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ScienceNews

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Cosmic Misfits

Wandering black holes could hold secrets to the early universe

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COVER Big black holes may not always reside in the hearts of massive galaxies. *Alfred Pasieka/ Science Photo Library/ Getty Images Plus*

FROM TOP: B. RANDALL; BRYANT TURFFS; MARTIN BERNETTI/AFP VIA GETTY IMAGES

Charting a course for the future of *Science News*

When *Science News* got its start in 1921, our founders knew that the surest path to deliver the latest news of science was through the dominant media of the day: newspapers. Our first iteration, *Science News Bulletin*, was mailed to subscribing newspapers across the country. Soon, librarians, teachers and science buffs asked if they could subscribe too. To meet that demand, in March 1922 the editors launched a new consumer publication, *Science News-Letter* (SN: 3/26/22, p. 16). That was the first iteration of the magazine you read today.

And in 1924, they launched yet another new product: "Science News of the Week" scripts that announcers read on local radio stations. Radio had just debuted; the first commercial broadcast was in 1920. The editors were clearly eager to embrace this revolutionary technology. By the 1930s, we were on the air nationwide, partnering with CBS on the *Adventures in Science* show, featuring editor Watson Davis interviewing scientists about the latest discoveries.

If I could tell our editorial forebears that nowadays most people read *Science News* on their mobile phones, I bet they'd be fascinated by the technology and the possibilities for connecting people with science anywhere, anytime.

I'd explain that people can find our journalism not just through the magazine and website, but also via RSS feeds, Twitter and Facebook. Email newsletters bring the science straight to people's inboxes, and our YouTube channel draws more than 200,000 views a month. Video on a phone? Imagine that.

I'd also say that to better serve our varied audiences, we're expanding our efforts on Instagram and TikTok, where vertical videos are wildly popular with teens and young adults — the next generation of science fans. I'd note that we also have coverage tailor-made for young people and teachers, through our *Science News Explores* website and print magazine and the Science News Learning program, which delivers the latest news and educator materials to more than 5,000 schools across the United States.

And I'd say that while we don't know what new technology will disrupt the news industry next, we'll be ready for it. This summer, we're embarking on a strategic planning process that will help us chart our path forward for the next three to five years. We will continue to deliver top-quality journalism in written form, develop innovative new products and build a business model that sustains us through the ongoing turbulence of the media economy.

I'm as excited about the future of *Science News* as I'm sure those very first editors were. It wouldn't be possible without you, our loyal readers. Stay tuned!

— Nancy Shute, Editor in Chief

Science News has gone through many changes in the last 100 years.

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SOCIETY FOR SCIENCE

Excerpt from the June 2, 1973 issue of *Science News*

50 YEARS AGO

Fly factory planned

A "fly factory" whose product is living flies—300 million of them every week—is to be built in southern Mexico to help eradicate screwworms, a major livestock pest.... They feed on living host animals through open wounds or sores. The fly factory will raise millions of screwworm flies, sterilize them with radiation and release them from low-flying aircraft to mate with native flies, producing eggs that will not hatch.

UPDATE: Mexico and the United States joined forces to finally purge North America of the screwworm scourge. The fly factory opened in 1976 and legions of sterilized screwworm flies were released in both countries, including along Mexico's Isthmus of Tehuantepec to obstruct northerly incursions. The eradication program was so successful that it spread to Panama. By 2006, the United States, Mexico and Central America declared themselves rid of the pest. Brief outbreaks still occur, but sterile flies remain an effective remedy. The tactic has inspired more recent efforts to control mosquitoes and other harmful pests (*SN: 9/12/20, p. 6*).

Marine biologist Jessica Pate swims alongside an oceanic manta ray. Pate's team recently found the first known manta ray nursery in Florida.

BRYANT TURFFS

THE SCIENCE LIFE

Meet the scientist on a mission to save Florida's rays

The first time Jessica Pate swam beside a manta ray off Florida's southern coast, the 2.5-meter-wide fish flipped belly-up and slowed to watch her. "I was kind of obsessed after that," Pate says. The marine biologist was so hooked that she founded the conservation group Florida Manta Project and has dedicated the last seven years to studying mantas and their kin.

Pate's work is paying off. Her team has since discovered the first known manta nursery in Florida's waters. And it's now clear that an elusive cousin of mantas—the sicklefin devil ray—also calls the western Atlantic home, the scientists report April 24 in the *Journal of the Marine Biological Association of the United Kingdom*.

Mantas and devil rays are both mobula rays, a genus that includes 11 species, nearly all of which are endangered. That's partly because these rays have slow reproductive cycles, Pate says, and partly because the animals are susceptible to injury from boat strikes or entanglement in fishing gear.

Before Pate began her work with oceanic mantas (*Mobula birostris*) off Florida, there was only one published study of sightings in the region. "There's just so little awareness that manta rays are present," she says, which makes conservation efforts difficult.

So Pate conducts aerial drone surveys, gathers accounts of citizen sightings and spends countless hours tagging, tracking and measuring the creatures. In 2020, her team reported the first known manta ray nursery in the western Atlantic—and the third nursery observed globally. Unfortunately, it's located in a heavily populated coastal area off South Florida, where recreational fishing is popular.

The Florida Manta Project has since launched an outreach campaign to build awareness of fishing best practices, such as keeping an eye out for mantas and reeling in lines until they've safely passed by. Sometimes, though, what appears to be a manta might be one of its relatives.

In 2018, a diver sent Pate a photo of a manta that turned out to be a sicklefin devil ray (*M. tarapacana*)—the first confirmed sighting of this species in the western Atlantic Ocean. Pate's follow-up analysis of aerial survey and fisheries observation data collected from 1996 to 2022 turned up 361 sicklefin devils in the western Atlantic and Gulf of Mexico.

Knowing that sicklefin devils populate the region, scientists can start filling in knowledge gaps about this species. Pate hopes that her team's continued efforts will help protect mantas and their kin by making the rays "as iconic and recognizable as manatees and sea turtles."

—*Brianna Randall*

TEASER

A new vegan leather can heal itself with fungi

A ripped leather jacket that can repair itself instead of needing to be replaced could one day be a reality, if the jacket is fashioned from fungus.

Scientists made a self-healing leather from mushrooms' threadlike structures called mycelium, building on past iterations of the material to allow it to fix itself. Described April 11 in *Advanced Functional Materials*, the novel approach could offer inspiration to researchers trying to break into the vegan leather market.

Bioengineer Elise Elsacker of the Vrije Universiteit Brussel and colleagues grew mycelium in a nutrient-rich soup. Taking skin from the liquid's surface, cleaning it with mild chemicals and drying it at 40° Celsius created a leatherlike material. Embedded in the leather were dormant chlamydospores, tiny nodules that can spring to life and grow more mycelium under the right conditions. After punching holes in the leather, the team doused it in nutrient broth to revive the spores. New mycelium regrew over the punctures, and healed areas were just as strong as undamaged areas. But the repairs left visible scars.

Before fungal frocks can become wardrobe staples, the team needs to find a way to control spore growth. That way, if a jacket gets rained on, it won't grow or potentially sprout mushrooms. —*Jude Coleman*

This vegan leather contains dormant fungal spores. When the leather gets a hole (top), spores can be revived to mend it (middle). But repairs remain visible (bottom).

FOR DAILY USE

Searching for meteorites? Ditch the magnets

It's time to drop the magnets, meteorite hunters. The commonly used method for identifying space rocks can destroy scientific information. Touching even a small magnet to a meteorite can erase any record the rock might have retained about the magnetic field of its parent body, researchers report in the April *Journal of Geophysical Research: Planets*. The concern isn't theoretical: Multiple fragments of the oldest known Martian meteorite appear to have had their magnetic memories wiped.

Planetary scientist Foteini Vervelidou of MIT uses meteorites from Mars to study its ancient past. Just a couple hundred are known to exist. Rarer still are specimens that carry imprints of the Red Planet's magnetic field, which collapsed about 3.7 billion years ago (SN: 9/19/15, *p.* 5). The oldest known Martian meteorite, which dates to about 4.4 billion years ago, therefore presents an "amazing chance to study the magnetic field," Vervelidou says. However, such opportunities can be readily squandered.

"Just about everyone wants to stick a magnet on the side of a potential meteorite," says Melinda Hutson, a meteoriticist at Portland State University in Oregon who didn't partake in the work. But doing so can rearrange the spins of the rock's electrons, Vervelidou and colleagues found. Tests with meteorite stand-ins showed that the rearrangement overwrites the imprint of a previous magnetic field, a process called remagnetization. And it may occur frequently. Of nine chunks thought to have broken off from the same oldest known meteorite from Mars, all had been remagnetized.

It's possible to identify a meteorite without erasing its memory. Vervelidou uses a susceptibility meter, which measures how an object would respond to a magnetic field. Fortunately for meteorite hunters, portable ones are available. —*Katherine Kornei*

HOW BIZARRE

This elephant peels only spotted bananas

Do you peel bananas from the top or bottom? One elephant does it a third way.

When handed a slightly browning banana, Asian elephant Pang Pha at Zoo Berlin will use her trunk to break the fruit, shake the pulp onto the ground, discard the peel and then shove the pulp into her mouth, researchers report in the April 10 *Current Biology*. The rare behavior could help shed light on how the animals learn complex movements.

When a zookeeper told neuroscientist Lena Kaufmann of Humboldt University of Berlin that one of the elephants peeled bananas, she decided to test it out for herself. For weeks, Kaufmann and colleagues couldn't get Pang Pha to replicate the behavior. That's because how the elephant eats depends on fruit ripeness.

Pang Pha ate green and yellow bananas whole, peel and all. It was only when Kaufmann offered the pachyderm a brown-spotted banana (shown below) that she revealed her peeling prowess. But the fruit can't be too brown. Pang Pha rejected completely brown bananas, throwing them aside. Around other elephants, she ate spotted bananas whole except for the last one, which she usually peeled.

Pang Pha may have gained the ability by observing human caretakers peel bananas. But elephants learning behaviors from people is very rare. And none of the zoo's other elephants, including Pang Pha's daughter, peel bananas. That suggests the skill isn't easily learned from elephant to elephant. —*Nora Bradford*

FROM TOP: E. ELSACKER *ET AL*/*ADVANCED FUNCTIONAL MATERIALS* 2023; L. KAUFMANN

Watch a video of an elephant peeling a banana at **bit.ly/SN_PachydermPeels**

News

GENETICS

The pangenome makes its debut

A new blueprint better reflects humankind's genetic diversity

Researchers have compiled the DNA profiles of 47 people into a human pangenome. The work reveals levels of human genetic diversity never seen before.

BY TINA HESMAN SAEY

More than 20 years after people got a peek at the first draft of the human genome, researchers have unlocked the next level: the human pangenome.

In a study published online May 10 in *Nature Biotechnology* and three studies published in the May 11 *Nature*, scientists describe the achievement and new biology that they are learning from it.

The more complete genetic instruction manual, which includes almost all the DNA of 47 people, will allow scientists to explore types of variation that could never be examined before, such as large chunks of duplicated, lost or rearranged DNA. That work could possibly reveal more details about the genetic underpinnings of various diseases and disorders, such as heart disease and schizophrenia.

The pangenome adds 119 million DNA bases—the information-carrying units of DNA—not present in the existing human genome, called the reference genome. Much of that DNA is in never-before-explored parts of the genome containing multiple copies of genes that are duplicated from originals elsewhere in the DNA.

Those duplicated parts are changing faster than nonduplicated portions of the genome, says Evan Eichler, a human geneticist at the University of Washington in Seattle and a leader of the Human Pangenome Reference Consortium. When Eichler and colleagues examined the types of variants that arise in these duplicated regions, they found "a very strong signal that the mutations that are occurring are fundamentally different from [mutations in] the rest of the genome," he says.

Some of these fast-changing duplicated regions are implicated in humans' large brains and other traits that set us apart from primate relatives, while other regions have been implicated in certain diseases.

Conversely, another study found that the very short arms of certain chromosomes, including chromosomes 13, 14 and 21, are becoming more alike as they swap DNA. Those short arms are important because they contain genes for making scaffolding for ribosomes, the machinery responsible for building every protein in the body.

But perhaps the biggest achievement of the project is that it is finally giving researchers a more complete look at the full spectrum of human genetic diversity.

The human reference genome released two decades ago derives mostly from one man, but is a patchwork quilt of more than 60 people's DNA. Though it has been restitched and added to over the years, the quilt still has holes. The first fully complete human genome, announced last year, contains all of the DNA of each human chromosome (SN: 4/23/22, p. 6). Except that genome wasn't from a person. It came from an unusual type of tumor that arose from a sperm fertilizing an empty egg. The genetic data from such tumors represents "not even one individual. It's from one half of one individual," says Timothy O'Connor, a human geneticist at the University of Maryland School of Medicine in Baltimore who isn't involved in the pangenome effort.

The pangenome is from actual people and contains the nearly complete DNA profiles of 47 individuals from across the world. That diversity "helps us to understand ourselves as a single human species, as a single human race," O'Connor says.

In the past, genetics research has been criticized for relying too heavily on DNA from people of European heritage. Studying just one population of people could mean missing genetic variants that have arisen in specific populations, O'Connor says. The pangenome "allows us to assess that population-specific variation in a much more detailed way. And hopefully, that will then lead to greater insight into the biology of everyone," he says.

Although the pangenome is a great first step to better represent all human genetic diversity, a lot more variation needs to be added for it to "really, truly be representative of everyone," O'Connor says. Latin Americans and Indigenous Americans are underrepresented, he notes, and there's nobody included from Oceania.

More diversity is coming, human geneticist Karen Miga of the University of California, Santa Cruz said in a May 9 news conference. The consortium plans to raise the total to 350 genomes by mid-2024.

In the meantime, new technologies have allowed researchers to examine types of genetic variants that have been difficult to study before. Duplicated regions were particularly challenging because scientists previously could read only short pieces of DNA. There was no way to tell where in the vast puzzle of the human genome those nearly identical pieces fit. Newer "long-read" DNA-sequencing technology makes it possible to decipher stretches of DNA many thousands of bases long. The ability to assess where some people have extra DNA and others are missing DNA, called structural variants, adds a more nuanced view of human genetics, O'Connor says.

For instance, Eichler's group mapped one version of a gene that has converted another copy into its own image. These conversions are surprisingly common: On average, each study participant had more than 2,000 instances across many genes.

Scientists hope the pangenome will help identify genetic changes that contribute to diseases and find treatments. But it may take a while before the data make a difference in medical clinics, Eichler says. ■

HIROSHI WATANABE/STONE/GETTY IMAGES PLUS

EARTH

Eruptions may have helped life emerge

Volcanic lightning seeded Earth with a key nutrient, scientists say

BY BAS DEN HOND

Millions of years ago, giant, explosive volcanic eruptions in what's now Turkey and Peru each deposited millions of metric tons of nitrate on the surrounding land. That nutrient may have come from volcanic lightning, researchers reported April 24 at a meeting in Vienna of the European Geosciences Union.

The discovery adds evidence to the idea that, early in Earth's history, volcanoes provided some of the materials that made it possible for life to emerge, says volcanologist Erwan Martin of Sorbonne University in Paris.

Nitrogen is an essential ingredient in biological molecules, such as proteins and DNA. The element also makes up about 78 percent of the atmosphere, primarily existing as molecules of two tightly bound nitrogen atoms. Only when these atoms are separated will they react with other elements and create forms of nitrogen useful to life, such as nitrate.

Some microbes can tease apart the nitrogen molecules and provide "fixed nitrogen" to plants and fungi. Human chemists can do it too, creating fertilizer. But before life could start, some nonbiological process must have been at play.

Lightning is the obvious candidate, Martin says. The extremely energetic electric discharges can tear apart nitrogen molecules, freeing up the atoms to combine with oxygen to form nitrogen oxides and, eventually, nitrate.

The lightning in thunderstorms, brought about by ice particles colliding and charging, separates nitrogen molecules every day, but at low rates and spread out over large areas. Volcanic plumes, in which dust particles do most of the colliding and charging, can provide localized lightning at staggering intensities. For instance, during one day of the 2022 eruption of Hunga Tonga-Hunga Ha'apai volcano in Tonga, there were about 400,000 discharges (*SN: 1/28/23, p. 10*).

But even such large amounts of lightning create relatively small amounts of nitrate. Huge eruptions — the kind that happen only every 100,000 years or so — could create much more. The idea that these rare events could produce and deposit a lot of nitrate is not new, Martin says, but nobody had actually looked at the nitrogen content of deposits from these eruptions until now.

Martin and colleagues sampled outcrops in Turkey and Peru linked to 10 enormous eruptions that happened between 20 million and 1 million years ago. The relatively dry climate of the locations helps ensure that any water-soluble nitrate that formed long ago would not have all leached out by now.

Nitrate that the team found contains oxygen isotopes in a similar proportion to the three types of oxygen isotopes that make up ozone molecules in the air. This shows that the compound was formed in the atmosphere and not by some process on the ground, the researchers say.

Based on their sampling, the scientists estimate that each eruption on average deposited about 60 million tons of nitrate.

Life may have begun roughly 3.7 billion years ago, long before the eruptions that Martin's team studied (*SN: 4/1/17, p. 6*). Still, Earth's early years were full of extreme volcanism. And some researchers think that lightning over volcanic islands may have played a role in the emergence of life, before even the continents were fully formed. On young Earth, Martin says, similar amounts of nitrate as those estimated in the new study could have been produced on such islands, long since submerged.

The study's concept is interesting, says marine chemist Jeffrey Bada of the Scripps Institution of Oceanography in La Jolla, Calif. But it doesn't account for the different composition of the atmosphere at the time that life first came on the scene, he says.

"In today's world, lightning on volcanic islands produces copious amounts of nitrogen oxides," Bada says. "But in the early Earth, when the atmosphere had little oxygen in it, the product would have been probably ammonia."

Martin notes that volcanic plumes contain a lot of water and oxygen-rich compounds that come from magma. In those early days, eruptions could have supplied some of the oxygen needed to make nitrate, he says.

But even if ancient volcanic lightning formed mostly ammonia, "it's still [a form of] nitrogen available for life," Martin says. "These are still things that need to be studied." ■

MARTIN BERNETTI/AFP VIA GETTY IMAGES

This 2015 volcanic eruption in Chile generated intense lightning. Such strikes free up nitrogen atoms in the air to react with other elements and make compounds that living organisms can use.

ASTRONOMY

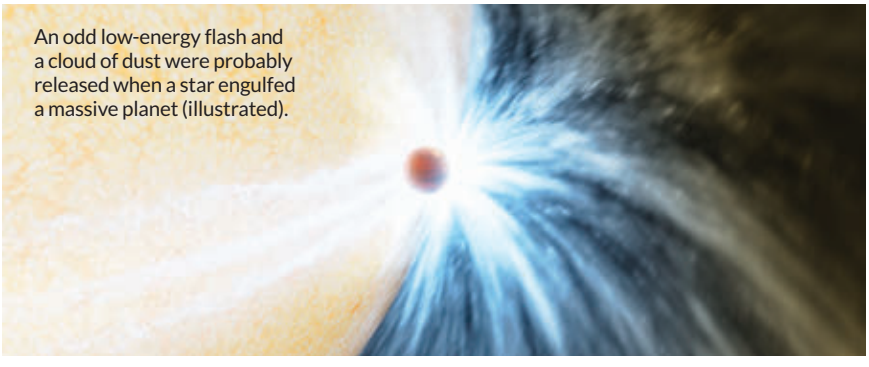
Scientists catch a star eating a planet

A burst of light and a cloud of dust gave away the planetary meal

BY JAMES R. RIORDON

A dusty belch is all that remains of a planet that was gobbled up by a star about 10,000 light-years from Earth. It marks the first time anyone has seen a star in the act of eating a planet.

Two telescopes captured a brief burst of light that was probably caused by a star swallowing a planet about 10 times as massive as Jupiter, scientists report in the May 4 *Nature*. Many planets, including Earth, are destined for similar ends.



An odd low-energy flash and a cloud of dust were probably released when a star engulfed a massive planet (illustrated).

"Planetary engulfment has been predicted for a very long time," says Kishalay De, an astrophysicist at MIT. "It was certainly exciting to realize we had found one."

De had been searching for pairs of stars orbiting each other. He used data from the Palomar Observatory in California to look for spots in the sky where bright lights suddenly appear. Such fluctuations can be a sign of stars coming close enough together that one will suck matter from the other (SN: 3/8/14, *p.* 8).

One event from 2020 stood out. A spot of light rapidly got about 100 times as bright as it had been. The increase could have been the result of two stars merging. But a second look by NASA's NEOWISE infrared space telescope suggested otherwise, De says.

Data from that observatory showed that the total amount of energy the flash released was just one-thousandth what it would have been if two stars had merged. What's more, chilly dust surrounded the mash-up instead of hot plasma that would normally indicate a merger among stars.

Assuming the event was a merger of some kind, the low energy suggested that one of the objects was a giant planet rather than a star, De and colleagues say. As the parent star noshed on the planet, a stream of cold dust sailed away like cosmic breadcrumbs from a stellar snack.

Planet-devouring stars are probably relatively common in the universe, says astrophysicist Smadar Naoz of UCLA. But the evidence has been circumstantial, Naoz says. Until now, astronomers have seen only signs of stars preparing for

ASTRONOMY

Fleeing black hole may be a galaxy

A new analysis raises questions about a starry wake's identity

BY LIZ KRUESI

A trail of starlight thought to indicate a runaway supermassive black hole may be something much more mundane: a spiral galaxy seen edge on.

In February, astronomer Pieter van Dokkum of Yale University and colleagues reported spotting a line of stars near a compact galaxy in Hubble Space Telescope images. The researchers' analysis suggested that three galaxies had interacted and merged, kicking a supermassive black hole out of its host galaxy (SN: 4/8/23, *p.* 11). The black hole then traveled through a nearby gas cloud, the scenario goes, triggering the formation of stars in a line that points toward the home galaxy and revealing the black hole's madcap escape.

But other researchers have been skeptical, with some suggesting that the scenario is unnecessarily complex to explain the linear feature. "We decided to explore what we thought was the most simple explanation," says astronomer Ignacio Trujillo of the Instituto de Astrofísica de Canarias in La Laguna de Tenerife, Spain.

Trujillo was inspired by a data plot in the original study, which compared the velocities of the stars in the linear feature with their positions, a comparison known as a velocity curve. To him, it looked like a spiral galaxy's plot of its pinwheel rotation, where the stars in the galactic disk all move at nearly the same speed. That, combined with van Dokkum and colleagues' estimate of the feature's mass — hundreds of millions of suns, which was surprisingly large for a simple line of stars — implied that the object is actually a spiral galaxy viewed on its edge, Trujillo says.

So he and colleagues compared characteristics of the linear feature with those of a well-studied spiral galaxy called IC 5249, which astronomers know is viewed edge on from Earth. The team looked at the objects' masses, surface brightnesses and general motions of stars. The properties of the galaxy and linear feature matched closely, the researchers report in a paper that was posted online April 25 at arXiv.org and will appear in *Astronomy & Astrophysics*.

The current evidence "is not conclusive either way," says Christopher Conselice, an astrophysicist at the University of Manchester in England who was not involved in either study. "A black hole being ejected from a galaxy would be

K. MILLER AND R. HURT/IPAC/CALTECH

a snack or debris from a presumed meal.

Naoz has pondered ways in which stars might gobble up planets. A star in the prime of life might consume a planet that wanders too close by in its orbit, she says. A dying star, on the other hand, will swallow a planet as the star swells to become a red giant. The star in the new study is in the early stages of becoming a red giant.

"One of the things that I found in the paper that I really liked was the detective work," Naoz says. The researchers pieced together evidence from multiple telescopes to confirm the star expanded outward to eat a planet.

There's a lot that's still mysterious about stars munching on planets, De says. But planned observatories with large infrared cameras should let astronomers look for bright, long-lived emissions that might reveal more planet-eating stars, he says.

Our sun will turn into a red giant and consume Earth in about 5 billion years. Because Earth is less massive than Jupiter, "the effects will certainly be more subdued," De says. "Finding Earthlike engulfments will be challenging, but we are actively working on ideas [for how] to identify them." ■

really cool," Conselice says. "But I think the simple explanation is that it's either an edge-on galaxy, or some kind of filament or tidal debris" left over from some previous galaxy interaction.

Van Dokkum still favors the black hole scenario, in part because of one new image. In the original Hubble images, the linear feature merely points toward a compact galaxy. In a new ultraviolet image, from the Very Large Telescope in Chile, "you start to see that this feature is actually connected to the galaxy," which strengthens the runaway black hole theory, he says.

Trujillo and colleagues suggest that the edge-on spiral galaxy and compact galaxy are independent structures coincidentally close to each other from our viewpoint.

The debate's resolution may have to wait at least until this summer when better imagery from Hubble arrives. ■

MATTEO FADEL

QUANTUM PHYSICS

Crystal helps Schrödinger's cat scale up

Jiggling atoms form an imaginary quantum feline with heft

BY EMILY CONOVER

In keeping with the grand tradition of tubby cats, a newly created quantum "cat" is particularly massive — at least for the quantum realm.

Scientists put a jiggling piece of sapphire crystal in what's known as a "cat state," in which an object exists in two different states simultaneously. It's a situation reminiscent of physicists' favorite imaginary feline, Schrödinger's cat, known for being alive and dead at the same time.

The new sapphire cat is a relatively hefty 16 micrograms, physicists report in the April 21 *Science*. That's close to half the mass of an eyelash and more than 100 trillion times the mass of cat states previously created with molecules. "We've reached a new regime where quantum mechanics apparently does work," says physicist Yiwen Chu of ETH Zurich.

In a quantum parable dreamed up in the 1930s by physicist Erwin Schrödinger, a cat is trapped in a box and, due to quantum effects, winds up alive and dead at the same time (SN: 6/25/16, *p.* 9). This paradoxical scenario doesn't happen in the real world. While quantum particles are capable of existing in two distinct states simultaneously — what's called a superposition — those effects wash out for cat-sized stuff.

Quantum effects are typically confined to atoms, molecules and the like. The everyday world visible to human eyes doesn't exhibit quantum properties. Scientists can coax certain tiny objects to display quantum features (SN: 5/26/18, *p.* 6). But scientists don't fully understand the border between the quantum and nonquantum realms.

"We really have only just begun to understand that intermediate regime," says Benjamin Sussman, a quantum physicist at the University of Ottawa in Canada who was not involved with the work. "It's of really profound interest to see how these quantum systems scale and how they behave."

Cat states are a special variety of quantum behavior that come close to re-creating Schrödinger's idea. They are superpositions of two states that are distinct according to the classical physics that describes the everyday world — like an alive or dead cat — rather than two states that exist only in the quantum domain, such as the energy levels of an atom.

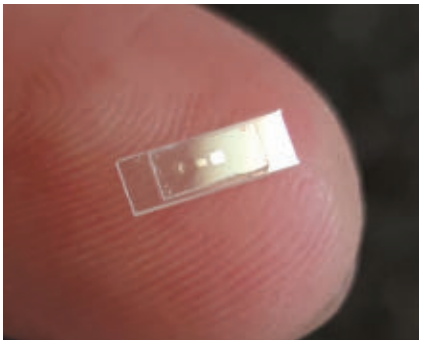
In the new experiment, the researchers jiggled a portion of a sapphire crystal in such a way that its atoms each moved in two directions at once. That distinction captures the spirit of Schrödinger's cat, Chu says.

The jiggling was confined within a sliver of the crystal consisting of 100 million billion atoms. That's large enough that, if extracted from the rest of the crystal, the sliver would be visible to the naked eye, Chu says.

Still, the oscillations of the atoms were tiny, about a millionth of a billionth of a millimeter — not exactly the scale of everyday objects. Other demonstrations of cat states have shown much larger spatial separation, despite being made up of fewer atoms.

In future work, Sussman says he'd like to see the researchers scale up not only the mass, but also the size of the oscillations. "That's going to be really hard but will be really interesting." ■

In a sapphire crystal within a specially designed device (shown on a fingertip), scientists created a mimic of the dead-and-alive Schrödinger's cat, in which the crystal's atoms each jiggle in two directions simultaneously.



HEALTH & MEDICINE

Ultrasound lets chemo into the brain

The method shows promise for treating aggressive, lethal tumors

BY MCKENZIE PRILLAMAN

Cracking the code to brain cancer treatment might start with cracking the brain's protective shield.

Nearly impenetrable walls of jam-packed cells line most of the brain's blood vessels. Although this blood-brain barrier defends the organ from harmful invaders, it also prevents many medications from reaching the brain.

Now, in an early-stage clinical trial, scientists delivered a potent chemotherapy drug into the brain by temporarily opening its protective shield with ultrasound and tiny bubbles. The work, described in the May *Lancet Oncology*, could lead to new treatments for those with brain cancer.

Better treatments are especially needed for glioblastoma, a common and aggressive type of brain tumor. Even after surgical removal, masses tend to reoccur. Patients' average life span after diagnosis averages a little over a year.

"There's really no established treatment for when the tumors come back," says neurosurgeon Adam Sonabend of the Northwestern University Feinberg School of Medicine in Chicago. Patients with recurrent glioblastomas "don't have any meaningful therapeutic options."

After the initial tumor has been removed, patients typically receive a relatively weak chemotherapy drug that can bypass the brain's barricade. Stronger drugs could help destroy any lingering disease — if the medicines could break through the barrier.

Sonabend and colleagues turned to a method using ultrasound that has previously succeeded at briefly opening the barrier (*SN: 12/12/15, p. 15*). An intravenous injection of fluid fills a person's blood vessels with microscopic bubbles. Ultrasound waves then shake the bubbles, which pry open the densely packed vessel walls in the targeted brain area.

To examine safety and dosing of this delivery method, 17 people had their regrown tumors removed and an ultrasound device implanted in their skulls, adjacent to the remaining cavity. Patients then received between two and six rounds of treatment spaced three weeks apart.

During each session, participants were injected with bubbles for 30 seconds while receiving pulses of ultrasound waves for nearly five minutes. The waves penetrated nearly eight centimeters into an area of the brain encompassing the tumor cavity. Patients then got a 30-minute intravenous infusion of paclitaxel, a powerful cancer drug that typically can't access the brain.

Brain tissue zapped by ultrasound had nearly four times as much paclitaxel as tissue outside of the device's range, the team found. MRI scans revealed that the blood-brain barrier mostly closed within an hour. Overall, the delivery method and maximum dosage allowed by the U.S. Food and Drug Administration were well tolerated. Side effects included headache and confusion.

The technique might help extend the life spans of glioblastoma patients. It also could be used to treat other types of brain cancer, says pediatric radiation oncologist Cheng-Chia Wu. Testing will take time, says Wu, of the Columbia University Irving Medical Center in New York City. But this is a "good first step in the right direction." ■

Glioblastoma (green in this CT scan) is a type of brain cancer that is difficult to treat. A study shows how pairing ultrasound with microbubbles temporarily opens the brain's protective barrier, allowing a potent chemotherapy drug to access the brain.

DR P. MARAZZI/SCIENCE PHOTO LIBRARY/GETTY IMAGES PLUS

HEALTH & MEDICINE

Pausing a cancer drug appears safe

Breast cancer didn't return for most women trying to conceive

BY AIMEE CUNNINGHAM

For women who've had breast cancer and would like to have a child, taking a break from a common treatment to try for a pregnancy seems to be safe in the short term.

A clinical trial studied the effect of temporarily halting hormone therapy, also called endocrine therapy, which reduces the risk that breast cancer will return. After about three years, the incidence of recurring or new breast cancer among women who paused the therapy was nearly the same as in a group that did not, researchers report in the May 4 *New England Journal of Medicine*. It's the first study designed to assess the safety of a treatment break among women who wish to become pregnant.

The women in the study had hormone-positive breast cancer, which means that estrogen, progesterone or both hormones can promote the growth of the cancer. Roughly 80 percent of breast cancers are hormone positive, according to the National Cancer Institute. Hormone therapy drugs reduce the levels of these hormones in the body or block the interaction between the hormones and cancer cells that spurs growth (*SN: 7/2/11, p. 16*). The treatment is a staple for hormone-positive breast cancers and is recommended for five to 10 years.

But hormone therapy, which can cause birth defects, cannot be taken during pregnancy. For women of reproductive age who have had hormone-positive breast cancer and want to have a child, a five- to 10-year wait may be untenable.

More than 30,000 U.S. women ages 20 to 44 are expected to be diagnosed with breast cancer in 2023. Studies have shown that younger breast cancer patients are concerned about the effect of treatments on fertility. Doctors typically recommend the drug tamoxifen for premenopausal

women with hormone-positive breast cancer, but there is a reduced willingness to start or stick with the drug in this age group.

"This is obviously a really challenging position for these women to be in," says Nicole Christian, a breast surgical oncologist at the University of Colorado School of Medicine in Aurora who was not involved in the research. "They're being treated, hopefully cured of their breast cancer, and they are looking forward to their long, hopefully healthy lives, and for many of these women, having a family is a part of that life."

In the study, breast medical oncologist Ann Partridge of the Dana-Farber Cancer Institute in Boston and colleagues tested whether pausing hormone therapy to pursue pregnancy and then resuming would alter the reduction in cancer risk associated with the therapy.

The women in the study were 42 or younger, and almost all had had early-stage disease: small tumors and limited spread of the cancer. They had previously had surgery and been on hormone therapy for 18 to 30 months. Some participants had also had chemotherapy. The hormone therapy break was intended to last for about two years to give time for attempting pregnancy, delivering a baby and breastfeeding if desired.

A comparison group consisted of women of the same ages with hormone-positive breast cancer who had been participants in other hormone therapy trials. But these women had not taken a break from the therapy.

The incidence of new or recurring breast cancer after about three years was just under 9 percent for the 516 women who paused therapy and just over 9 percent for the 1,499 women in the comparison group. Of the nearly 500 women for whom there was pregnancy information, 317 had at least one live birth. A majority of women in the trial resumed the hormone therapy.

> "Cancer takes away so much control for people that this allows them to add back some element of control in terms of their planning for their future and that of their family."
>
> ANN PARTRIDGE

When treating breast cancer in women of reproductive age, one of the first things that comes up for many patients is whether they will be able to have children, says breast cancer surgeon Mary Gemignani of Memorial Sloan Kettering Cancer Center in New York City. Though longer-term data are needed, she says, "at least we know that, for this short term, [taking a break] appears to be safe."

The team plans to follow the women in the study for 10 years. For now, this initial data to support trying for a pregnancy is helpful to have, Partridge says. "Cancer takes away so much control for people that this allows them to add back some element of control in terms of their planning for their future and that of their family." ■

ANIMALS

Comb jelly has odd nervous system

Fused nerve cells hint at a different evolutionary path

BY JAKE BUEHLER

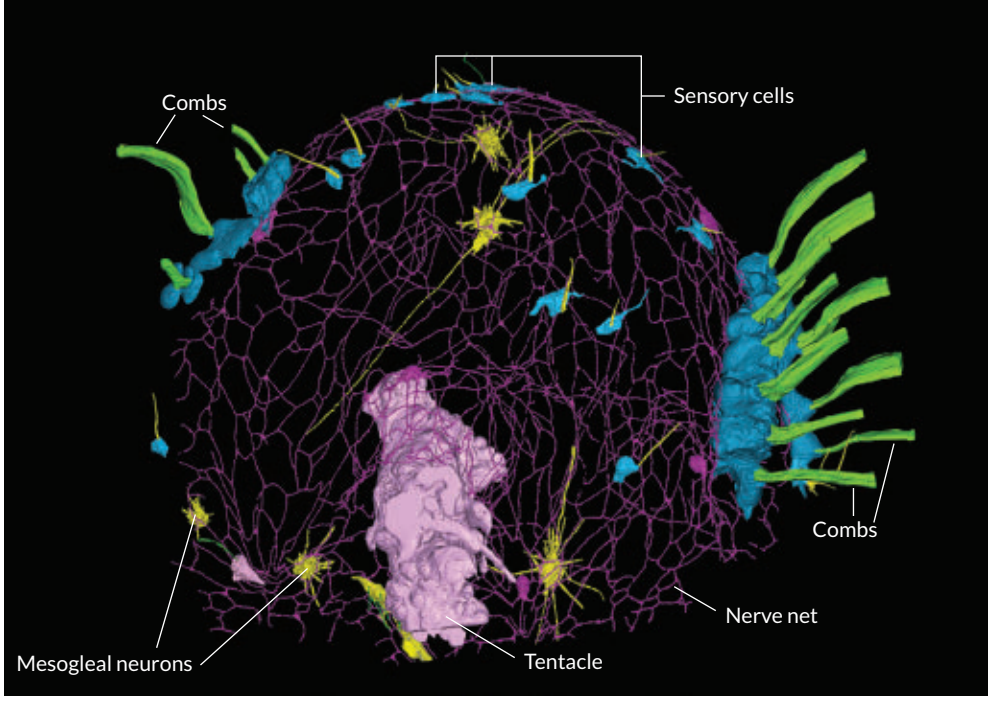
Shimmering, gelatinous comb jellies don't appear to have much to hide. But their mostly see-through bodies cloak a nervous system unlike that of any other known animal, researchers report in the April 21 *Science*.

In the nervous systems of everything from anemones to aardvarks, electric impulses pass between nerve cells, allowing for signals to move from one cell to the next. But the comb jellies' cobweb of neurons, called a nerve net, is missing these distinct connection spots, or synapses. Instead, the nerve net is fused together. Its long, stringy neurons share a cell membrane, a new 3-D map shows.

It's possible the bizarre tissue represents a second, independent evolutionary origin of a nervous system, says comparative neurobiologist Pawel Burkhardt of the University of Bergen in Norway.

Superficially similar to jellyfish, comb jellies get their nickname from the rows of beating, hairlike combs that the creatures use to swim. Also known as ctenophores, comb jellies make up one of the earliest branches on the animal tree of life, so their possession of a simple nervous system has been of particular interest to scientists studying how such systems evolved.

Studies of a sea walnut suggest it and other comb jellies have a unique nervous system.



This 3-D map of a sea walnut nervous system shows a synapse-free nerve net (purple) and two kinds of cells with synapses outside of the net: sensory cells (light blue) and mesogleal neurons (yellow).

Burkhardt, along with neurobiologist Maike Kittelmann of Oxford Brookes University in England and colleagues, examined a type of comb jelly called a sea walnut (*Mnemiopsis leidyi*) using electron microscopes. The resulting 3-D map of a 1-day-old sea walnut revealed the synapse-free fusion between five sprawling neurons that make up the tiny ctenophore's nerve net.

The traditional view is that the nervous system evolved once, hundreds of millions of years ago in the last common ancestor of all animals save sponges. As a result, all known nervous systems should have in common key structures—like synapses.

But the unique architecture of the comb jelly nerve net and the creatures' ancient position in the animal kingdom raise the possibility that the nervous system actually evolved twice, Burkhardt says. Further work on the development of comb jelly neurons is needed to help verify their evolutionary origin, he says.

The origins of animals' nervous systems are murky. Sponges—competitors for the title of most ancient animal group—don't have nervous systems, or muscles or vision proteins, for that matter. But mounting evidence suggests that ctenophores are even older than sponges (SN: 1/25/14, *p.* 16).

If comb jellies arose first, it "implies that either sponges have lost a massive number of features, or that the ctenophores effectively evolved them all independently," says paleobiologist Graham Budd of Uppsala University in Sweden.

If sponges emerged first, it's still possible that the comb jelly nerve net evolved independently rather than being inherited from a neuron-bearing ancestor and modified over time, Burkhardt says. Outside the nerve net, comb jellies have neurons with synapses. Mesogleal neurons in the gelatinous body layer may provide nutrients and structural support to the nerve net. And sensory cells may communicate with the nerve net to adjust the beating of the combs. The existence of neurons with and without synapses might mean that ctenophores are mosaics of two nervous systems of differing evolutionary origins.

Joseph Ryan, a bioinformatician at the University of Florida in Gainesville, doesn't think the results necessarily point to the independent evolution of a nerve net. Given how long comb jellies have been around, their nervous system may have started off with synapses and had plenty of time to evolve into something highly specialized, Ryan says.

Other animals, including a species of true jellyfish, may have fused nervous systems. Studying them in detail, along with nerve nets in other types of comb jellies, could determine just how unusual this synapse-free nervous system is. ■

FROM TOP: P. BURKHARDT AND M. KITTELMANN; ALEXANDRE JAN

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HEALTH & MEDICINE

Hair grays when stem cells get stuck

In mice, the cells must hustle to furnish follicles with pigment

BY TINA HESMAN SAEY

Hair might go gray when stem cells with wanderlust have their travels interrupted.

Stem cells involved in making the pigment that gives hair color behave much differently than other stem cells are thought to, researchers report in the April 27 *Nature*. Rather than staying put, melanocyte stem cells travel up and down mouse hair follicles all while oscillating between two different forms of maturity. But it's not the unusual behavior that leads to graying. It's when these stem cells stop their quirky ways that hair loses color.

That movement is strange behavior for stem cells, says hair follicle biologist William Lowry of UCLA. Stem cells usually settle into a niche, or compartment, dividing when they need to. "Their progeny go off and do interesting things … whereas the stem cells typically stay put," says Lowry, who coauthored a commentary about the work in the same issue of *Nature*.

Stem cells are immature cells that make more of themselves and give rise to cells that will mature to perform specific tasks. Melanocyte stem cells can become melanocytes, the cells that make melanin, the pigment that colors hair and skin.

Qi Sun and Mayumi Ito Suzuki, stem cell biologists at New York University Grossman School of Medicine, didn't set out to study gray hair. They wanted to know how melanocyte stem cells in hair follicles behave. The scientists had previously implicated such cells in skin cancer.

To understand these cells' life cycle, Sun watched a patch of hair follicles on a mouse over the mouse's lifetime. She saw melanocyte stem cells move from a compartment at the base of the follicle to the follicle bulge, then return to the base.

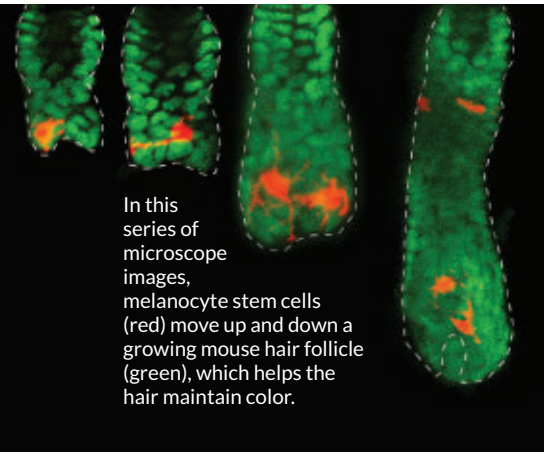
That isn't the only odd behavior. The stem cells mature into an intermediate form that ultimately gives rise to melanocytes. For other stem cells, there is no going back once they start maturing. But melanocyte stem cells can toggle between the less-mature and more-mature states.

That flexibility is key for hair color, the researchers report. Melanocyte stem cells must be in the intermediate state to migrate to the base of the growing hair shaft, where some develop into melanocytes that color hair. The less-mature state regenerates a pool of stem cells that can mature to touch up roots.

The stem cells must move because proteins that help control cell maturity and proliferation are found in different parts of the hair follicle. A protein called WNT that's made in the base causes stem cells to mature into melanocytes, the team found. But too much WNT kept the stem cells from reverting to their regenerative state.

As mice aged, or if the team plucked hairs to make them grow faster, worn-out stem cells became stuck in the hair follicle bulge. There they couldn't mature into the intermediate stage needed to travel to the base and form melanocytes, which led hair to turn gray. Getting stem cells moving and restarting the maturation cycle gave hair back its color.

This sort of cellular behavior may cause human hair to turn gray, says Rui Yi, a stem cell biologist at Northwestern University Feinberg School of Medicine in Chicago. But until scientists can observe human hair follicles over time, he says, it's not possible to say for sure. ■



In this series of microscope images, melanocyte stem cells (red) move up and down a growing mouse hair follicle (green), which helps the hair maintain color.

Q. SUN *ET AL*/*NATURE* 2023

NEUROSCIENCE

AI can help read people's minds

Pairing brain activity data with GPT decoded thoughts

BY LAURA SANDERS

Like Dumbledore's wand, a scan can pull long strings of stories straight out of a person's brain — but only if that person cooperates.

This "mind-reading" feat, described in the May *Nature Neuroscience*, has a long way to go before it can be used outside of sophisticated laboratories. But the result could ultimately lead to seamless devices that help people who can't talk or otherwise communicate easily.

"I thought it was fascinating," says Gopala Anumanchipalli, a neural engineer at the University of California, Berkeley who wasn't involved in the study. "It's like, 'Wow, now we are here already,'" he says. "I was delighted to see this."

The work also raises privacy concerns about unwelcome neural eavesdropping (SN: 2/13/21, *p.* 24).

As opposed to implanted devices that have shown recent promise, the new system requires no surgery (SN: 12/17/22 & 12/31/22, *p.* 8). And unlike other external approaches, it produces continuous streams of words instead of having a more constrained vocabulary.

For the new study, three people lay inside a bulky MRI machine for at least 16 hours each. They listened to stories, mostly from *The Moth* podcast, while functional MRI scans detected changes in blood flow in the brain. These changes are proxies for brain activity, albeit slow and imperfect measures.

With this neural data in hand, computational neuroscientists Alexander Huth and Jerry Tang of the University of Texas at Austin and colleagues were able to match patterns of brain activity to certain words and ideas that the people heard. The approach relied on a language model that was built with GPT, one of the forerunners that enabled today's AI chatbots (SN: 4/8/23, *p.* 24).

Once the researchers knew which brain activity patterns matched the words in the stories, the team could work backward, using brain patterns to predict new words and ideas. The process inched along in an iterative way. A decoder ranked the likelihood of words appearing after the previous word, then used the brain activity patterns to help pick a winner and ultimately land on the gist of an idea.

"It definitely doesn't nail every word," Huth says. The word-for-word error rate was actually pretty high, about 92 to 94 percent. "But that doesn't account for how it paraphrases things," he says. "It gets the ideas."

For instance, when a person heard, "I don't have my driver's license yet," the decoder spat out, "She has not even started to learn to drive yet." Such responses made it clear that the decoders struggle with pronouns, though the researchers don't know why.

Decoders could also roughly reproduce stories from people's brains in two different scenarios: as people silently told a rehearsed story to themselves, and as they watched silent movies. The fact that these situations could be decoded was exciting, Huth says, because "it meant that what we're getting at with this decoder, it's not low-level language stuff." Instead, "we're getting at the idea of the thing," he says.

The study "gives us a glimpse of what might be possible in the future," says Sarah Wandelt, a computational neuroscientist at Caltech who wasn't involved in the work.

Fast-moving advances in brain decoding can spur discussions of mental privacy, something the researchers addressed in the study. "We know that this could come off as creepy," Huth says. "It's weird that we can put people in the scanner and read out what they're kind of thinking."

But the team found that the new method isn't one-size-fits-all: Each decoder was quite personalized and worked only for the person whose brain data had helped build it. What's more, a person had to voluntarily cooperate for the decoder to identify ideas. If a person wasn't paying attention to an audio story, the decoder couldn't pick that story up from brain signals. Participants could thwart the eavesdropping effort simply by ignoring the story and thinking about animals, doing math problems or focusing on a different story.

"I'm glad that these experiments are done with a view to understanding the privacy," Anumanchipalli says. "We should be mindful, because after the fact, it's hard to go back and put a pause on research." ■

ANTHROPOLOGY

Deer tooth hid ancient human DNA

Genetic material can be extracted without damaging artifacts

BY BRUCE BOWER

A new, nondestructive way to recover ancient DNA has shown its potential for illuminating Stone Age people's lives.

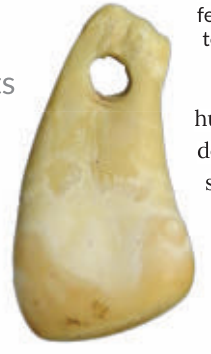
Genetic material extracted from a pierced deer tooth, possibly worn as a pendant, identifies its maker or wearer as a female *Homo sapiens* who lived roughly 20,000 years ago in Siberia, researchers report May 3 in *Nature*. Comparisons of DNA indicate that the female who handled the artifact was closely related to people who lived farther east in Siberia around the same time (SN: 10/4/14, p. 12).

Applying the technique to other finds could help clarify whether males and females alike made and used ornaments, says molecular biologist Elena Essel of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. "By extracting DNA from tools and ornaments directly, we can now begin to study the division of labor and the role of individuals in Pleistocene societies," Essel says.

The method could also help determine whether *H. sapiens* or Neandertals made bone pendants and stone tools dating to as early as about 45,000 years ago at several sites in southwestern Europe, says Carles Lalueza-Fox, an evolutionary geneticist at the Institute of Evolutionary Biology in Barcelona who was not involved in the work.

Researchers usually extract ancient DNA from powder drilled out of bones and teeth. But there is reticence to drill into and disfigure, or potentially destroy, rare and delicate finds such as pendants and other ornaments. *H. sapiens* and Neandertal DNA can also be isolated from artifact-bearing sediment, though that DNA cannot identify the sex or species of who handled specific tools or ornaments.

Essel and colleagues soaked a pierced deer tooth in a sodium phosphate solution for three 30-minute periods at each of four temperatures. The pendant — unearthed at Denisova Cave in Siberia in 2019 — started in a room temperature solution and moved to increasingly hotter solutions ending at 90° Celsius.



A new method isolated a Stone Age female's DNA from this pierced deer tooth without destroying the item.

Treatment at 90° C released human DNA that had penetrated deep into the pendant via extensive contact when it was made or used, the team says. Lower temperatures released DNA closer to the pendant surface that originated from surrounding sediment, including that of an elk species.

Analyses of the human and elk DNA estimated that the pendant is roughly 18,500 to 24,700 years old. That range is consistent with radiocarbon dates for burned wood unearthed near the pendant.

Neandertals and other Stone Age hominids called Denisovans periodically occupied Denisova Cave from nearly 300,000 years ago until about 55,000 years ago. Bone tools and ornaments previously found at the site indicate that *H. sapiens* visited as early as about 30,000 years ago.

Excavators in 2019 wore gloves and face masks to minimize contaminating artifacts with their own DNA. Scientists should use those measures and refrigerate dug-up objects to boost the new technique's odds of isolating ancient DNA, Essel says. ■

ANIMALS

Poop time capsule tells condor secrets

2,200 years' worth of raptor guano reveals a resilient population

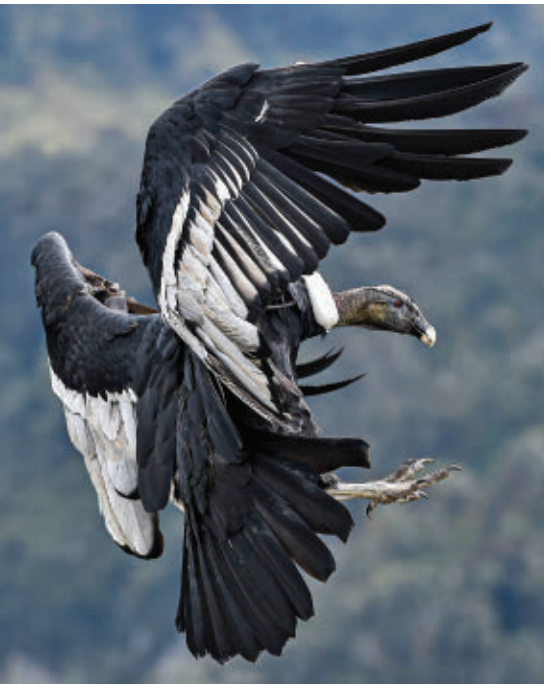
BY JAKE BUEHLER

For over 2,000 years, Andean condors have been nesting—and pooping—in the same cliffside grotto high in the Andes. This gargantuan pile of guano is now providing an unprecedented peek deep into the birds' past, revealing a surprising fidelity to raising chicks there even as the region changed dramatically.

Analyses of the deposit show that the condors overhauled their diet after European colonization of the Americas. The birds also mostly abandoned the site for a millennium, possibly due to volcanic eruptions, scientists report in the May 10 *Proceedings of the Royal Society B*.

"A material that could easily be ignored or discarded as waste can actually teach us quite a bit about how populations, communities and ecosystems respond to environmental change," says Rachel Reid, a paleoecologist at Virginia Tech in Blacksburg who didn't partake in the work.

The Andean condor is one of the world's largest flying birds. Preserved poop in a cliffside nest used by one population for thousands of years is giving scientists a peek into the birds' history.



LUIS ROBAYO/AFP/GETTY IMAGES PLUS

With a wingspan of over 3 meters and the heft of a toddler, Andean condors (*Vultur gryphus*) are the world's largest birds of prey. Found in the Andes and along the western coast of South America, the condors are also threatened with extinction. Only about 10,000 birds remain, and their numbers are declining.

Efforts to protect them hinge on understanding their behavior and ecology. But studying Andean condors can be challenging: The birds spend most of their time on the wing in remote mountain areas, which makes them difficult to capture and monitor, says paleoecologist Matthew Duda of Queen's University in Kingston, Canada.

In 2014, Duda's colleagues found a condor nest in Argentina's Nahuel Huapi National Park, tucked in a cliffside nook that turned out to be a ripe source of information. Researchers hiked an hour from the nearest road and rappelled 10 meters down along the cliff just to reach the nest. Unlike most condor nest sites, this one was sheltered from rain and snow. Instead of washing away, the droppings of successive breeding pairs built up layer upon layer, creating a dense, pale mound.

The preserved poop provided the "perfect opportunity for us to go back in time," Duda says. The scientists carved a 25-centimeter-deep slice out of the guano pile. DNA and ratios of specific chemicals in the sample hinted at what the condors ate over time. Other chemicals such as sulfur and potassium as well as preserved algae indicated changing environmental conditions linked to local volcanic eruptions.

Chemical dating of the samples revealed that the oldest layers in the deposit are at least 2,200 years old. That the condors have been using this nest for so long is "extremely surprising," Duda says. Most species of birds return to the same area to raise young, but rarely the exact same nest. If the condors keep coming back to the same nest, "it implies that where these birds are nesting is a super important part of their ecology and their behavior," he says.

The rate at which feces accumulated slowed drastically from 1,650 to 650 years ago, dropping from 0.08 centimeters per year to 0.003 cm/yr. That slowdown suggests condors largely left the site for a millennium, the team says. Around the same time, nearby volcanoes went through a volley of eruptions that would have blanketed the region's vegetation in heavy ash and driven herbivores away. With fewer carcasses to feed on, the condors may have glided away to scavenge in greener pastures and returned after the volcanic paroxysms ceased, Duda and colleagues suspect.

Similar connections between eruptions and declines in bird populations have previously been documented in guano records, says paleoecologist Dulcinea Groff of the University of Wyoming in Laramie. For instance, ancient excrement has linked dips in Gentoo penguin populations to volcanic strife (SN: 5/13/17, p. 17).

The condor guano also revealed a major diet shift, Duda's team says. Before Europeans colonized South America, Andean condors primarily scavenged the carcasses of beached whales and some native land mammals such as llamas and guanacos. In recent centuries, livestock like sheep and cattle have made up the bulk of the birds' diet.

And unlike modern condors, those that lived centuries ago didn't have elevated lead and mercury levels in their bodies. Lead can accumulate in scavengers that eat carcasses shot with certain types of ammunition. And mercury can accumulate from exposure to contaminated environments. Scavengers excrete some of the toxic metals in droppings, which can then be detected by scientists. The finding helps confirm that heavy metal contamination is a recent phenomenon.

Since the study is a snapshot of one nest, Duda's team plans to find similar condor nests to see whether the same patterns written in guano emerge. In the meantime, the birds' loyalty to this one nest site—even through volcanic mayhem—highlights just how crucial preserving such sites may be for condor conservation, Duda says. ■

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The Great (Shrinking) Salt Lake

Many of the world's saline lakes are in trouble, leaving locals with tough decisions about how to use the water

By Brianna Randall

In fall 2022, the Great Salt Lake hit its lowest water level since record keeping began. The lake's elevation sank to nearly six meters below the long-term average.

At Antelope Island State Park near Salt Lake City in the fall of 2022, three duck hunters dragged a sled across cracked desert sand in search of the water's edge. The birds they sought were bunched in meager puddles far in the distance. Just to the west, the docks of an abandoned marina caved into the dust and a lone sailboat sat beached amid sagebrush.

"Biologists are worried that we're on the brink of ecological collapse of the lake," says Chad Yamane, the regional director of Ducks Unlimited, a nonprofit that conserves, restores and manages habitats for North America's waterfowl, and a waterfowl hunter himself.

Last fall, the Great Salt Lake hit its lowest level since record keeping began. The lake's elevation sank to nearly six meters below the long-term average, shriveling the Western Hemisphere's largest saline lake to half its historic surface area. A report released in January by researchers at Brigham Young University in Provo, Utah, said that the Great Salt Lake will likely disappear within five years if water consumption continues at the current rate.

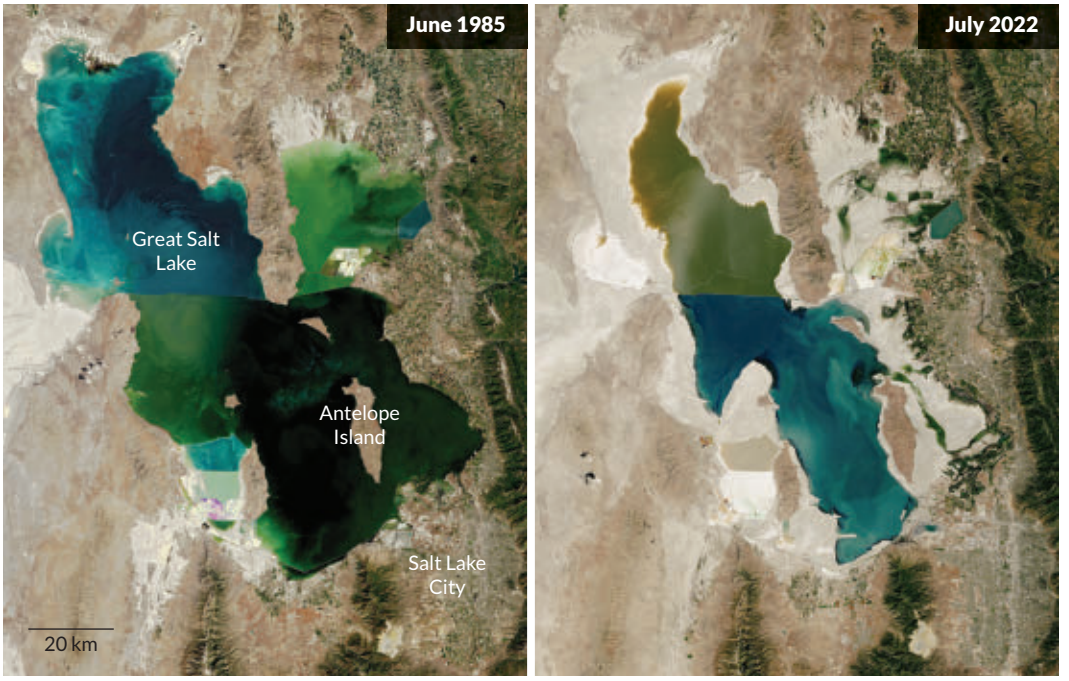
The lake's shrinking threatens to upend the ecosystem, disrupting the migration and survival of 10 million birds, including ducks and geese. But duck hunters aren't the only ones worried about the Great Salt Lake. The decades-long decline in lake level is raising alarm bells for millions of people who live in the region. As the lake recedes, its namesake city and surrounding communities face a host of potential problems.

The low lake level and increasing salinity threaten to disrupt economic mainstays like tourism, mineral extraction and brine shrimp harvesting—and are a sign that agricultural producers might be withdrawing more water than the region can support. Exposed sediments can become windblown and exacerbate air pollution, which can contribute to asthma, lung cancer and cardiopulmonary disease, among other health issues. "It concerns everyone," Yamane says. "It's now on the forefront of every Utahan's mind."

And the Great Salt Lake isn't unique. Many of the world's saline lakes are facing a double whammy: People are taking more water from the tributaries that feed the lakes, while a hotter, drier climate means it takes longer to refill them.

Saline lakes are found on every continent and include the Caspian Sea, the largest lake in the world, as well as the Dead Sea, the lowest in the world. Saline lakes are terminal lakes—they have no drain, meaning no rivers flow out of them. As water evaporates, salts are left behind from the minerals that wash off the surrounding landscape. Since they are usually found in arid landscapes that receive little precipitation, saline lakes are the first in line to be affected by long-term droughts, which are becoming more common with climate change.

At the same time, the people who live in these deserts are increasingly diverting freshwater for crops, homes and industry. Residents siphon water from streams and rivers into canals, pipelines or reservoirs before that water can reach the lakes. As



These processed satellite images show the surface area of the Great Salt Lake in June 1985, when the water level was unusually high thanks to heavy rain and snowmelt, compared with July 2022, when the level approached its record low.

OPPOSITE PAGE: C. YAMANE; THIS PAGE, BOTH: NASA EARTH OBSERVATORY IMAGES BY JOSHUA STEVENS, USING LANDSAT DATA FROM THE USGS AND DATA FROM THE NATIONAL WATER INFORMATION SYSTEM

the lakes shrink with less freshwater inflow, their concentration of salt increases.

Lake Poopó, a high-elevation lake in Bolivia that used to stretch 90 kilometers long and 32 kilometers wide, is now a salty mud flat. The Aral Sea in Kazakhstan and Uzbekistan, once the world's fourth largest lake, has at times in recent decades withered to a tenth of its historic 68,000-square-kilometer surface area. India's largest inland salt lake, Sambhar Salt Lake, is in severe decline, as is Africa's Lake Chad. Some saline lakes, like Nevada's Winnemucca Lake, dried up so long ago — the waters that fed them diverted to agricultural fields or for other human uses — that most people have forgotten they were ever wet.

The good news is Utahans still have time to halt or even reverse the Great Salt Lake's decline by using less water. Cutting agricultural and other outdoor water use by a third to half through a combination of voluntary conservation measures and policy changes could turn things around for the lake, the report says. If Utahans succeed, the Great Salt Lake can be a model for how to save other saline lakes around the world.

Why the decline?

Like other terminal lakes, the Great Salt Lake naturally rises or falls based on how much water falls into and evaporates out of its watershed each year. Most of the precipitation falls as snow in the winter, melting each spring to fill streams that eventually empty into the lake. Because it's surprisingly shallow for its size — an average of just over four meters deep — the Great Salt Lake fills or drains quickly. In the 1980s, for instance, a wet spell swelled the lake's surface area to nearly 6,000 square kilometers, more than twice as big as it is today.

Despite natural variations, the lake level is undisputedly trending downward. Hydrologic modeling by Wayne Wurtsbaugh and Sarah Null, both experts on the lake based at Utah State University in Logan, shows that if people had not started siphoning water from the rivers and streams in the region in 1847, when Mormon settlers led by Brigham Young arrived, the lake would be 3.4 meters higher than it is currently.

Today, three-quarters of the water consumed within the Great Salt Lake watershed is used to irrigate crops, mainly hay that feeds cattle that produce beef or dairy, the state's chief agricultural commodities.

Mineral extraction from the Great Salt Lake accounts for 9 percent of the water consumed. Companies divert briny water directly from the lake to extract its minerals and produce table salt, fertilizer or magnesium metal. Another 9 percent of the water consumed in the basin gets piped to cities to supply homes and businesses with water for indoor, outdoor and industrial uses. The remaining 8 percent is lost from evaporation from lakes and reservoirs in the basin.

Climate change has also contributed to the Great Salt Lake's record lows. The worst megadrought in 1,200 years, exacerbated by human-caused climate change, has ensnared the American Southwest for the last 22 years. The lake isn't refilling fast enough to keep up with the withdrawals upstream, while higher temperatures spur more evaporation from the lake.

People use more water to grow crops or keep lawns green when it's hot and dry, which Patrick Donnelly, a research scientist with the U.S. Fish and Wildlife Service in Missoula, Mont., likens to a climate tax on our waterways. An agricultural producer needs more water to grow the same crops in northern Utah than they did 15 years ago, Donnelly says.

Donnelly and colleagues measured changes in 18 saline lakes in the Intermountain West, including the Great Salt Lake, finding an average surface area decrease of 27 percent from 1984 to 2018. The surface area of wetlands in the region diminished by nearly half. The researchers reported in 2020 in *Global Change Biology* that these losses were driven largely by demands from irrigated agriculture coupled with higher temperatures that increase evaporation.

And the demand for freshwater is only increasing. Utah is the fastest growing state in the United States, and 80 percent of the people live in the Great Salt Lake watershed.

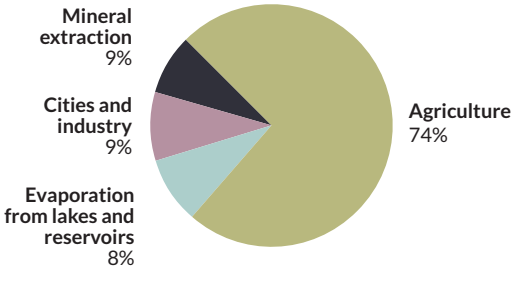
Donnelly says it's "unrealistic" to think that the Great Salt Lake region can stretch its water far enough to meet current and increasing demands. He points to a proposal to further dam and divert the Bear River — the tributary that provides over

H_2O whereabouts

The vast majority of water consumed in the Great Salt Lake watershed, based on estimates from 2020–2022, goes toward agriculture, with mineral extraction, cities, industries and evaporation accounting for smaller proportions.

SOURCE: B.W. ABBOTT *ET AL*/ BRIGHAM YOUNG UNIV. 2023

Proportion of water consumed for various uses



C. CHANG

A marina near Antelope Island northwest of Salt Lake City sits high and dry in 2022, when the Great Salt Lake water level hit a record low.

B. RANDALL

half of the Great Salt Lake's freshwater and is already riddled with canals, ditches and reservoirs—to supply growing communities in Utah. The project would lower the level of the Great Salt Lake by more than a meter and a half and push salinity to over 22 percent, threatening the lake ecosystem, Wurtsbaugh and Null reported in the book *Great Salt Lake Biology*, published in 2020.

Consequences of a dry lake

The region is already feeling the consequences of a shrinking lake. Mineral extraction industries are finding it increasingly difficult to get water to their ponds and processing plants. Some ranchers worry they won't be able to take their full allotment of irrigation water from the lake's freshwater tributaries. Even Utah's famous ski resorts feel the impact: An estimated 5 to 10 percent of the fluffy powder that draws millions of tourists to the area's slopes comes from snowfall triggered by the lake's relatively warm waters.

If the Great Salt Lake dries completely, the consequences become much more dire. Owens Lake in Central California offers an example of what happens when saline lakes are drained for human water consumption. It went dry in 1926, just 13 years after the Los Angeles Department of Water and Power diverted the Owens River into a 375-kilometer-long aqueduct to supply water to Southern California. This engineering feat turned fertile farmlands into an eerie dust bowl and caused health problems for residents in nearby communities.

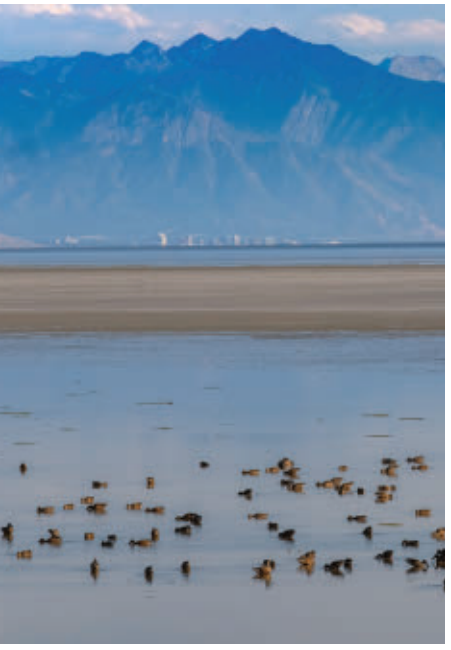
Once a lake bed is exposed, winds kick up ferocious dust storms. Owens Lake has been among the largest sources of dust pollution in the nation. The City of Los Angeles has spent more than $2.5 billion mitigating the dust through projects at the lake bed such as shallow flooding, seeding and planting vegetation, spreading gravel or tilling the ground.

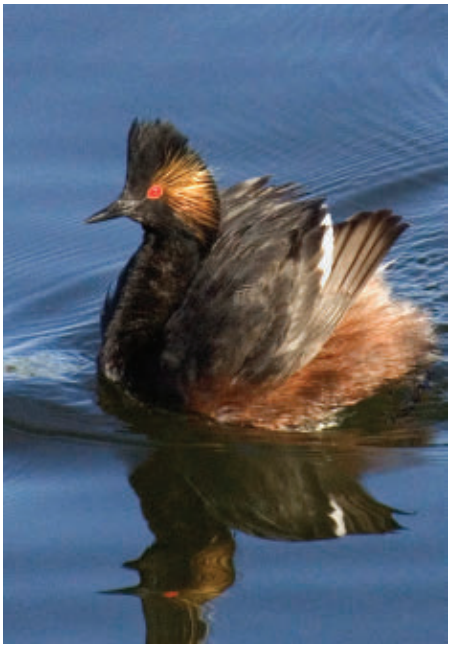
This is sobering news for Salt Lake City, which had at least seven times as much lake bed exposed last fall as Owens Lake. "In the summers when we get a strong south wind, you can literally watch a cloud of dust coming off the lake where the lake bed has been exposed because of the low receding water," Yamane says.

Sediments at the bottom of saline lakes also collect a slew of pollutants from human activities, such as chemicals from urban and agricultural runoff and toxic mine waste. Historical mining and smelting around the Great Salt Lake, for example, deposited heavy metals like mercury and lead that have accumulated in the lake bed's sediments. Once exposed, these metals can be transported by dust particles and may increase rates of disease associated with air pollution, according to the January report from the BYU team.

The drying is also bad for birds. The Great Salt Lake supports nearly 350 different species, many of them migratory birds that use the lake to rest and refuel as they cruise north or south along the Central and Pacific flyways. While many migrating birds can make do with any lake, fresh or salty, some species are saline specialists, like eared grebes and phalaropes.

According to a 2017 report by the National Audubon Society, more than half of the saline lakes in the West that are most important for birds have





The Great Salt Lake is an important stopover for migrating birds (above left), including the eared grebe (right).

shrunk by 50 to 95 percent in their surface area over the last 150 years. "The birds are competing now for a much more limited resource than they did before," says John Luft, manager of the Great Salt Lake Ecosystem Program at the Utah Division of Wildlife Resources.

During some fall migrations, 5 million eared grebes — perhaps 95 percent of the species's entire population — have stopped over in Utah, Luft says. Each grebe needs to eat up to 30,000 brine shrimp per day from the Great Salt Lake before continuing on its long migratory journey to points farther south. Brine shrimp flourish between 12 and 17 percent salinity, but they start to decline drastically once salinity passes that threshold — and the south arm of the Great Salt Lake reached 18 percent last September. (For comparison, the ocean averages about 3.5 percent salinity.)

What to do about it

While Wurtsbaugh says that "drying is definitely the projection and the worry," he believes residents can help halt the decline by using less water.

Null agrees. "We can save Great Salt Lake, but it's a long solution, not something that we're going to fix overnight." The most important way to make progress, she says, is for people to care enough to change their behavior.

Utahans have the second highest per capita use of water in the country. Encouraging people to use less water is the simplest — and cheapest — way to begin refilling the Great Salt Lake. This includes using rain barrels, reducing the need for irrigation in urban and suburban areas through xeriscaping, and improving the efficiency of irrigation structures on farms and ranches.

Permanently mandating water cutbacks would cost between $5 to $32 per person, according to Wurtsbaugh and Null's research. The BYU team's report, coauthored by 32 Great Salt Lake experts, emphasizes that conservation is not only the most cost-effective response, but also "the only way to provide adequate water in time to save Great Salt Lake." Specifically, the report stresses the importance of reducing outdoor water use, especially on agricultural fields.

Last year, faced with withering streams and ominous lake levels, the Utah State Legislature passed a slew of bills focused on voluntary water conservation. "Honestly, I look at this as our time to shine," says Joel Ferry, executive director of the Utah Department of Natural Resources. "The people of Utah … want to solve the problem."

Some of the recent legislation calls for obvious fixes — like banning any requirements that residents water their lawns. Before this legislation, fines for not keeping your grass green were common around Salt Lake City. Other laws focus on making sure basic systems are in place to track water use, from the individual to the watershed level.

For instance, the legislature allocated $250 million to install tens of thousands of meters to track people's outdoor water use. According to Wurtsbaugh, a previous effort to install meters in the Weber River, which flows into the Great Salt Lake, showed that "just knowing how much water you're using compared to what your neighbor's using" meant people used about 25 percent less water. Metering also opens the door to charging people accurately for the water they use. Currently, most residents pay a flat fee for all outdoor water, regardless of whether they are watering a few flowers or filling an entire swimming pool.

Since agriculture accounts for three-quarters of the water use in the Great Salt Lake region, Utah is also encouraging farmers and ranchers to conserve water. This shift has the advantage of making operations more drought resilient, says Ferry, who is also a fifth-generation rancher who irrigates with water from the Bear River. "Producers want to be part of the solution. They have to be."

In 2022, the Utah Department of Agriculture and Food's Water Optimization Program granted $70 million to help farmers and ranchers install drip or sprinkler systems that use less water. The Utah State Legislature also appropriated $40 million last year to preserve flows to the lake. Much of that

FROM LEFT: LEAMUS/ISTOCK/GETTY IMAGES PLUS; HAL BERAL/CORBIS/GETTY IMAGES PLUS

is dedicated to setting up a water trust to lease water rights from farmers or ranchers willing to sell. Essentially, a water trust would pay irrigators to leave some or all of the water they are permitted to use in the stream or river instead of diverting it to water crops. These water leases could last a single summer or several years.

Water leasing is helping restore other ailing saline lakes. In Nevada, purchasing water rights from willing sellers has boosted the level of Walker Lake, about 150 kilometers southeast of Reno. But because water is so valuable in the arid West, it's an expensive way to refill a lake. The Walker Basin Restoration Program has spent at least $92 million but has only acquired 53 percent of the water needed to support native fish and wildlife in the lake.

Big infrastructure and Mother Nature

If water conservation programs don't work, Utahans might be faced with a more extreme solution to save the Great Salt Lake.

The alternative to conservation measures, says Null, is "hanging our hopes on big new infrastructure projects" that attempt to refill the lake by bringing water from other basins. One example is the Central Utah Project, which has been in the works for more than 80 years and is still incomplete.

This project pipes up to 310 billion liters of water annually from the Colorado River Basin in eastern Utah, infamously over-tapped already, into a series of reservoirs and tunnels to supply water for irrigation, municipal and industrial uses in the Great Salt Lake's watershed. According to the U.S. Bureau of Reclamation, the initial plans for the Central Utah Project put it "among the most complex" water resources development projects ever undertaken by the bureau, estimated to cost $3 billion once all phases are complete.

In the Aral Sea, dikes were built to preserve the remaining sliver of wet habitat, which meant permanently sacrificing the rest of the historical lake area. In California, Mono Lake was saved by a lawsuit based on the public trust doctrine, which says that the government has a responsibility to protect resources that belong to everyone. The court's decision cut off water to cities in Southern California that held water rights to the river that fed Mono Lake. Los Angeles made up the difference in part through water conservation measures.

Ferry says Utah isn't closing the door on any options. Some of the more unorthodox ideas floating around Salt Lake City include ramping up the state's cloud-seeding programs to boost precipitation and piping water from the Pacific Ocean to refill the lake.

The Great Salt Lake watershed covers much of Utah, as well as some of Idaho, Wyoming and Nevada. This map shows where urban and agricultural land uses are concentrated.

But the most common strategy echoed by the Utahans interviewed for this story: Pray for snow.

"I'm very optimistic that we are at the lowest of lows," Ferry said last fall, "as long as we get some snow."

Utah did receive a record-setting amount of snow this past winter, so the situation is looking up—at least for now. But it will take several years of above-average precipitation to reverse Utah's lingering drought. "Mother Nature has a huge role to play in this," Yamane says. "And it's going to take a mind-set change, a cultural change and policy changes. But along with Mother Nature, we should be able to save it." ■

Explore more

- Benjamin W. Abbott *et al.* "Emergency measures needed to rescue Great Salt Lake from ongoing collapse." January 2023.

Brianna Randall is a freelance writer based in Missoula, Mont.

TERESA GÓMEZ (GEOSPATIAL ANALYSIS, DATA AND TECHNOLOGY SPECIALIST)/BYU LIBRARY

Oddball Black Holes

These cosmic behemoths defy expectations and may offer a glimpse into the early universe

By Ashley Yeager

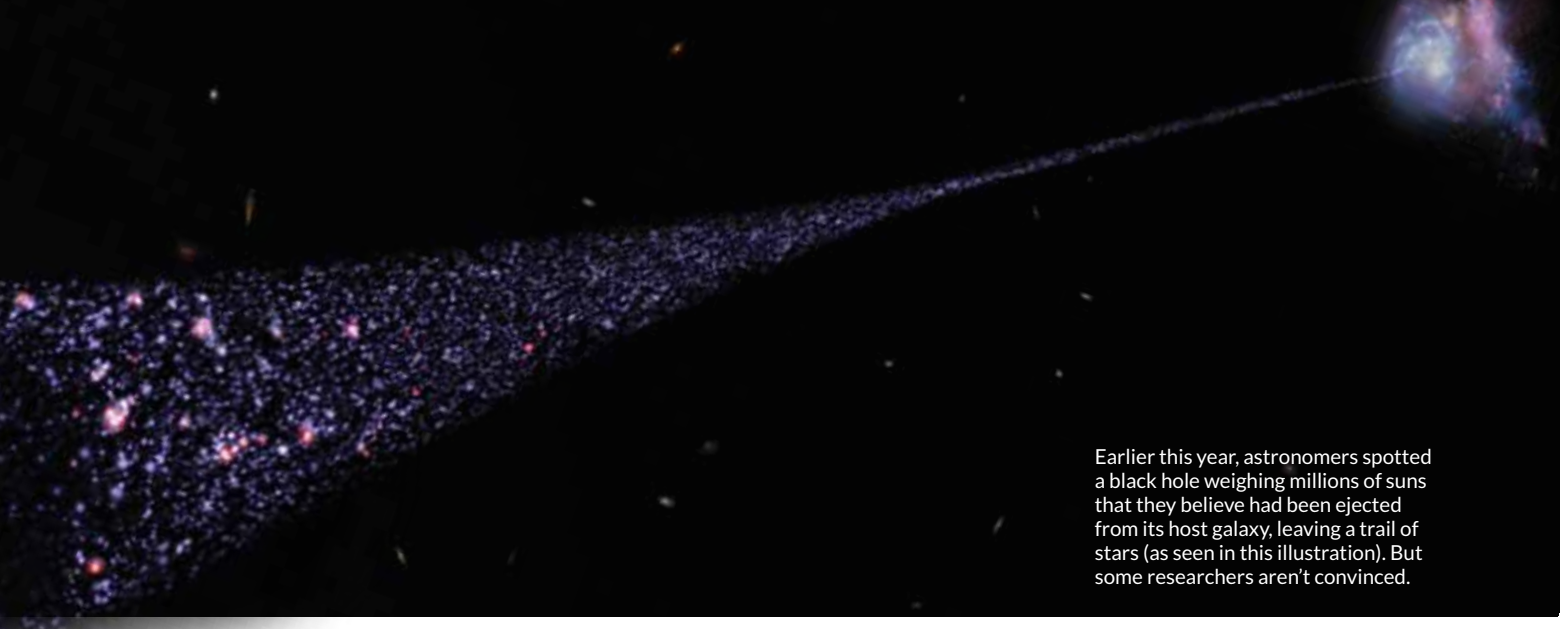
Our galaxy's heart is a gluttonous monster. Like the mythical Kammapa of the Sotho people of southern Africa, the Milky Way's central, supermassive black hole has swallowed nearly everything around it, growing heftier and heftier the more it eats. And it's not alone. Black holes weighing as much as thousands, millions or even billions of suns sit at the center of nearly all known massive galaxies.

For decades, scientists thought that was the only place they'd find such behemoths, because only massive galaxies had enough material to feed the monsters' excessive appetites. But beginning about two decades ago, computer simulations of the earliest black holes started turning up oddities—big black holes that weren't smack-dab where they were expected. These misfits must be nothing more than flukes, many scientists reasoned at the time, dismissing the results without a second thought.

But others weren't so certain the oddballs should be cast off. If observations show that these unusual black holes exist in the nearby universe, these astrophysicists speculated, they could be untapped clues to the universe's infancy and adolescence.

"We can, weirdly, [learn about] the super-beginning of the universe by looking at things really close to us," says theoretical astrophysicist Jillian Bellovary of Queensborough Community College in New York City.

The notion remained just an idea for years. But now, the existence of these misfits isn't so easy to ignore. Astronomers have turned up signs of a number of unexpectedly massive black holes



Earlier this year, astronomers spotted a black hole weighing millions of suns that they believe had been ejected from its host galaxy, leaving a trail of stars (as seen in this illustration). But some researchers aren't convinced.

NASA, ESA, LEAH HUSTAK/STSCI

in the universe's tiniest galaxies, and surprisingly, some of those black holes don't appear to sit at their galaxies' centers. Even more intriguing, astronomers have spotted evidence of black holes wandering at their galaxies' edges, and in rare cases, being kicked from their homes into intergalactic space.

Perhaps these black holes aren't merely cosmic nonconformists but instead big players in the story of our universe. If so, they are a tool for probing one of the greatest mysteries in all of astrophysics — how the cosmic Kammapas we see today came to be.

"Without understanding what black holes are doing, you cannot understand galaxy evolution," says Xiaohui Fan, a cosmologist at the University of Arizona in Tucson, making it impossible to explain the landscape of the universe.

Little galaxies' big black holes

Our current cosmological understanding of how black holes got so big goes something like this: As galaxies grow, collide and merge over cosmic time, they take on gobs of new stars, gas and dust. The black holes at the galaxies' centers grow in lockstep, ballooning as they merge with one another and feed on the newly acquired material. A rough estimate puts a supermassive black hole's heft at somewhere around a thousandth of the mass of its home galaxy.

> "I always like to think about the outliers, or the weird little rejects, or the nonconformists."
>
> JILLIAN BELLOVARY

In this scenario, the universe's littlest galaxies, called dwarf galaxies, probably didn't go through many mergers in the past. Tipping the scales at only about a trillionth the mass of the Milky Way, they should have relatively runty black holes, or none at all.

But in the late 2000s, astrophysicist Marta Volonteri of Institut d'Astrophysique de Paris at Sorbonne University helped run computer simulations that tracked the evolution of massive black holes from birth to today. In those efforts, almost as soon as they popped into existence, even the smallest galaxies could have surprisingly large black holes. As time passed, some of those galaxies never grew or merged with others, leaving them unmarred after billions of years of cosmic evolution.

A wild idea occurred to Volonteri and her colleagues: These galaxies and their black holes were relics of the universe's birth. If massive black holes in dwarf galaxies did exist, and if astronomers could find them, those black holes would be an unprecedented window into how the first black holes formed.

The first hints that they do exist came from a serendipitous find by astronomer Amy Reines. More than a decade ago, she was in graduate school at the University of Virginia in Charlottesville poring through telescope data on a dwarf galaxy 30 million light-years from Earth. It was bursting with stars, and Reines was trying to learn more about how these balls of hot gas are born.

Initially Reines looked at data from the galaxy, called Henize 2-10, in radio and near-infrared wavelengths of light. She spotted a cosmic baby rattle, a roughly 300-light-year-long bridge of gas connecting two dusty balls swaddling newly coalescing stars. A deeper dive into the data revealed extreme radio emissions right in the middle of the rattle, along with bright X-rays coming from the same spot, inklings of a huge black hole with a mass of a million suns.

"I hadn't seen this before," says Reines, now at Montana State University in Bozeman. Dwarf galaxies, she too had assumed, shouldn't have big black holes. She remained skeptical of her interpretation until a few months later when she attended a talk in Seattle at the 2011 American Astronomical Society meeting.

It was there that Bellovary, then a postdoctoral researcher at the University of Michigan in Ann Arbor and collaborating with Volonteri, presented new simulations of galaxy formation. Bellovary described the formation of galaxies with a range of masses and histories, and discussed how the results could make predictions about how massive black holes are scattered throughout the universe.

Like Volonteri's earlier work, Bellovary's simulations suggested that big galaxies were not the only ones to harbor big black holes; scrawny galaxies could have them too.

In a session at the same meeting, Reines highlighted her discovery of dwarf galaxy Henize 2-10 and its uncharacteristically massive black hole. Like two black holes circling each

Dwarf galaxy Henize 2-10 is about 30 million light-years away and may host a supermassive black hole.

X-RAY: CXC/NASA, UNIV. OF VIRGINIA, A. REINES *ET AL.*; RADIO: NRAO/AUI AND NSF; OPTICAL: NASA, STSCI

other and then colliding, unexpected computer simulations met unexpected real-world observations.

The combined work suggested that not only do massive galaxies have big black holes, but maybe a majority of galaxies do too, Fan says. And that raised a lot of new questions about how black holes and galaxies grow up together.

After hearing Bellovary's talk and publishing her own findings, Reines shifted her research focus from the birth of stars to finding big black holes. The behemoths pulled her in. She launched an effort to search for them in dwarf galaxies. Like other astronomers, she decided to scan the skies for the rings of cosmic crumbs that burn brightly around feeding black holes at the centers of galaxies—active galactic nuclei. That's where black holes should be, she assumed. "I mean, it's in the name, active galactic nuclei," she explains.

Reines combed through data from the Sloan Digital Sky Survey looking for the visible-light signatures of central black holes. Of the roughly 25,000 dwarf galaxies in her analysis, 151 of them appeared to harbor a big black hole, she and colleagues reported in 2013.

Volonteri says she was elated by the results. They validated her wild idea that dwarf galaxies could have really big black holes, and possibly that those black holes could tell us something about the very first black holes.

A key clue may be in the masses of dwarf galaxies' black holes. The two leading ideas for how the first black holes formed create black holes of different masses. One idea supposes that these black holes formed from the implosion of the first stars and would tend to be relatively lightweight. The other idea suggests that the first black holes formed from the direct collapse of giant gas clouds and would be heavier. If the gas cloud idea is correct, it could explain another cosmic puzzle: how black holes in the early universe got so big so fast. "We observe them, and they are already huge," Bellovary says. If the history of the universe was displayed on a clock, these monsters would have mere seconds to form, she explains.

If big black holes in dwarf galaxies are indeed ancient relics from the early universe, their masses should be akin to the masses of the first black holes. If so, they could help explain how the seeds of some of the heftiest black holes we see today formed.

According to a recent estimate, the black hole in Henize 2-10

tips the scales at a few million suns. That's a data point in favor of the direct cloud collapse idea, but it's just one measurement with a lot of assumptions. For now, measuring black holes' masses is no easy task.

Welcome help from wanderers

Fortunately, there's another way to get a clue to the masses of early black holes. It relies heavily on another type of oddball—big black holes that don't sit exactly at the center of dwarf galaxies.

When Bellovary shared her simulations back in 2011, the idea of big black holes in scrawny galaxies wasn't the only surprise. Her work also predicted that some Kammapas would be off-kilter from their galactic centers, wandering around the dwarfs' edges after failing to fall to their cores.

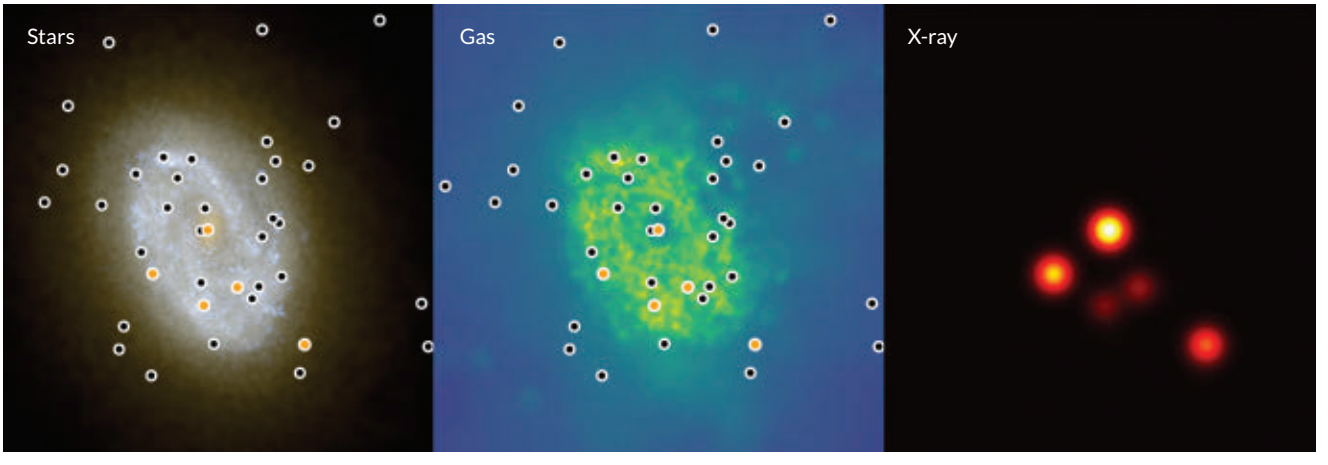
"I always like to think about the outliers, or the weird little rejects, or the nonconformists," Bellovary says. She chose to rerun her simulations, zooming in on the littlest galaxies. When she did, she found that half of the massive black holes in dwarf galaxies should be off-center, she reported in early 2019 in *Monthly Notices of the Royal Astronomical Society*.

As if on cue, Reines came in a few months later with observations that bolstered Bellovary's simulations. Using the Very Large Array of radio telescopes in New Mexico, Reines and colleagues had peered at emissions coming from 111 dwarf galaxies, 13 of which most likely had big black holes. Of those 13 big black holes, a few appeared to sit off-center from their galaxies' cores (SN: 6/22/19, *p.* 12).

Finding wanderers was a jackpot. "Once a black hole starts wandering, it does not grow in mass anymore," Volonteri says. The lowest-mass wanderers should roughly match the initial mass of the very first black holes, making them a good proxy for the seeds that would later grow into supermassive black holes.

Unfortunately, the mass of wanderers is even harder to figure out than the mass of Kammapas sitting at their galaxies' cores.

Misfit predictions In computer simulations, big black holes don't show up only at galaxy centers. Simulations predict that this galaxy has many in its halo (black circles). The five heftiest black holes (orange) include four that are off-kilter. Simulated gas and X-ray views show how these black holes might appear to astronomers in telescope images.



A. RICARTE ET AL/ASTROPHYSICAL JOURNAL LETTERS 2021

Researchers are instead turning to these wanderers' overall numbers for clues. If the earliest black holes—the seeds of today's supermassive black holes—formed from the direct collapse of huge gas clouds flowing into galaxies, then wanderers shouldn't be very common in dwarf galaxies. That's because converting a gas cloud's mass into a massive black hole is difficult and thus expected to be a rare phenomenon, Volonteri explains. An easier way to form early black holes—through the implosion of the first stars—would result in many more wanderers.

Another possible scenario that scientists are now considering is whether mergers of early stars or black holes in dense galaxy cores could have made the seeds of supermassive black holes. That process would also result in a lot of wanderers. But these black holes would be somewhat more massive than black holes formed from stellar implosions.

Because signs of wanderers keep popping up, researchers are leaning away from the direct collapse idea. But to truly get a better sense of how big black holes formed, researchers need to census wandering black holes not only in the nearby universe but also further back in time, says Angelo Ricarte of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass. We need to know if what's happening now is similar to what happened then, because the environment in the early universe was very different.

Off-kilter black holes in big galaxies, and beyond

Massive galaxies appear to have wanderers too, some that are flying across their host galaxies at 10 times the speed of wanderers in dwarf galaxies.

But scientists aren't entirely sure if these black holes gone rogue are real. When one turned up in 2003 in Volonteri's simulations, scientists blew it off. The rogues showed up again in Bellovary's simulations. The reaction? Skepticism. And that skepticism remained even when astronomers announced bright, flashy X-ray signals coming from candidate rogues.

Several years ago, a Hubble Space Telescope image and data from other observatories offered evidence of a black hole with a billion suns' worth of mass getting booted to the edge of its galaxy (SN: 4/29/17, *p.* 16). And earlier this year, images from Hubble

The X-ray light (pink in inset) coming from the edge of a galaxy some 4.5 billion light-years from Earth could be a wandering big black hole that was thrown from the center of its own galaxy when that galaxy merged with a larger one.

X-RAY: CXC/NASA, UNH, D. LIN *ET AL*. OPTICAL: NASA, STSCI

and the Keck Observatory revealed the possibility of a trifecta of supermassive black holes interacting, with one given so much oomph that it's been ejected to intergalactic space (SN: 4/8/23, *p.* 11). But a separate team proposes that what some scientists are calling a rogue black hole might instead be a galaxy viewed edge on (see Page 8).

Volonteri continues to track each candidate rogue, along with other oddball black holes astronomers have put forward. They all somehow have to fit into our full understanding of the history of supermassive black holes, she says. And once again, how often they show up in observations could provide clues to the fuller picture.

If observations show that slow-moving wanderers are abundant, then collisions and mergers of really big black holes are presumably rare. Slow-moving wanderers haven't interacted with other black holes and so haven't picked up extra zing relative to the stars around them. The story the universe would be telling us is that the supermassive black holes we see today didn't grow through repeated mergers after all. But, Volonteri says, if there are a lot of supermassive black holes being shot from the centers of their galaxies to the distant edges, black hole interactions, including mergers, must be common.

With a few dozen candidate oddballs in dwarf galaxies and only a few far-flung rogue candidates identified, the picture is not yet clear. What we do know, Fan explains, is that understanding cosmic evolution requires a good sense of the birth and evolution of the "dark sector" of galaxies — including black holes.

More observational evidence of oddballs would help, and more astronomers have joined the search. In 2021, a team including Reines and Mallory Molina of the University of Utah in Salt Lake City reported a new way to spot signs of massive black holes in dwarfs, specifically if the behemoths are feeding on gas and dust. The technique searches dwarfs for a red glow given off by an unusual type of iron. And a team from Dartmouth reported last year that very-high-energy X-rays may also reveal obscure behemoths.

Future observatories may aid in the hunt too. The Vera C. Rubin Observatory, located in Chile and slated to turn on next year, can sweep the skies looking for wanderers. And the next-generation Very Large Array, a proposed radio observatory, will be sensitive enough to spot signs of black holes in dwarf galaxies.

With the goal of detecting collisions of very massive black holes, the Laser Interferometer Space Antenna, or LISA, and the proposed Einstein Telescope may one day offer clues to how common cataclysmic black hole interactions are and have been.

Time and new technology will tell. For now, oddball black holes spark our imagination, prompting us to ask big questions and uncover new evidence in the pursuit of a deeper understanding of cosmic history. With each purported discovery, you can't help but wonder: What else is hidden out there? Perhaps there are other oddities not yet discovered that could tie us to the earliest universe, Bellovary says, and reveal our cosmic origins. But only if we're willing to chase the misfits and their stories. ■

Explore more

- Amy E. Reines. "Hunting for massive black holes in dwarf galaxies." *Nature Astronomy*. January 2022.

COMMITTED TO STEM EDUCATION

Cecilie Prine is a science teacher at Lander Middle School in Lander, Wyo. With over 20 years' experience teaching health and science, Cecilie is passionate about helping her students connect with the world around them. Cecilie, who has participated in the Society for Science's Advocate Program for three years, shared her thoughts with us.

The Advocate Program provides educators across the country with training and support for teaching scientific research and helping students enter science competitions. Advocates also receive a stipend and an all-expenses-paid trip to attend the Advocate Training Institute in Washington, D.C.

Why is it important for students to have opportunities to pursue scientific research?
Science is a global endeavor, and I want my students to see how their work here in Wyoming can make a wider impact. Increasing participation in science fairs not only gives these young people opportunities to see their role in science, but also gives them the skills to move forward in other fields.

What has your experience in the Advocate Program been like?
The program has had such a positive influence on our science fair and has provided me with support and opportunities to fine-tune our science fair program.

Learn more about the Society's Advocate Program:
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In the Blood
Charles Barber
GRAND CENTRAL PUBLISHING, $29

BOOKSHELF

Blood-clotting tale brings the drama

The average human body holds about 5 liters of blood. Lose a liter, and you may go into shock. Lose two more, and you'll probably die.

For doctors treating traumatic injuries, keeping a patient's blood in their body is "one of the most fundamental problems of survival," Charles Barber writes in his fast-paced new book, *In the Blood*.

Solutions to that problem haven't changed all that much in centuries. Doctors can pack a wound with gauze or put pressure on blood vessels to slow bleeding. While other areas of medicine have leaped ahead over time, Barber notes, emergency medicine has largely stood still, an inertia that's had deadly consequences. Some 50,000 people in the United States bleed to death every year.

You'd think, then, that a product that can stanch bleeding would be celebrated in the streets, snapped up immediately by military doctors and emergency rooms alike. You'd be wrong. *In the Blood* chronicles the invention and bafflingly slow adoption of QuikClot and its successors, inexpensive clotting agents that can stop big bleeds in minutes. Barber, who's also written about criminal justice and mental health, leads readers on the path from product invention to implementation—and it's a treacherous journey.

Barber starts his story, which races like a thriller, in Mogadishu, Somalia, at the scene of the 1993 battle that inspired the movie *Black Hawk Down*. After two American helicopters were shot down, John Holcomb, then a U.S. Army major, and other doctors treated dozens of injured soldiers, many of whom died from loss of blood.

That horrific experience electrified Holcomb. Better hemorrhage control was urgently needed, and he was the man to lead the charge. In 2002, Holcomb became head of the Army Institute of Surgical Research, a research laboratory focused on improving combat casualty care. Holcomb championed the development of different clotting candidates, including HemCon, a bandage containing a shrimp-shell chemical, and Factor Seven, an injected drug that boosts the body's clotting capability, sometimes lethally, it turned out.

In Barber's telling of the story, Holcomb's character is complex, shifting between savior and villain. Under his watch, the Army poured millions of dollars into his favorite products. It's hard to grasp what motivated Holcomb, but Barber argues that he was long unwilling to consider other options—like QuikClot—data be damned. QuikClot seemed to be more effective than the rest. But it didn't come with a big Army budget or a biotech company's backing. It was born in an inventor's basement.

The inventor was Frank Hursey, a mild-mannered engineer from Connecticut who discovered in 1983 that the ground-up mineral zeolite could mop up the water in blood. By concentrating the molecules involved in clotting, Hursey's invention sped up the process. In 1999, he partnered with "swashbuckling salesman" Bart Gullong, who helped develop and promote the product. Barber pulls readers into their adventure, though he occasionally meanders too far into their backstories.

The action picks up when Barber digs into the evidence behind different clotting agents. He describes clear-cut animal tests, moving accounts from soldiers in the field and reports linking Factor Seven to stroke, heart attack and death. A central question of the book, then, is not so much "How do you stop a hemorrhage?" as "How do you get a hemorrhage-stopping product to the people who need it?"

Hursey and Gullong were up against entrenched military and pharmaceutical interests from the get-go. The company that produced Factor Seven aggressively marketed the drug, Barber reveals, even in the face of its flaws. It's clear that he is rooting for the underdogs. He lays out facts for readers like a mason placing bricks, building a solid case against a system where money sways whether a medical product gets used. Even when the data suggest it shouldn't.

In 2008, Holcomb finally recommended an improved version of Hursey's invention, called QuikClot Combat Gauze, for use in the military, "an almost unimaginable victory," Barber writes. In recent years, QuikClot gauze has made its way into hospitals, and consumers can now buy it on Amazon for $18.99.

Though Hursey remains largely unknown, Barber calls his discovery "paradigm-shifting." Hursey "took bleeding control largely out of the hands of doctors," Barber writes, "and put it into the hands of police officers, EMTs, adventurers, soldiers, hikers, and moms and dads." —*Meghan Rosen*

SOPONE NAWOOT/ISTOCK/GETTY IMAGES PLUS

APRIL 8, 2023

The head and the heart

Scientists used light to raise a mouse's heart rate, increasing anxiety-like behaviors in the animal. The study offers a new angle for studying anxiety disorders, ***Bethany Brookshire*** *reported in "In mice, anxiety isn't all in the head"* (SN: 4/8/23, p. 9*).*

Reader **Barry Maletzky** asked why strenuous exercise, which elevates heart rate, doesn't typically induce anxiety.

Heart rate isn't everything, says neuroscientist **Karl Deisseroth** of Stanford University. The heart may race, but the brain provides important context, which is key to the body's response. In the study, elevating a mouse's heart rate in a neutral environment—such as a small, dim chamber—did not induce anxious behaviors, **Deisseroth** says. The anxious behaviors increased only when the heart rate was raised in a threatening context, like an open space where a small mouse could be a snack for a predator.

Monkey business

Some macaques inadvertently made stone flakes while using rocks to crack open nuts, raising questions about whether ancient stone flake tools attributed to hominids were made accidentally, ***Bruce Bower*** *reported in "Monkeys' stone flakes look like hominid tools"* (SN: 4/8/23, p. 13*).*

Reader **Jerald Corman** wondered how scientists knew that the monkeys created the stone flakes unintentionally.

We know this because the flakes were produced only when a monkey attempted to hit a nut with a rock and missed, says primatologist **Lydia Luncz** of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. The monkeys "pay absolutely no attention to whatever breaks off. They don't pick it up. They don't look at it," she says. "When a stone breaks multiple times, they just pick a new one."

AI ethics

The chatbot ChatGPT and other artificial intelligence tools are disrupting education, ***Kathryn Hulick*** *reported in "Homework help?"* (SN: 4/8/23, p. 24*).*

The material that ChatGPT generates is technically not considered plagiarism because it's new and original, **Hulick** wrote. Reader **Joel Sanet** wondered about student papers that may have been written entirely by AI. Can a human plagiarize or steal the intellectual property of an inanimate object?

Plagiarism means passing off someone else's work as your own. "If you claim that you wrote something, but it was actually written by a chatbot, that would be a type of plagiarism," says **Casey Fiesler**, an expert in technology ethics at the University of Colorado Boulder. It's important to remember that in most situations, plagiarism isn't illegal, **Fiesler** says. In education, it's almost always an honor code violation. "The most important thing is to be honest about how you're using AI," she says.

Intellectual property is a whole other, very interesting issue, **Fiesler** says. "The U.S. Copyright Office recently established that work created wholly by AI cannot be copyrighted because there isn't a human author," she says. "But I suspect that in the coming days, we'll see a lot of discussion (and litigation) that tests the edges of ownership and intellectual property when it comes to AI."

Correction

"Homework help?" incorrectly stated that Jon Gillham's AI-detection tool identified 97 percent of 20 text samples created by ChatGPT and other AI models as AI-generated. The tool identified all 20 samples as AI-generated, with 99 percent confidence, on average.

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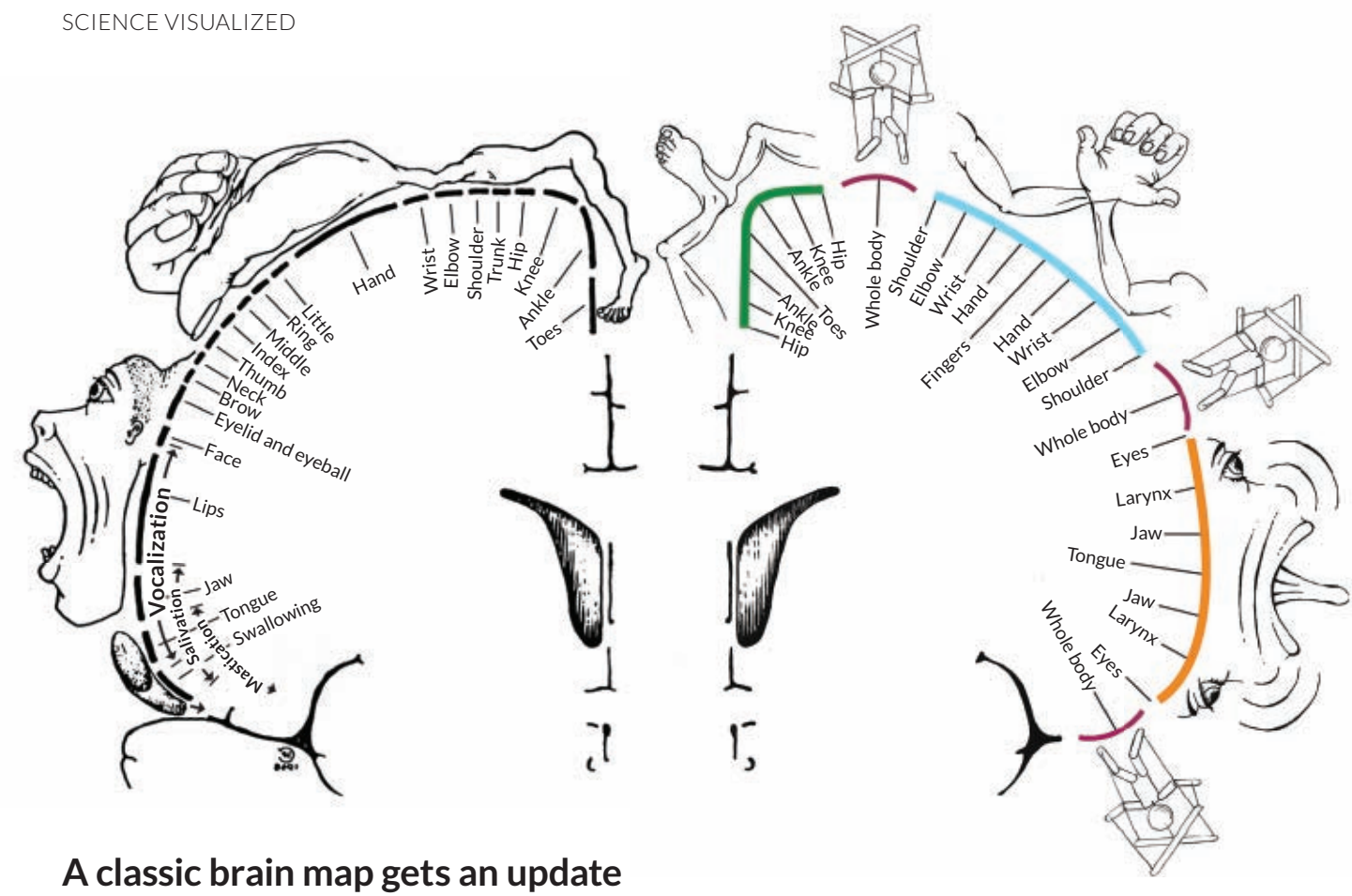

A classic brain map gets an update

The traditional view of how the human brain controls voluntary movement might not tell the whole story.

The motor homunculus, a diagram of the primary motor cortex, has reigned supreme in neuroscience since the 1930s. It shows how this narrow brain region is divided into sections, each assigned to a body part that can be controlled voluntarily. The space each part spans on the motor cortex is proportional to how much control one has over that part.

A new map reveals that in addition to having regions devoted to specific body parts, three newfound areas control integrative, whole-body actions. And representations of where specific body parts fall on this map are organized differently than previously thought, researchers report in the May 11 *Nature*.

For decades, research in monkeys has hinted that something about the classic view was amiss. Scientists conducting this research "have known for 50 years that the homunculus isn't quite right," says Evan Gordon, a neuroscientist at Washington University School of Medicine in St. Louis.

For the new study, Gordon and colleagues gathered functional MRI data on volunteers performing various tasks. Two people completed simple movements like wiggling just their toes, as well as complex tasks like simultaneously rotating a wrist and moving a foot. The fMRI data revealed which parts of the brain activated when each task was performed, allowing the researchers to trace which regions were functionally connected to one another. Seven more participants had their brains scanned while not doing any particular task to see how brain areas communicate during rest.

Testing only a few people for many hours offers unique insights into neural connectivity, Gordon says. "We constantly start seeing things that people have never really noticed before."

In the classic map (top left), control of body parts is spread along an unbroken expanse of the primary motor cortex. In the updated map (right), control is divided into three sections: lower body (green), arms and torso (blue) and head (orange). The order of specific body parts is different as well, with most parts being connected to two spots on the motor cortex. Between these sections, the team also found three regions that coordinate whole-body movement (purple). They connect to a brain network involved in action control and pain sensation.

Using data from three previous fMRI studies, which examined around 50,000 people, Gordon and colleagues verified that this organization is consistent across many people. Similar patterns also appear in datasets from macaque monkeys, children and a stroke survivor.

Because of the connections to the pain senstation network, the team plans to see if the whole-body regions play a role in certain kinds of pain. The researchers also hope their findings will prompt more in-depth research into what specific areas of the brain do. With new techniques and equipment, there is much left to explore, Gordon says. "Brain mapping isn't dead." —*Nora Bradford*

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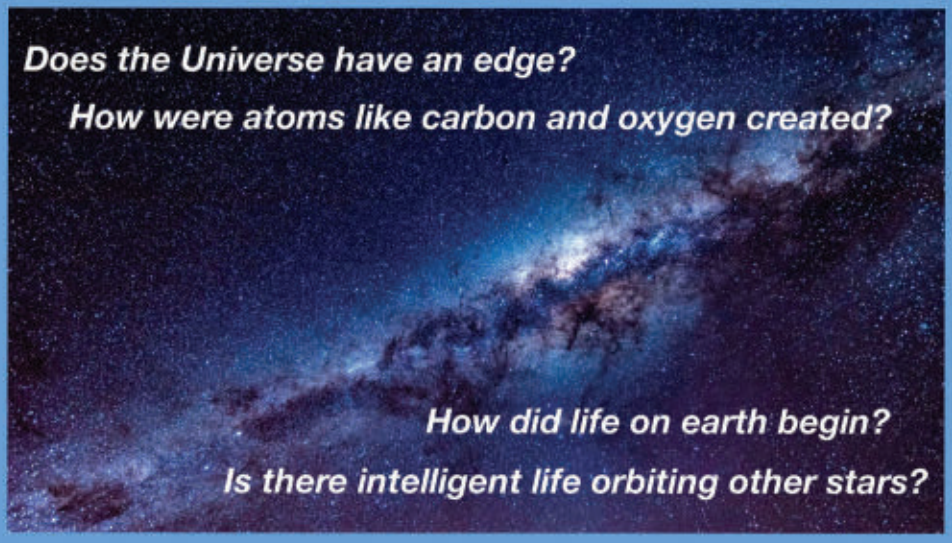

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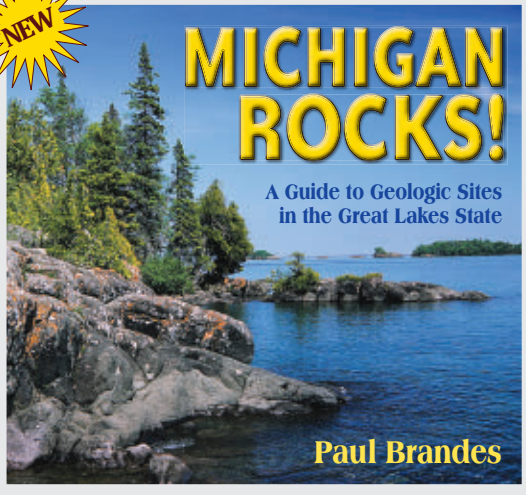

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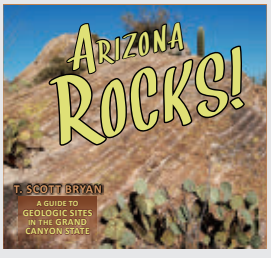

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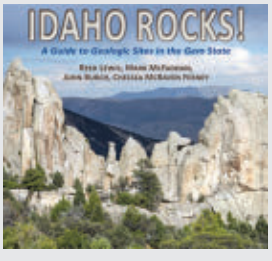

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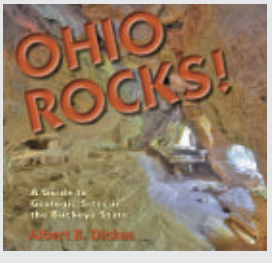

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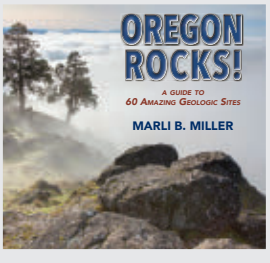

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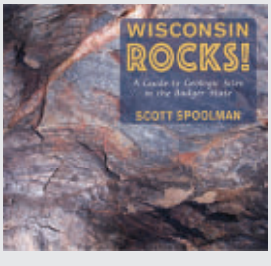

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