchers used the wing bone of a modern-day female mallard to make detailed replicas of one of the flutes. When played, the instruments produced high-pitched sounds similar to the calls of the common kestrel and the Eurasian sparrow hawk, raising the possibility the instruments were used to lure birds. Evidence suggests the inhabitants of Eynan-Mallaha used the talons of these birds of prey as tools and may have worn them as ornaments, Davin says.

Although these are the oldest known wind instruments from the Middle East, older flutes made of bone and ivory have been unearthed in Germany (SN: 7/18/09, p. 13). —*Sid Perkins*

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