Pearl Symmetry Explained | Pluto's Dark Side

Science News

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MIND-ALTERING Therapies

Can psychedelic drugs ease depression, PTSD and other mental health disorders?

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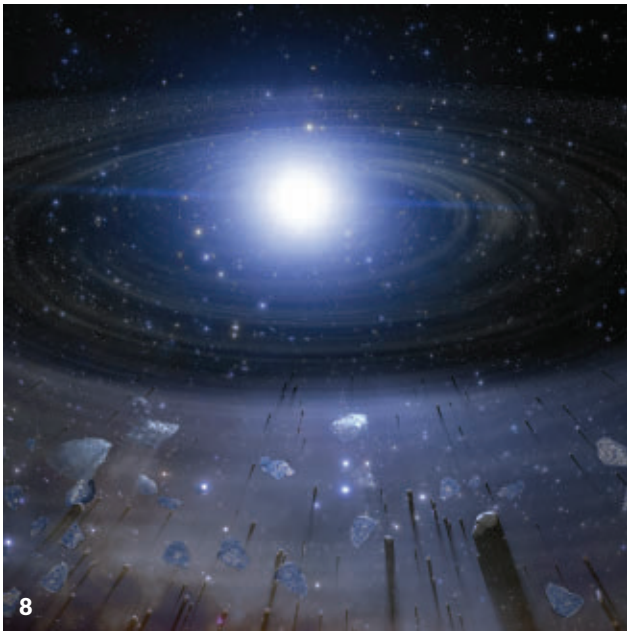
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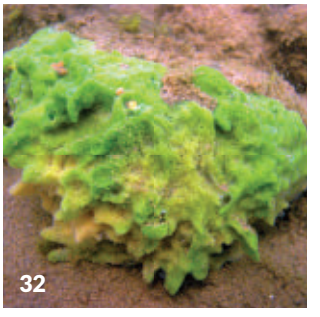
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Departments

COVER When coupled with psychotherapy, mind-altering drugs offer some people relief from depression and other mental health disorders. *Michael Morgenstern/theispot.com*

Rethinking psychedelics and mental health

The psychedelic drug LSD has had a long, flamboyant history, including its promotion by former Harvard psychologist Timothy Leary in the 1960s. He envisioned LSD as a way to "become sensitive to the many and various levels of consciousness" and embrace personal and cultural change.

Leary later lamented that his call to "turn on, tune in, drop out" was too often misinterpreted as "get stoned and abandon all constructive activity," rather than as an aid to transformative change. If Leary were alive today, I'm sure he'd be fascinated by the groundswell of interest in testing psychedelics as a treatment for mental health problems such as depression and post-traumatic stress disorder.

In this issue, neuroscience senior writer Laura Sanders explores the growing evidence that mind-altering drugs — including LSD, MDMA and psilocybin — can bring people relief when combined with psychotherapy in a research setting (Page 20). Recently, recreational use of psychedelic drugs has also increased, with some local governments decriminalizing their use.

But at this point, it's unclear if the latest resurgence of scientific interest in psychedelics will bring with it the healing and growth that Leary envisioned, or end up as just more experiments that fail to live up to their promise. So many questions have yet to be answered, including how the chemicals work in our brains, who is most likely to be helped and whether treatments can be delivered safely and cost-effectively.

To help answer these questions, Sanders turns not just to scientists but also to members of Indigenous communities that have been using psychedelics in healing for centuries, typically in spiritual and ceremonial contexts. Her sources note that Indigenous communities have much more holistic approaches to the use of psychedelics than medical researchers do.

"These sacred plant medicines have been a huge part of their culture and lives for a very long time," Sanders told me. "Their perspective is missing from a lot of these single studies, and the way people talk about these drugs [as] being 'rediscovered.' It's one of those things that looks different, depending on where you're standing."

Psychedelics still carry considerable cultural baggage from the '60s, when their role in the counterculture and political protests helped convince the U.S. government to classify them as illegal substances. That makes it difficult for researchers to run clinical trials and may dissuade potential patients.

To find out what it's like to use psychedelics as medication, Sanders interviewed Kanu Caplash, 22, who participated in a clinical trial testing MDMA as a treatment for PTSD. "He spent several hours talking with me about his experience," Sanders said. "He was so beautifully eloquent; I'm really grateful to him for being willing to talk with us about it." The treatments helped, Caplash says. He no longer thinks of suicide, and feels more at peace with himself.

Who else might get relief from psychedelic therapies is still unclear, but what's indisputable is that current treatments for mental illnesses fall short for many people who need help. Broadening the search for better ways may bring us unexpected insights. — *Nancy Shute, Editor in Chief*

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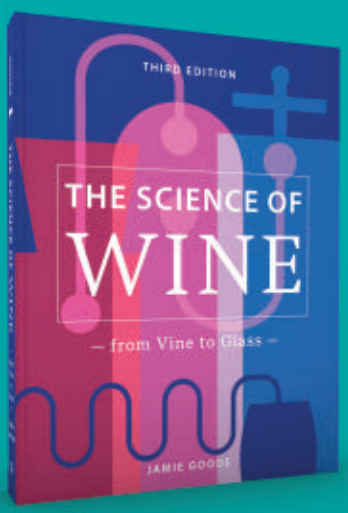
Gifts that Intrigue, Inform, and Inspire

A beautiful collector's object, this is one of the most scientifically important and visually stunning works on butterflies and moths ever created.



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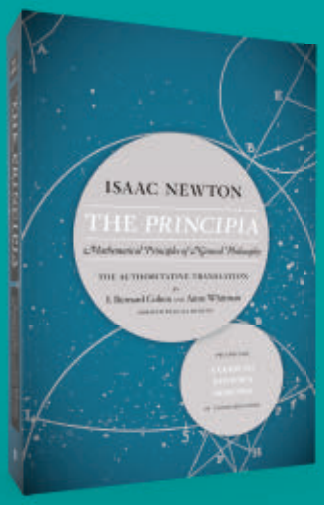
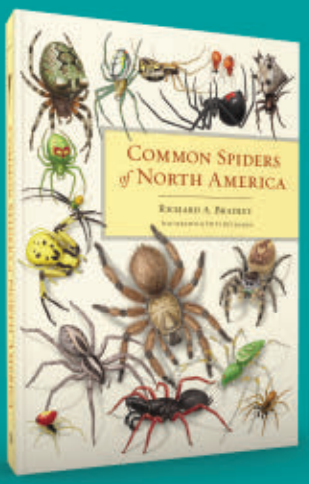
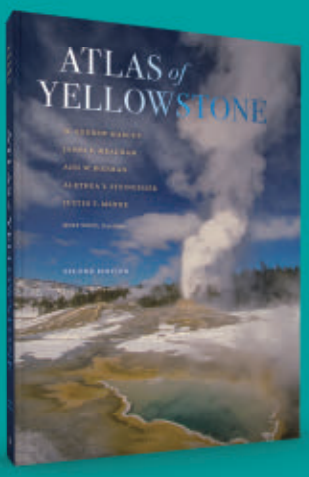


"We owe modern civilization to this towering genius of science."
—Neil deGrasse Tyson



This brilliant field guide provides a comprehensive resource for identifying and appreciating nearly 500 species of spiders.



The award-winning authoritative reference for the world's first national park, in celebration of its 150th anniversary.

UNIVERSITY of CALIFORNIA PRESS

Excerpt from the December 4, 1971 issue of *Science News*

50 YEARS AGO

Apparent cure for rabies

The painful and always fatal virus disease rabies may at last be licked — not with the traditional series of rabies vaccine shots that sometimes ward off the disease after a person has been bitten by a rabid animal, but by the timely use of relatively simple medical techniques.... As a result [a 6-year-old boy] is the world's only known survivor of rabies.

UPDATE: Though the boy was vaccinated, the shots — which have improved since the 1970s — didn't prevent disease. Medical techniques used to treat him, including inserting a tube to help him breathe, giving seizure medication and draining fluid buildup on the brain, proved that rabies patients can survive. Yet the disease is still almost always fatal once people show symptoms. In 2004, a 15-year-old girl became the first known unvaccinated rabies survivor (*SN: 1/29/05, p. 77*). Doctors treated her using the Milwaukee Protocol. This controversial method puts patients in a coma to protect the brain while the immune system mounts defenses. But even with that treatment, most patients still die.

A herd of *Mussaurus patagonicus* dinosaurs, including hatchlings in nests, a group of juveniles and fully grown adults, gather together in this artist's representation.

THE –EST

Herd mentality goes way back for dinosaurs

A treasure trove of fossilized eggs, nests and skeletons is the earliest evidence yet of dinosaurs traveling in herds.

Newly unearthed egg clutches were found near the skeletal remains of dozens of newborn, juvenile and adult dinosaurs, suggesting that the animals stayed together throughout their lives. At about 193 million years old, the finds displace the previous oldest evidence of dinosaur herd behavior by at least 40 million years, researchers report October 21 in *Scientific Reports*.

Paleontologist Diego Pol of the Museo Paleontológico Egidio Feruglio in Trelew, Argentina, and colleagues found 69 individual dinosaurs and over 100 eggs, all of the early sauropod ancestor *Mussaurus patagonicus*, in southern Argentina.

Mind-bogglingly massive sauropods didn't arise until later. But fossils of *Mussaurus* and other sauropod ancestors were already showing evidence of a growth spurt. Increased energy demands of larger bodies, Pol and colleagues suggest, may have required these dinosaurs to coordinate their efforts, forming herds to forage across long distances.
— *Carolyn Gramling*

TEASER

Recycled materials can make long-lasting batteries

Lithium-ion batteries with recycled cathodes can outperform batteries made from pristine materials, a study finds.

Demand for the batteries — which power devices from smartphones to electric vehicles — may outstrip the supply of some key ingredients. Ramping up recycling could help avert shortages. But some manufacturers worry that impurities in recycled materials may cause performance to falter.

"Based on our study, recycled materials can perform as well as, or even better than, virgin materials," says materials scientist Yan Wang of Worcester Polytechnic Institute in Massachusetts.

Using shredded spent batteries, Wang and colleagues extracted the electrodes and dissolved the metals in an acidic solution. By tweaking the solution's pH, the team removed impurities such as iron and copper and recovered over 90 percent of three key metals: nickel, manganese and cobalt. Those metals formed the basis for the team's cathode material.

In tests, it took 11,600 charging cycles for batteries with recycled cathodes to lose 30 percent of their initial capacity. That's better than the 7,600 cycles for batteries with new cathodes, the team reports October 15 in *Joule*. Those extra cycles could translate into years of better performance, Wang says. — *Carolyn Wilke*

JORGE GONZALEZ

PICTURE THIS

How scientists got a peek at Pluto's dark side

When NASA's New Horizons spacecraft flew past Pluto in 2015, almost all the images of the dwarf planet's unexpectedly complex surface were of the side illuminated by the sun. Darkness shrouded the dwarf planet's other hemisphere. Some of it, like the area near the south pole, hadn't seen the sun for decades.

Now, Pluto's dark side has come into dim view, thanks to the light of one of the dwarf planet's moons and one scientist's determination, researchers report in the October *Planetary Science Journal*.

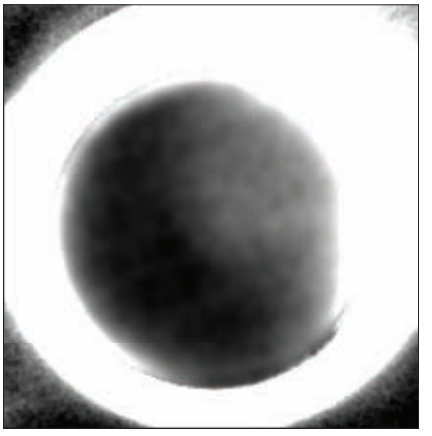
Before New Horizons passed by Pluto, mission scientists suspected the dwarf planet's largest moon, Charon, might reflect enough light to illuminate Pluto's surface. So the team had the spacecraft turn back toward the sun to take a parting peek at Pluto.

At first, the images just showed a ring of sunlight filtering through Pluto's hazy atmosphere. "It's very hard to see anything in that glare," says planetary scientist John Spencer of the Southwest Research Institute in Boulder, Colo. "It's like trying to read a street sign when you're driving toward the setting sun and you have a dirty windshield."

Spencer and colleagues took a few steps to pull details of Pluto's dark side out of the glare. First, the team had the spacecraft take 360 short snapshots of the backlit dwarf planet. Each was about 0.4 seconds long to avoid overexposing the images. The team also took snapshots of the sun without Pluto in the frame so that the sun's light could be subtracted out after the fact.

Tod Lauer of the National Optical Astronomy Observatory in Tucson, Ariz., tried to process the images in 2016. But other data from the mission took up most of his attention, so he didn't have the time to tackle such a tricky project.

But "it was something that just sat there and ate away at me," Lauer says. He tried again in 2019. Because the spacecraft was moving as it took the images, each image was a little bit blurred. Lauer wrote a computer code to remove that blur from each individual frame. Then he added the reflected Charon light in each of those hundreds of images together to produce a single image.



New Horizons took snapshots of the backlit dark side of Pluto in 2015. Scientists used those images to create this view. Some light and dark spots were illuminated by one of Pluto's moons.

"When Tod did that painstaking analysis," Spencer says, "we finally saw something emerging in the dark there ... giving us a little bit of a glimpse of what the dark pole of Pluto looks like." — *Lisa Grossman*

This mummified woman from a roughly 4,000-year-old cemetery in western China belonged to a population with a long history in the region.

RETHINK

DNA tells origin story of Bronze Age mummies

Mystery mummies from China have a surprising ancestry. These people, with facial features suggesting a European heritage, belonged to a population with ancient Asian roots. Until now, scientists had pegged the Bronze Age bunch as newcomers.

Desert heat mummified people buried in western China's Tarim Basin roughly 4,000 years ago. Those people belonged to the Xiaohe culture, which mixed animal herding with plant cultivation. Preserved cheese, wheat and clothes made from western Eurasian wool found in the graves pointed to distant origins or contacts.

Archaeogeneticist Yinqiu Cui of Jilin University in Changchun, China, and colleagues analyzed DNA from 13 Tarim Basin mummies and five mummies from the nearby Dzungarian Basin from around 5,000 to 4,800 years ago. Tarim people had Asian ancestry mainly traceable to hunter-gatherers who lived in northern Eurasia over 9,000 years ago. That finding suggests that the Xiaohe people did not mate with outsiders for many millennia, the researchers report October 27 in *Nature*.

No DNA links were found to western Eurasian herders from the Afanasievo culture, who some researchers have regarded as Xiaohe precursors. But Afanasievo ancestry did appear in the Dzungarian mummies. Perhaps the Xiaohe people picked up dairy consumption and other habits from Afanasievo descendants in the Dzungarian Basin, the researchers say. — *Bruce Bower*

FROM TOP: NOIRLAB, SWRI, JHUAPL, NASA; WENYING LI/XINJIANG INSTITUTE OF CULTURAL RELICS AND ARCHAEOLOGY

BODY & BRAIN

How to choose a booster shot

A *Science News* writer explores the COVID-19 vaccine options

BY TINA HESMAN SAEY

In October, my state health department informed me that I was eligible for a COVID-19 vaccine booster. It had been six months since I'd had my second dose of Pfizer's vaccine. To decide whether I really needed one, and if so, which of the three authorized vaccines available in the United States to get, I looked at the evidence and talked to some experts. Here's what I learned.

Let's start with Johnson & Johnson. Everyone who got that shot as their initial vaccine should get a booster, experts say. That's because the antibody levels from that one-dose vaccine don't rise as high as they do with the two-dose mRNA vaccines from Pfizer and Moderna.

There are few studies on J&J boosters, but the AstraZeneca vaccine, which is built on similar technology but not available in the United States, provides some clues. Both vaccines use adenoviruses to deliver DNA instructions for cells to build the coronavirus' spike protein, which primes an immune response. Combining AstraZeneca's vaccine with a boost from an mRNA vaccine is more effective, studies show, than getting another dose of AstraZeneca.

For instance, in Sweden, two doses of AstraZeneca were about 50 percent effective at preventing symptomatic illness. AstraZeneca followed by Pfizer was 67 percent effective, and AstraZeneca boosted with Moderna was 79 percent effective, researchers reported October 18 in the *Lancet Regional Health – Europe*.

For people like me who got an mRNA vaccine in the first go-around, the booster decision is more complicated. Much of what's known about mRNA booster shots comes from Israel, where everyone 12 and older has been eligible for a third dose of the Pfizer vaccine since the end of August. People who were fully vaccinated with two doses and had no underlying health risks had a very low chance of developing severe COVID-19 or being admitted to a hospital: Just 3.1 of every 100,000 healthy vaccinated people got severe disease, researchers reported October 29 in the *Lancet*.

But with underlying health risks, that number climbs. Of every 100,000 fully vaccinated people with one or two health risks, 82 developed severe disease. And with three or more health risks, the rate was 113 of every 100,000 people. Getting a booster dropped the severe disease rate for those with one or two health conditions to 3.2 per 100,000 and cut the rate by a bit more than half — to 51.6 per 100,000 — for those with three or more health conditions. As someone with a couple of health conditions that make me more vulnerable, this evidence convinced me to get a booster shot.

For young, healthy people the risk equation may be different. Sachin Nagrani, medical director of Heal, a company that provides primary health care via telehealth visits and house calls, says it's OK for young, healthy people to wait for more data on vaccine longevity before getting a booster. But people 65 and older, people with health conditions or people in assisted-living facilities should probably get a booster now.

Once I decided to get a booster, I had to choose which one. I considered the different types of immunity produced by the vaccines. mRNA vaccines give gangbuster levels of neutralizing antibodies, which help keep the coronavirus from infecting cells. But adenovirus-based vaccines like J&J's and AstraZeneca's seem better at revving up long-lasting protection from the immune system's T cells. And some evidence suggests that a combo of an mRNA vaccine and an adenovirus-based vaccine could have some advantages.

Studies comparing different combinations of COVID-19 vaccines provide some guidance on what kind of booster shot a person should get.

MARC BRUXELLE/ALAMY STOCK PHOTO

A study in France that wasn't really about boosters offers evidence of the potential benefit of mixing. Participants got either two doses of the Pfizer vaccine or a dose of AstraZeneca with a Pfizer chaser. Infection rates were low for both groups. But people who got two Pfizer doses were twice as likely to get infected with the coronavirus as those who got the mix, researchers reported October 21 in *Nature*. That was 10 infections among the 2,512 (0.39 percent) who got the mixed doses, compared with 81 infections among the 10,609 people (0.76 percent) who got Pfizer alone.

I asked one of that study's authors, Jacqueline Marvel, an immunologist at the International Center for Infectious Disease Research in Lyon, whether I should switch to J&J for my booster shot. "I'm not sure you want to change the vaccine just for increasing the T cell response," she said. That surprised me.

"I'm pro T cell," she said. But "neutralizing antibodies are what you want to have first. The antibodies stop the virus from getting into the cells, and protect you much earlier than the T cells would." To maximize antibodies, the mRNA vaccines are the way to go.

So I decided to stick with an mRNA shot. Which one — Pfizer vs. Moderna — came down to convenience. Few of the grocery stores, pharmacies and other vaccine providers in my area offer the Moderna vaccine (and even fewer have J&J), but Pfizer doses are plentiful. So I got a Pfizer booster. My arm ached for a little while, but that's a price I'm more than willing to pay to avoid severe illness and to help protect those around me from getting infected. ■

The tiny gray blobs embedded in this slice of clear diamond are the first natural samples of davemaoite, a mineral made in the lower mantle. The discovery could help explain where some of Earth's heat comes from.

AARON CELESTIAN/NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY

EARTH & ENVIRONMENT

A newfound mineral contains the source of some of Earth's heat

Discovered in a diamond, davemaoite forms only in the mantle

BY CAROLYN GRAMLING

When it comes to knowing what actually lies deep inside the Earth, diamonds are a geologist's best friend.

Tiny bits of rock trapped inside a diamond are opening a brand-new window into what the planet's lower mantle looks like. Inside the diamond is a newly identified silicate mineral dubbed davemaoite that could have formed only in the lower mantle, researchers report in the Nov. 12 *Science*. It's the first time that scientists have definitively proved that this type of lower mantle mineral — previously predicted from and synthesized in laboratory experiments — actually exists in nature.

The team named the mineral for experimental high-pressure geophysicist Ho-kwang (Dave) Mao (*SN: 10/21/00, p. 260*).

Diamonds act like time capsules, locking in minerals in their original form while the gems journey to the surface. The diamond bearing the telltale mineral inclusion came from a mine in Botswana and formed at depths greater than 660 kilometers, the upper boundary of Earth's lower mantle.

Using analytical techniques including X-ray diffraction, X-ray fluorescence imaging and infrared spectroscopy, mineralogist Oliver Tschauner of the University of Nevada, Las Vegas and colleagues identified the chemical makeup and structure of the new mineral, pegging it as a type of calcium silicate perovskite.

Scientists had previously estimated that about 5 percent to 7 percent of the lower mantle must be made up of this mineral, Tschauner says. But directly observing minerals from the deep Earth is fiendishly difficult: Minerals that are stable in the intense pressures of the lower mantle — which extends to 2,700 kilometers below Earth's surface — begin to rearrange their crystal structures as soon as the pressure lets up.

Even the planet's most common mineral, a lower mantle magnesium iron silicate known as bridgmanite, was largely theoretical until 2014, when Tschauner and colleagues discovered it within a meteorite in Australia (*SN: 1/10/15, p. 4*). The force of the meteorite's impact generated crushing pressures in the rock similar to those of the deep mantle. To date, bridgmanite is the only other high-pressure silicate mineral confirmed to exist in nature.

Davemaoite is a calcium silicate mineral but is also host to a rogue's gallery of different elements that sneak into its crystal structure. That includes rare-earth elements, as well as radioactive elements such as uranium, thorium and potassium. Radioactive elements have long been thought to produce about a third of the heat circulating in the lower mantle (the other two-thirds is left over from Earth's formation 4.55 billion years ago). The new study not only confirms the mineral's existence, but also that the mineral hosts elements that are sources of heat deep inside Earth.

The diamond from Botswana also contains a high-pressure form of ice, as well as another high-pressure mineral known as wüstite. The presence of those inclusions helped narrow down the rough pressures at which the davemaoite might have formed: somewhere between 24 billion and 35 billion pascals, Tschauner says. It's hard to say exactly what depth that corresponds to, he adds. But the discovery directly links heat generation (the radioactive materials), the water cycle (the ice) and the carbon cycle (represented by the formation of the diamond itself), all in the deep mantle, Tschauner says.

Another intriguing aspect of this new mineral is that it's surprisingly rich in potassium compared with laboratory predictions, says Sang-Heon Shim, a geophysicist at Arizona State University in Tempe. Most experimental efforts to create the mineral have come up with "nearly pure calcium silicate perovskite," Shim says.

Scientists can only speculate about the source of the extra potassium, but this unexpected composition hints that the lower mantle may be a more motley mix than previously thought, with complexity difficult to predict from lab studies alone. ■

ATOM & COSMOS

Stars offer a peek inside exoplanets

Elements on white dwarfs hint at the makeup of rocky worlds

BY KEN CROSWELL

Planetary debris falls onto a white dwarf star in this illustration. Elements from such debris on white dwarfs hint that the mantles of faraway rocky worlds differ from those in our solar system.

If a real Captain Kirk ever blasts off for other stars in search of rocky planets like ours, he may find lots of strange new worlds whose innards bear no resemblance to Earth's.

A smattering of heavy elements sprinkled on 23 white dwarf stars suggests that most of the rocky planets that once orbited the stars had unusual chemical makeups, researchers report November 2 in *Nature Communications*. The elements, presumably debris from busted-up worlds, provide a possible peek at those worlds' mantles, the region between the crust and core.

"These planets could be just utterly alien to what we're used to thinking of," says geologist Keith Putirka of California State University, Fresno.

But deducing what a long-gone planet was made of from what it left behind is fraught with difficulties, cautions Caltech planetary scientist David Stevenson. Rocky worlds outside of the solar system may have exotic chemical compositions, he says. "It's just that I don't think this paper can be used to *prove* that."

After a sunlike star expands into a red giant star, it ultimately blows off its atmosphere, leaving behind its small, dense core, which becomes a white dwarf star. That resulting star's great gravity drags heavy chemical elements into its interior, so most white dwarf stars have pristine surfaces of hydrogen or helium.

But more than a quarter of white dwarf stars sport surfaces with heavier elements such as silicon and iron. Those elements may have come from planets that once circled the stars and met their ends when the stars expanded into red giants (*SN: 9/24/11, p. 10*). The heavy elements on these white dwarf stars haven't yet sunk beneath the stellar surface.

For that reason, astronomer Siyi Xu of the Gemini Observatory in Hilo, Hawaii, has long studied white dwarfs. Then she met Putirka. Because he is a geologist, "he was like, 'Oh! We can look at this problem from a new perspective,'" Xu says.

Xu had been measuring the abundances of chemical elements littered on white dwarf stars by studying the wavelengths of light, or spectra, the stars give off. Putirka realized that those measurements could indicate what rocks and minerals had made up the destroyed planets' mantles, which constitute the bulk of a small planet's rock, because different rocks and minerals contain different chemical elements.

By examining white dwarf stars within about 650 light-years of the sun, Putirka and Xu reached a startling conclusion about the ripped-apart rocky planets. Contrary to conventional wisdom, most of the planetary mantles didn't resemble those of the sun's rocky planets — Mercury, Venus, Earth and Mars — the researchers say.

For example, some of the white dwarf stars have a lot of silicon, suggesting that their planets' mantles had quartz — a mineral that in its pure form consists solely of silicon and oxygen. But there's little, if any, quartz in Earth's mantle. A planet with a quartz-rich mantle would probably differ greatly from Earth, Putirka says.

Such exotic mineral compositions might affect, for example, volcanic eruptions, continental drift and the fraction of a planet's surface that consists of oceans versus continents. And all those phenomena might affect the development of life.

Stevenson, however, is skeptical of the new finding. When measuring the elemental composition of a "polluted white dwarf," he says, "you do not know how to connect those numbers to what you started with."

That's partly because the destruction of rocky worlds around sunlike stars is complicated, Stevenson says. The planets first get blasted by the red giant star's bright light. Then they may get engulfed by the star's expanding atmosphere and may even crash into one another.

Each of these traumatic events could alter a planet's elemental makeup, as well as possibly send some elements toward the white dwarf ahead of others. As a result, the planetary remains that end up on the star's surface at one snapshot in time may not reflect the worlds' starting compositions.

Xu agrees that astronomers don't know precisely how such breakups play out or which elements wind up falling onto the white dwarfs. Future theoretical studies could provide insight into the matter, she says.

Astronomers have caught asteroids disintegrating around white dwarf stars, Xu notes, which offer a small window into the breakup process. Future observations of these white dwarf stars, she says, could help reveal any changes in elemental composition over time. ■

J. DA SILVA, NOIRLAB/AURA AND NSF

ATOM & COSMOS

Astronomers rethink mission planning

New survey outlines U.S. space-science priorities into the 2030s

BY MARIA TEMMING

The Astronomy and Astrophysics Decadal Survey is a sneak preview of the next 10 years of U.S. space science. Every decade, experts assembled by the National Academies of Sciences, Engineering and Medicine collect input from astronomers nationwide to recommend a prioritized list of projects to policy makers and federal agencies. Key among those priorities are major space missions. Past to-do lists have been topped by specific big-ticket items, such as the James Webb Space Telescope (*SN: 10/9/21 & 10/23/21, p. 26*). This year, astronomers are shaking things up.

The new decadal survey, which charts the course for U.S. astronomy and astrophysics from 2022 to 2032, recommends that NASA create a program to develop several major space telescopes at a time. Investing early in multiple mission concepts could curb the risk of individual missions becoming too unwieldy and expensive, according to the report released November 4.

The recommendations "are super important," says astronomer Scott Gaudi of Ohio State University in Columbus. "They really focus the direction of astronomy in the United States — and sort of by extension the rest of the world," he says, because of international partnerships.

The proposed multimission program would reshape how major space missions are planned. In the past, "you would pick a priority, you'd build it, you'd launch it, and then you would think about what the next priority was," says astrophysicist Jonathan Fortney of the University of California, Santa Cruz, a member of the survey committee. But space telescopes are getting more ambitious, complex and expensive, Fortney says. The one-at-a-time model doesn't work so well when a single mission can take decades from blueprint to blastoff.

Having several big projects in the works offers some insurance. If researchers work on one mission for a few years and realize that the technology isn't there to make it fly on time, NASA could switch gears and send another telescope to space instead, Fortney says.

"It's the best possible outcome," says Gaudi, who was not involved in writing the report. The approach could boost confidence that big space missions can stay on budget and on schedule, he adds, after the large cost overruns and delays that have mired the long-awaited James Webb Space Telescope. This new plan is "really needed to advance astronomy into the next few decades," he says.

The first priority, according to the report, should be a space telescope that views the universe in infrared, optical and ultraviolet wavelengths, filling a gap left by other instruments. The Hubble Space Telescope mainly looks at optical and ultraviolet light, while the James Webb telescope will primarily see the universe in infrared.

With a light-collecting area more than twice as wide as Hubble's, this proposed observatory could glimpse exoplanets that are a tenth of a billionth as bright as the stars they orbit, and could tease out the specific wavelengths of light given off by those planets. The planet-hunting telescope could also observe stars, galaxies and other objects. With an estimated cost of $11 billion, the telescope would be slated to launch in the early 2040s.

Five years after starting work on that flagship mission, NASA should begin developing both a far-infrared telescope and an X-ray telescope, each costing an estimated $3 billion to $5 billion, the report recommends. A far-infrared window into the universe could help scientists study how water behaves in forming planetary systems, Fortney says. A successor to NASA's Chandra X-ray Observatory could reveal new details of galaxy evolution, supermassive black hole behavior and other energetic phenomena (*SN: 8/31/19, p. 32*).

On the ground, astronomers' highest priorities, according to the survey report, are completing two major optical observatories, the Giant Magellan Telescope in Chile and the Thirty Meter Telescope in Hawaii — though the latter project faces opposition from Native Hawaiians (*SN: 8/1/20, p. 4*).

The survey also notes that it is time to replace the Very Large Array in New Mexico and the Very Long Baseline Array of telescope dishes scattered across the United States. The proposed successor to these world-class radio observatories is the Next-Generation Very Large Array, which would be 10 times as sensitive.

Fortney is optimistic that NASA and other federal agencies will make the decadal survey's top-ranked priorities a reality. "The record has been quite good, in terms of the most prominent recommendations being born out," he says. ■

IMAGE COURTESY OF S. GAUDI

The latest Astronomy and Astrophysics Decadal Survey recommends that U.S. researchers build a planet-hunting space telescope inspired by the previously proposed mission HabEx (illustrated).

Researchers approach two humpback whales near the West Antarctic Peninsula as part of a project that tracked the animals' feeding behavior.

DUKE UNIV. MARINE ROBOTICS AND REMOTE SENSING, UNDER NOAA PERMIT 14809-03 AND ACA PERMITS 2015-011 AND 2020-016

LIFE & EVOLUTION

Whales eat more than we thought

Whale poop's ecosystem value was also underestimated

BY JONATHAN LAMBERT

Industrial whaling has plundered the seas of giant whales for much of the last century, reducing their numbers by up to 99 percent for certain species. Some scientists thought that krill — the tiny crustaceans that many whales eat in gargantuan gulps — would explode in number as a result, mostly free from the feeding pressure of the largest animals that have ever lived.

But that didn't happen. Instead, Antarctic krill numbers have dwindled since the mid-20th century by more than 80 percent in areas heavily trafficked by whalers. Many other consumers of krill, such as seabirds and fish, have also suffered in the absence of the crustaceans and their giant eaters.

Now, scientists have a clearer idea why this happened: whale poop, or rather, the lack of it.

A new study finds that baleen whales, including blue and humpback whales, eat on average three times as much krill and other food as previously thought, and more food in means more poop out. Paradoxically, the collapse of the krill may stem from fewer whales excreting iron-rich, digested krill, denying ecosystems some crucial nutrients they need to thrive. Phytoplankton blooms, which sustain krill and many other parts of the food web, rely on that iron. Restoring whale populations to prewhaling levels could help bolster these ecosystems and even store more carbon in the ocean, researchers report in the Nov. 4 *Nature*.

"It's hard to know what role whales play in ecosystems without knowing how much they're eating," says Joe Roman, a marine ecologist at the University of Vermont in Burlington who wasn't involved in the research. Whales' food intake was coarsely understood before, he says, and this study will "allow us to better understand how the widespread depletion of whales has impacted ocean ecosystems."

Assessing the diet of Boeing 737–long creatures that gulp down hordes of centimeters-long invertebrates far below the surface of the ocean is not a trivial undertaking. Previous estimates relied on dissections of dead whales or inferring whales' metabolic needs based on their size. "These studies were educated guesses, and none were conducted on live whales in the wild," says Matthew Savoca, a marine biologist at Stanford University's Hopkins Marine Station in Pacific Grove, Calif.

But new technology gave Savoca and colleagues "a chance to answer a really basic biological question about some of the most charismatic animals on Earth."

The researchers needed to know three things: how often whales feed, how big are the gulps they take and how much food is in each gulp. Using sensors suction-cupped to the backs of 321 individuals of seven whale species, the researchers could tell when the whales lunged for prey, a reliable sign of feeding. Aerial drones snapped photos of 105 whales, which the researchers used to estimate gulp size. Finally, sonar mapping revealed the density of krill in key feeding areas.

Combining these datasets provided a more detailed look at feeding than ever before, says Sarah Fortune, a marine ecologist at Fisheries and Oceans Canada in Winnipeg. Savoca and his colleagues "measured all the things you need to measure to get an accurate estimate of consumption" for baleen whales, she says.

It turns out that, on average, baleen whales eat about three times as much food as earlier estimates suggested. For example, a blue whale on average puts down 16 metric tons of krill in a day, the researchers found. Energetically, that's equivalent to around 10 million to 20 million calories, or about 30,000 Big Macs, Savoca says.

Whales aren't eating that much every day. The animals go for months without a bite when migrating vast distances.

But the sheer volume of food that they consume, and then excrete, suggests that whales shape ocean ecosystems to a larger degree than previously thought, Savoca says, making their loss that much more impactful.

That's because one role that whales play is nutrient cycler. By feeding on iron-rich krill in the deep and returning some of that iron to the surface in the form of poop, whales help keep this crucial element in the food web. Excessive whaling might have broken this iron cycle. With less iron at the surface, phytoplankton blooms shrink, krill numbers crash and the ecosystem becomes less productive, Savoca says.

Before industrial whaling killed millions of whales in the 20th century, baleen whales in just the Southern Ocean alone, a key feeding area, consumed 430 million metric tons of Antarctic krill each year, the researchers estimate. That's more than twice the biomass of Antarctic krill living in those waters today. Even with today's diminished populations, researchers estimate that whales prevent about 1,200 metric tons of iron from being lost each year, left to drift down to the dark deep of the Southern Ocean.

Whales are probably not the only factor behind the staggering loss of krill, Savoca says, but the evidence suggests that "whales play a role here, and when you wholesale remove them, the system becomes, on average, less productive."

Some whale populations are rebounding. If whales and krill could be brought back to their early 1900s numbers, the productivity of the Southern Ocean could be boosted by 11 percent, the researchers calculate. That increased productivity would translate into more carbon-rich bodies, resulting in the storage of 215 million metric tons of carbon annually, the equivalent of taking more than 170 million cars off the road for a year, the team suggests.

"Whales are not the solution to climate change," Savoca says. "But rebuilding whale populations would help a sliver, and we need lots of slivers put together to solve the problem." ■

E.R. DEGGINGER/ALAMY STOCK PHOTO

LIFE & EVOLUTION

Elusive equation describes all bird eggs

Shape formula may help with food and conservation research

BY RACHEL CROWELL

For years, scientists have tried to crack a mathematical mystery: Is there an equation that can perfectly describe each and every bird egg? Variable shell shapes complicated things. But it turns out the answer is simple. A formula using just four dimensions can calculate the profile shape of any avian egg, researchers report in an upcoming issue of the *Annals of the New York Academy of Sciences*.

The outline of a bird egg resembles one of four shapes: circular, elliptical, oval or pear-shaped. It was that last shape that had eluded the eggs-perts. Previously, researchers developed an equation that accounted for round eggs like those of brown hawk owls (*SN: 8/5/17, p. 9*), elliptical eggs like an emu's and oval eggs like a chicken's. But that formula didn't apply to the pear-shaped, or conical, eggs of birds like great snipes and king penguins.

The old formula had a few basic inputs: egg length, maximum breadth and the location of the egg's maximum diameter in relationship to the midpoint of the egg's length. To develop the universal equation, the researchers added one additional function and incorporated a fourth variable. Calculating that variable requires measuring an egg's diameter at a spot that's a quarter of the egg length away from the egg's pointed end.

A new mathematical equation describes the profile shape of all natural bird eggs.

The finding could have real-life implications, says Darren Griffin, a geneticist at the University of Kent in England, who did the work with Kent biologist Michael Romanov and Valeriy Narushin, an agricultural engineer formerly at Kent. For example, being able to calculate an egg's shape could help designers create better padded or formfitting egg containers, minimizing grocery store waste or the disappointment of arriving home and finding cracked eggs in a carton.

The equation could also help conservation efforts. When reintroducing a bird species, "one of the considerations would be 'How likely are the eggs to break?'" Griffin says. Knowing an egg's math could help researchers calculate which parts are most vulnerable to cracking, which in turn could help scientists assess where and how best to place eggs in certain habitats to help grow a bird population there.

The formula's simplicity "makes this approach practical for field studies" and requires such simple measurements that researchers could even collect them from digital photographs, says Mark Hauber, an ornithologist at the University of Illinois at Urbana-Champaign. "My lab had been working on something like this, but we weren't able to derive the new math."

The discovery of the egg equation came while the researchers were exploring how to nondestructively assess the sexes of avian embryos before eggs are incubated. The group was looking for physical differences between the attributes of eggs containing female and male embryos, Narushin says. The universal formula is an initial step in "resolving such an enigma." Now the team is searching for a universal formula for computing the volume and surface area of various eggs, as well as exploring "mathematical shell secrets," Narushin says, such as why shell thickness differs by species. ■

LIFE & EVOLUTION

Were 'penis worms' the first hermits?

Fossils suggest the critters lived in shells 500 million years ago

BY SID PERKINS

Hermit crabs have been taking shelter in abandoned shells for millions of years. But the "hermit" lifestyle has existed for far longer, new evidence suggests.

Remains of ancient squatters are preserved in rocks laid down as seafloor sediments during the Cambrian Period about 500 million years ago in what is now southern China, researchers report in the Nov. 8 *Current Biology*. Previously, the oldest known fossils suggesting hermiting behavior dated to about 170 million years ago, says Martin Smith, a paleontologist at Durham University in England.

Today, aside from hermit crabs, a few other species of crustaceans and worms will inhabit the cast-off shells of other marine creatures, mostly for protection against predators.

Smith and colleagues found dozens of empty cone-shaped shells that probably belonged to hyoliths, once-common marine invertebrates that died out more than 250 million years ago. But four of those shells appear to have been inhabited by priapulid worms — commonly known as penis worms, thanks to their suggestive body shape. Because there were no free-ranging priapulids preserved in the ancient sediments, the researchers propose that the worms were living inside the shells.

A relatively consistent ratio between the size of a worm and the shell it was preserved within suggests that the animals picked a shell based on size and then moved to another after outgrowing an adopted home, Smith says. Modern-day hermit crabs use the same strategy, though none of the roughly 20 species of penis worms around today have this hermiting behavior.

The researchers "made some good observations to support their claims" that the association between the shells and the penis worms isn't merely fortuitous, says paleontologist Jakob Vinther of the University of Bristol in England. It's not clear, however, whether the priapulids carried the shells from place to place, like hermit crabs do, or whether the animals merely lived inside them, he says.

A great variety of creatures — most of the major groups of animals alive today, including a proliferation of predators — evolved rapidly during the Cambrian Period, which began about 542 million years ago (*SN: 4/27/19, p. 32*). As a result, many researchers refer to that explosion of diversity as life's Big Bang.

"Perhaps it's not a surprise that some priapulids became hermits when you think about what this predatory arms race was all about: eating, ducking and hiding," Vinther says. ■

Sea creatures known as penis worms (one illustrated) hid out in empty shells, possibly for protection from predators, about 500 million years ago, newly described fossils suggest.

LIFE & EVOLUTION

How pearls get their round shape

Understanding the symmetry could inspire better materials

BY RACHEL CROWELL

For centuries, researchers have puzzled over how oysters grow perfectly round pearls around irregularly shaped grains of sand or bits of debris. Now a team has shown that oysters and other mollusks use a complex pearl-growing process that follows mathematical rules seen throughout nature.

Pearls form when an irritant gets trapped inside a mollusk. The animal protects itself by building smooth layers of mineral and protein — together called nacre — around the irritant. A mollusk adapts each new nacre layer built over this asymmetrical center to the ones preceding it. By smoothing out irregularities, the result is a round pearl, researchers report in the Oct. 19 *Proceedings of the National Academy of Sciences*.

"Nacre is this incredibly beautiful, iridescent, shiny material that we see in the insides of some seashells or on the outside of pearls," says Laura Otter, a biogeochemist at the Australian National University in Canberra.

A pearl's symmetrical growth relies on the mollusk balancing two basic capabilities, Otter and colleagues discovered. First, the mollusk corrects growth aberrations that appear as the pearl forms, preventing those variations from propagating over the pearl's many layers. Otherwise, the pearl would be lopsided.

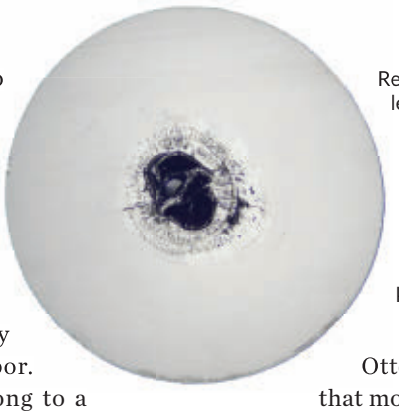
Additionally, the mollusk modulates the thickness of nacre layers, so that if one layer is especially thick, subsequent layers will be thinner. This helps maintain a similar average thickness over the pearl's thousands of layers so that it looks round and uniform. Without that constant adjustment, a pearl might resemble stratified sedimentary rock, amplifying small imperfections that detract from its spherical shape.

Otter's group studied keshi pearls

ZHIQIAN ZHANG, YUNNAN UNIV.

collected from Akoya pearl oysters (*Pinctada imbricata fucata*) at a pearl farm in eastern Australia. The team used a diamond wire saw to cut the pearls into cross sections, then examined the gems using Raman spectroscopy, a nondestructive technique that allowed the researchers to characterize the pearls' structure. In one example, the team counted 2,615 layers in a pearl, which were deposited over 548 days.

The analysis revealed that fluctuations in the thicknesses of the pearls' layers of nacre exhibit a phenomenon called 1/f noise, or pink noise, in which events that appear to be random are actually connected. In this case, the formation of nacre layers of different thicknesses is dependent on the thickness of previous layers. The same phenomenon is at work in seismic activity: The rumbling of the ground seems random, but is actually connected to previous recent seismic activity. Pink noise also crops up when monitoring heartbeats and brain activity, says team member Robert Hovden, a materials scientist and engineer at the University of Michigan in Ann Arbor. These phenomena "belong to a universal class of behavior and physics," Hovden says.



Researchers have learned how a mollusk lays down layer after layer of nacre around a misshapen lump of debris to create a symmetrical pearl (a cross section of a keshi pearl is shown).

This is the first report that a mollusk heals its nacre, and that "when a defect arises, it heals itself within a few [layers] without using an external scaffolding or template," says Pupa Gilbert, a physicist who studies biomineralization at the University of Wisconsin–Madison. "Nacre is an even more remarkable material than we had previously appreciated."

Otter agrees, noting that mollusks are able to make "a super light and super tough material so much more easily and better than we do with all our technology." Made of just calcium carbonate and protein, she says, nacre is "3,000 times tougher than the materials from which it's made."

Hovden adds that this new understanding of pearls could help scientists make "the next generation of super materials." ■

LIFE & EVOLUTION

Assassin bugs calm prey before striking

A gentle tap, perhaps mimicking a friendly signal, lulls spiders

BY JAKE BUEHLER

Assassin bugs live up to their name. The insects stalk and feed on other small invertebrates, jabbing them with a venomous proboscis. Some species even hunt spiders and use a strange trick to gain the upper hand.

Using their antennae, assassin bugs tap spiders, which appears to discombobulate them long enough to let the assassin bugs make a toxic strike, researchers report September 29 in the *Biological Journal of the Linnean Society*. The findings provide insight into some of the sophisticated hunting tactics that predators evolve when targeting dangerous prey.

Thread-legged bugs are a subfamily of particularly gangly assassin bugs, and some species spend their lives in a place most insects avoid: spiderwebs. Silently creeping along a spider's silk, an assassin bug takes care to make its vibrations seem benign before violently seizing the spider and injecting venom.

While watching *Stenolemus* assassin bugs hunt spiders, ecologists Anne Wignall and Fernando Soley took note of the bugs' habit of lightly knocking their antennae on spiders once the bugs were within striking distance.

"It struck us early on that tapping prey was a really strange thing to do," says Wignall, of Massey University in Albany, New Zealand. "Watching [the bugs] spend so much time and effort on stealth, only to essentially tap [the spiders] on the shoulder was absolutely fascinating."

To figure out why the bugs tap, Wignall and Soley, of the Organization for Tropical Studies in San José, Costa Rica, studied 30 web-building cellar spiders (*Pholcus phalangioides*) in the lab. The researchers replicated the antennae tapping by gently brushing spiders on the leg with a dog hair. After the tapping, the team measured the spiders' responses to a vibrating tuning fork touching the web, which mimicked a struggling insect. Responses included turning toward the fork, attacking it or not responding at all.

Tapped spiders were far less aggressive than those that weren't tapped, fully ignoring the fork four times as often. Tapped spiders also attacked the fork only about a quarter as often as their untapped counterparts.

Wignall thinks that the assassin bugs reduce spiders' aggression levels by imitating the types of physical touch that these typically solitary spiders experience near fellow spiders. "Whenever they do come across another spider, it's usually because it's a close relative such as a sibling in the nest, or a potential mate," she says, "both of which are situations in which aggression would not be a good idea."

Ondřej Michálek, an invertebrate zoologist at Masaryk University in Brno, Czech Republic, calls this a "completely valid hypothesis." Many spiders avoid cannibalism by using tactile signals that could be copied by adroit predators, thereby deceiving the arachnids, he says.

Going forward, Wignall wants to understand the tapping in greater detail, determining how many taps are sufficient to pacify a spider and the number of spider species that the bugs are manipulating. ■

JISEOK GIM

LIFE & EVOLUTION

A migrating songbird is heading west

Warming may be shifting where an Asian species spends winter

BY JAKE BUEHLER

As the chill of autumn encroaches on Siberia's grasslands, Richard's pipits usually begin their southward trek to warmer latitudes. But a growing number of the slender, larklike songbirds seems to be heading west instead, possibly establishing a new migratory route.

This would be the first new route known to emerge on an east-west axis in a long-distance migratory bird, researchers report October 22 in *Current Biology*. The finding could have implications for how scientists understand the evolution of bird migration routes over time and how birds adapt to a shifting climate.

Richard's pipits (*Anthus richardi*) typically breed in Siberia during the summer and travel south for the winter to southern Asia. Occasionally, "vagrant" birds get lost and show up far from this range, including in Europe. But as a Ph.D. student at the Université Grenoble Alpes in France, evolutionary biologist Paul Dufour noticed, along with colleagues, that sightings and photo records of the pipits wintering in southern France had increased from a handful of birds annually in the 1980s and 1990s to many dozens in recent years.

So, Dufour, now at the University of Gothenburg in Sweden, and colleagues started monitoring the pipits in France and Spain to see where they were coming from, and if the birds were visiting Europe on purpose or just getting lost.

The researchers captured seven pipits in France during the winter of 2019–20, tagging them with a sensor that estimates geographic position based on light levels and day length. The team released the birds and successfully recaptured three of them the next winter. Those sensors showed that the birds had all flown back to the same part of southwestern Siberia for the summer before returning to France.

The team also examined images taken by citizen scientists of 331 Richard's pipits in Europe and North Africa, categorizing the birds by apparent age.

A Richard's pipit stands in Fréjus, France. Larger numbers of the songbirds have been wintering in southern Europe instead of southern Asia in recent years, researchers say.

GAËTAN JOUVENEZ

Among songbirds in general, Dufour says, vagrants are usually young birds. Songbirds tend to follow a migration route based on instincts written into their DNA, replicating the trip their ancestors took. But storms or mutations that create faulty wayfinding abilities can send young songbirds off target.

A songbird's first migration creates a mental map for every migration after. So in the new study, any adult Richard's pipits identified in Europe must have made the trip more than once. Since more than half of the birds in southern Europe and nearby northwestern Africa documented in the winter were adults, Dufour and colleagues think that many of these pipits are seasonal migrants.

Contemporary shifts in migration routes are more common in species that travel via the cues of a traveling group, like geese or cranes. Since songbirds usually migrate alone, changes to migration patterns are rarer, Dufour says.

What's more, east-west migration is unusual in birds. Most species that travel this way migrate short distances within the tropics, says ornithologist Jessie Williamson of the University of New Mexico in Albuquerque, who was not involved with the research. "It's exciting that an understudied migratory behavior like east-west migration is in the spotlight," she says.

If the pipits' European trek is in fact now an established route, it's possible that the detour was facilitated by climate change. Dufour's group used computer models that estimate climate suitability for the pipits in Europe based on variables like temperature and precipitation. The researchers compared two periods — 1961 to 1990 and 1990 to 2018 — and found that higher temperatures in the latter period have made most parts of southern Europe a better wintering location for the birds than they were before.

The selection of European wintering grounds may also involve the loss of habitat at ancestral, southern Asian sites, but the researchers haven't investigated that yet. Climate change could be affecting that too, Dufour says. But "we suspect that habitat modification in Southeast Asia — increasing urbanization, less open areas — may also be part of the equation."

Ginny Chan, an ecologist at the Swiss Ornithological Institute in Sempach who was not involved with the research, says that the types of environmental changes that could be hurting bird populations "are happening very quickly in the traditional wintering range [for the pipits] in South and East Asia." In India, the Richard's pipit population has declined by more than 90 percent over the last couple of decades, Chan says.

Other Siberian bird species that typically migrate south may also be making their own westward routes, Dufour suspects. The yellow-browed warbler and Siberian chiffchaff, for instance, have recently shown up in Europe in growing numbers.

If other Siberian songbird species are also establishing new western migration routes, migratory songbirds may be more flexible travelers than scientists previously thought, Dufour says.

That could offer hope for the survival of bird species worldwide dealing with a changing climate. But the new research, Dufour says, shouldn't overshadow studies of other migratory birds, such as barnacle geese and the European pied flycatcher, that show that some species are less able to cope with climate change. ■

GENES & CELLS

Tweaked stem cells help geckos regrow more perfect tails

Geckos can regrow tails, but they are pale imitations of the original. Now, genetically modified stem cells are helping the lizards grow back better tails, researchers report October 14 in *Nature Communications*.

A gecko's tail is an extension of its spine, with the vertebrae to prove it. But a regenerated tail is "just a bunch of concentric tubes of fat, muscle and skin," says biologist Thomas Lozito of the University of Southern California in Los Angeles.

That's because stem cells in adult geckos send a molecular signal that encourages the formation of cartilage, but not bone or neural tissue, in regrowing tails. Lozito and colleagues took embryonic stem cells, which develop into a wider range of tissues than adult stem cells, and modified them to ignore the signal. When the cells were implanted in the tail stumps of geckos that had their tails removed, the tails that grew back had some neural tissue and bonelike grooves in the cartilage.

The work is a step toward developing regenerative therapies to treat hard-to-heal wounds in people. — *Freda Kreier*

HUMANS & SOCIETY

Partial skull adds to the mystery of how *Homo naledi* treated the dead

A partial skull found in a South African cave system has fueled the belief that an ancient hominid known as *Homo naledi* deliberately disposed of its dead in caves.

A researcher holds the reconstructed skull of a *Homo naledi* child, based on fossil pieces and teeth (lighter-colored areas) found in a cave.

Paleoanthropologist Lee Berger of University of the Witwatersrand in Johannesburg and colleagues pieced together 28 skull fragments and six teeth from a child's skull. The fossils were discovered in a narrow opening located about 12 meters from an underground chamber where explorers first found *H. naledi* fossils (*SN: 10/3/15, p. 6*). Features of the skull qualify it as *H. naledi*, which had skeletal characteristics of both present-day people and *Homo* species from around 2 million years ago.

"The case is building for deliberate, ritualized body disposal in caves by *Homo naledi*," Berger said at a November 4 news conference. That argument is controversial, but there's no evidence that the skull was washed into the space or dragged there by predators or scavengers.

Berger's group describes the partial skull, nicknamed Leti, in two papers published November 5 in *PaleoAnthropology*. Leti probably dates to the same time as other *H. naledi* fossils, between 335,000 and 236,000 years ago. — *Bruce Bower*

ATOM & COSMOS

Neutron star smashups may forge more gold than other collisions

The origins of elements heavier than iron are mysterious. One birthplace came to light in 2017 when two neutron-rich dead stars collided and spewed out gold and other hefty elements. A few years later, the smashup of a neutron star and a black hole left scientists wondering if that type of clash is a more prolific element foundry.

Collisions of two neutron stars probably take the cake, scientists report in the Oct. 10 *Astrophysical Journal Letters*.

To create heavy elements after either type of collision, neutron star material must be flung into space, where a series of nuclear reactions transform the material.

How much material escapes into space, if any, depends on various factors. For example, in neutron star–black hole collisions, the black hole has to be relatively small, or else it will swallow the neutron star right away without ejecting anything, says MIT astrophysicist Hsin-Yu Chen.

Chen and colleagues considered a range of possibilities for the properties of colliding neutron stars and black holes, such as the distributions of their masses and how fast they spin. The team then calculated the mass ejected by each type of collision under varied conditions. In most scenarios, neutron star–black hole mergers made a smaller quantity of heavy elements than neutron star duos — in one case only about a hundredth the amount.

Still, the ultimate element factory ranking remains up in the air because the team didn't consider other possible sources of heavy elements such as exploding stars (*SN: 8/14/21, p. 8*). — *Emily Conover*

ATOM & COSMOS

Recent supernova gave scientists a peek at a star's last year of life

A mad scramble to observe the moments after a star's death is helping to reveal how the star lived out its last year.

Astronomers reported the exploding star just 18 hours after it flared up on March 31, 2020, in a galaxy about 60 million light-years away from Earth. The supernova occurred in an area watched by NASA's Transiting Exoplanet Survey, which images large portions of the sky every half hour. Such data allowed scientists to precisely track how the eruption brightened over time.

To learn more, the team viewed the supernova with many telescopes in the hours and days that followed. That provided the supernova's spectrum, an accounting of its light broken up by wavelength, at various points after the blast.

All that data revealed that in its last year, the star had expelled some of its outer layers into space, researchers report October 26 in *Monthly Notices of the Royal Astronomical Society*. The amount of material ejected was nearly a quarter of the mass of the sun. When the supernova went off, it launched a shock wave that plowed through that material, generating light picked up by the telescopes.

Aging stars fuse heavier and heavier elements in their cores. For this star, the switch to fusing oxygen atoms together may have triggered the shedding, Samaporn Tinyanont of the University of California, Santa Cruz and colleagues say. — *Emily Conover*

A Change of Course

A sailor is one of many struggling with unfamiliar fungal infections

By Aimee Cunningham

Tyson Bottenus once captained an 80-foot schooner called the *Aquidneck*. He sailed tourists off the coast of Newport, R.I., discussing the area's history and sites. In January 2018, he had finished another season at the schooner's helm and had recently gotten engaged to his partner of many years, Liza Burkin. To celebrate, the couple, avid cyclists who've ridden through New Zealand and Japan, set off for a bike tour of Costa Rica.

"We were on this very, very dusty road for a long time," Bottenus remembers of a ride to Montezuma on the Nicoya Peninsula. "It was a dirty, sandy, hard-packed road." While going downhill, Bottenus crashed, badly scraping his elbow. The next morning, a doctor spent about an hour picking out little rocks and cleaning dirt from

For Tyson Bottenus, shown below at the helm of the *Aquidneck*, being the captain of a schooner was "one of the best jobs I've ever had."

COURTESY OF T. BOTTENUS

the wound before she bandaged it up. The injury kept him from swimming but otherwise didn't disrupt the trip.

About a month after returning to Rhode Island, Bottenus started having headaches. He couldn't control his mouth properly — his speech was off, and he was drooling. Eventually his doctor ordered an MRI, which revealed a lesion in his brain. "My first thought was, I must have some sort of cancer," he says. "I'm only 31.... I'm way too young for this."

It wasn't cancer. Nor was it any of the infections proposed as doctors searched for a diagnosis. Two brain biopsies didn't provide enough tissue to identify the problem.

Doctors believe Bottenus picked up a fungal infection during a 2018 biking trip in Costa Rica. He is shown here after the crash that injured his arm.

COURTESY OF T. BOTTENUS

In August 2018, Bottenus became very ill and was hospitalized. He couldn't walk. His mouth muscles weren't working. And he could no longer tie the drawstring of his pants with a square knot, a common knot sailors use to fasten two ropes together. It's a knot Bottenus has taught others and could previously do with his eyes closed. "I'm a captain of boats, supposedly," he remembers thinking. "I am not the person I think I am."

Finally, a third brain biopsy, taking a slightly larger amount of tissue, yielded a diagnosis: Bottenus had a fungus growing in his brain. It was a black mold called *Cladophialophora bantiana* that can breach the blood-brain barrier. The best medical guess is that Bottenus was exposed in Costa Rica — probably from the dusty air he inhaled, or maybe from the debris-laden wound on his elbow.

People are exposed to fungi all the time, and usually we get along just fine. Fungi are in the air, in the soil and in us, part of the community of microbes that live in our bodies. Fungi that inhabit plant roots form crucial partnerships with more than 90 percent of land plant species, helping the plants absorb water and nutrients from the soil in exchange for food. But some fungi are also infectious pathogens that can cause pneumonia, blindness and meningitis.

Emerging threats

An estimated 2 million people globally die from fungal diseases each year. And pathogenic fungi tend to harm those with the least means. Fungal keratitis, an infection of the cornea, strikes more than a million people annually, estimates suggest, and blinds around 600,000. Found in tropical and subtropical areas, the disease — usually treatable when diagnosed early — often impacts young, poor agricultural workers. Another example, chronic pulmonary aspergillosis, is a lung infection that commonly occurs in people already burdened with lung damage from tuberculosis.

Fungal infections are also a threat to people with HIV, a virus that weakens the immune system. When defenses are down, typically benign fungi can take advantage of the gaps in our immunological armor and cause an infection. In resource-rich areas, fungal infections have decreased with earlier HIV diagnosis and the availability of antiretroviral drugs. But in places where people can't get early, consistent HIV care, fungal infections have stubbornly persisted as dangerous complications of HIV and AIDS.

Advances in modern medicine that have extended lives have also led to more fungal infections. Organ transplantation and treatments for cancer and autoimmune diseases have created a large population of people who regularly take drugs that inhibit components of the immune system, leaving these patients susceptible to fungal invaders.

Some fungi have emerged as recent threats to human health. First reported in Japan in 2009 as the cause of an ear infection, a yeast called *Candida auris* unexpectedly caused outbreaks of invasive infections — those that reach the blood, spinal fluid or other typically sterile areas of the body — on three continents a few years later. Hospital patients are especially at risk from the yeast, which is resistant to certain antifungal drugs.

Scientists have proposed that the emergence of *C. auris* as a danger to people may be tied to our warming climate, with the yeast gaining temperature tolerance in the environment. That could explain why *C. auris* can replicate inside human bodies, a niche that's usually too hot for many fungi.

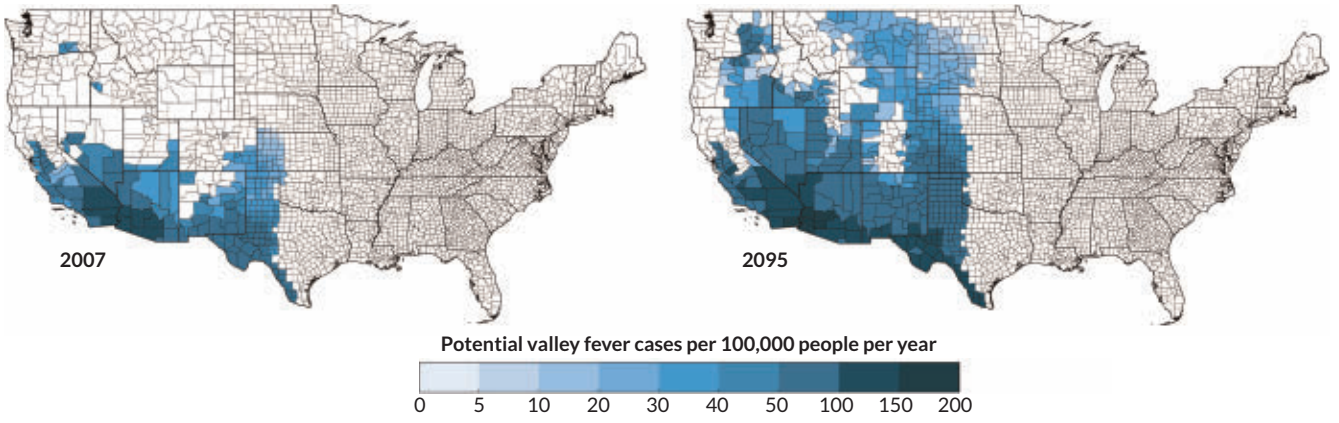
The warming climate may make other fungal pathogens more widespread. *Coccidioides*, a fungus that shape-shifts from a soil-dwelling,

1.5 million
Estimated worldwide deaths from tuberculosis in 2020

1.8–3 million
Estimated worldwide deaths from COVID-19 in 2020

2 million
Estimated worldwide annual deaths from fungal diseases

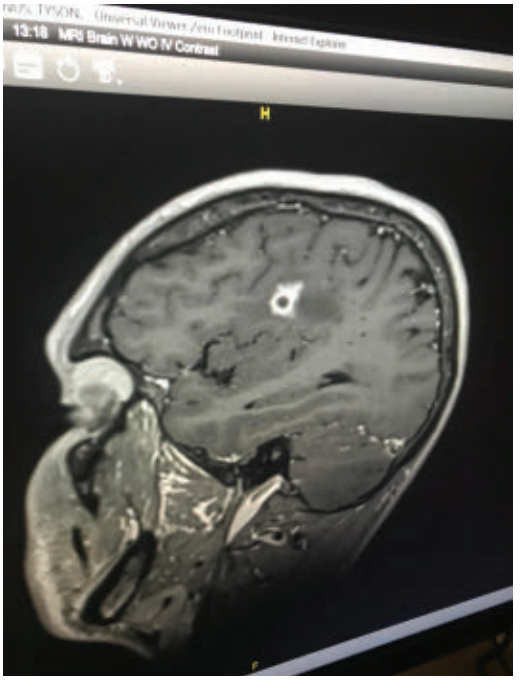
SOURCES: WORLD HEALTH ORGANIZATION; GLOBAL ACTION FUND FOR FUNGAL INFECTIONS



One fungus' spread
By the end of the century, global warming could expand the habitat of the fungus that causes valley fever. These maps show the predicted increase in the incidence of the disease, which today is found mainly in the southwestern United States. Symptoms include fever, fatigue and cough.

fluffy mold to aerosolized spores to round, parasitic cells at the site of infection, causes a disease called valley fever. Someone who breathes in the spores might not have symptoms at all or could become fatigued, short of breath and develop a fever, cough and night sweats. It's among the fungal pathogens that can strike healthy immune systems. In the United States in 2019, 18,407 cases were reported to the U.S. Centers for Disease Control and Prevention.

Coccidioides is primarily found in southwestern states, but global warming could change that. "The entire western United States has been identified as potential habitat," says medical mycologist Bridget Marie Barker of Northern Arizona University in Flagstaff. The fungi thrive in hot, dry environments where there are brief, heavy rains. Climate change is expected to make western states hotter and alter precipitation patterns. Research reported in *GeoHealth* in 2019 predicts that by 2100, the areas impacted by *Coccidioides* could expand north in the western half of the country and annual cases could increase by 50 percent.



This 2018 image of Tyson Bottenus' brain shows a lesion (white spot) that was later diagnosed as an infection with a fungus called *Cladophialophora bantiana*.

Treatment pitfalls

Despite the heavy burden of fungal diseases and the potential for that burden to grow, there are no approved vaccines against fungi, and the medicine cabinet of fungal remedies is not deep. There are only a few types of antifungal drugs. It's difficult to develop antifungals in part because fungi are eukaryotes. Like us, and unlike bacteria, their cells have distinct, membrane-bound compartments, including a nucleus that holds their genetic material. That shared biology means that if a drug can kill fungi, it might harm us too.

The antifungals that do exist "are not spectacular," says pediatric infectious disease physician and medical mycologist Damian Krysan of the University of Iowa Carver College of Medicine in Iowa City. Even with treatment, invasive fungal infections are difficult to survive. For example, an invasive infection with the mold *Aspergillus* has a mortality rate ranging from 40 to 90 percent in patients with weakened immune systems, depending on where the infection is, among other factors. For a cancer patient with a great prognosis who develops an *Aspergillus* infection, Krysan says, "you can be cured of your cancer and die of your fungal infection."

Even diagnosing a fungal infection is challenging. For one, there are fewer diagnostic tests specific to fungi than there are for viruses and bacteria. Another problem is that the symptoms of a fungal infection can resemble those caused by other pathogens. And fungi grow slowly, so it takes longer to confirm that a blood or tissue sample is

FROM TOP: M.E. GORRIS *ET AL/GEOHEALTH* 2019; COURTESY OF T. BOTTENUS

infected with a fungus. A delayed diagnosis can mean delayed treatment, which complicates the chances of recovery.

Into this uncertain medical terrain landed Bottenus, a previously healthy young man who acquired an exceedingly rare fungal infection in his brain.

Uncharted waters

Bottenus has been treated with antifungal drugs and steroids. It's been a "vicious cycle," says Robbie Goldstein, an infectious disease physician at Massachusetts General Hospital who has been part of Bottenus' team of doctors. The steroids reduce the inflammation from the infection, which puts dangerous pressure on Bottenus' brain. But the steroids also suppress his immune system, impairing his ability to clear the fungus. When doctors have tried to taper the steroids, the inflammation in Bottenus' brain has gotten worse.

As the COVID-19 pandemic began, Bottenus became nervous that being immunocompromised put him at greater risk of getting sick from the coronavirus. So he stopped taking the steroids. The resulting inflammation triggered a stroke at the end of March 2020. In the several weeks he spent in the hospital, pandemic restrictions prevented Burkin from visiting.

Bottenus is still coping with the effects of the brain infection and the stroke. He has lost most of his peripheral vision. His speech is altered. Navigation is a struggle — he has a hard time finding his way around, even in his home. Bottenus kept telling himself that he'd wake up one day and be back to where he used to be. "But of course that's a fantasy," he says.

Yet other brain functions don't seem to have been harmed. Bottenus began graduate school in the fall of 2020 and has done well in his classes. "He can't really bike across our neighborhood by himself," Burkin says, "but he can write a 20-page research paper."

The whole experience has changed Bottenus' personality, Burkin says. Her adventurous partner has become reliant on structure and routine. "I think that's really normal for people who've gone through a life-threatening disease, where you have no control," she says. Bottenus says, living "is as much adventure as I can get."

In the published cases of *C. bantiana* infections, the death rate can be as high as 70 percent. Many times, the infection isn't diagnosed until a patient's autopsy, Goldstein says. For those who live with this infection, he says, the studies "don't say what that life is like." Bottenus and Burkin are crossing uncharted medical territory.

COURTESY OF T. BOTTENUS

Tyson Bottenus and his partner, Liza Burkin, an urban planner, ride their tandem bike in the spring of 2021. Bottenus' infection with a rare fungus is "the universe being purely chaotic," Burkin says.

For now, Bottenus is a passenger on friends' boats. When he bikes, he follows Burkin, or they ride a tandem. He makes sure to have his cell phone when he goes out, in case he gets lost. "He used to literally be able to do celestial navigation and lead us on bike tours across continents," Burkin says. "I don't know that it is permanent, these changes. I don't think there's any way to know."

But "I can't blame this fungus," she says. "We were out on a bike ride and some dirt got into his body."

Sometimes a doctor meets a patient after they've already been seriously harmed by an infection, Goldstein says. But he got to know Bottenus from the beginning, when the young sailor was searching for a diagnosis. Goldstein says this experience has made him really aware, when he's talking to a patient, of how devastating an infection can be to the life they had before.

"Before there was an infection," he says, "there was a person." ■

Explore more

- Matthew C. Fisher *et al*. "Threats posed by the fungal kingdom to humans, wildlife and agriculture." *mBio*. May 5, 2020.

A Serious Look at Psychedelics

Evidence is building that these mind-altering drugs can treat PTSD and depression, but hurdles remain

By Laura Sanders

In 2019, Denver residents (above) voted to decriminalize psilocybin mushrooms, which can induce a psychedelic shift in consciousness. In 2020, Oregon legalized psilocybin-assisted therapy, recognizing its possible medicinal value. Other locales may soon follow suit.

MICHAEL CIAGLO/GETTY IMAGES

Kanu Caplash was lying on a futon in a medical center in Connecticut, wearing an eye mask and listening to music. But his mind was far away, tunneling down through layer upon layer of his experiences. As part of a study of MDMA, a psychedelic drug also known as molly or ecstasy, Caplash was on an inner journey to try to ease his symptoms of post-traumatic stress disorder.

On this particular trip, Caplash, now 22, returned to the locked bathroom door of his childhood home. As a kid, he used to lock himself in to escape the yelling adults outside. But now, he was both outside the locked door, knocking, and inside, as his younger, frightened self.

He started talking to his younger self. "I open the door, and my big version picks up my younger version of myself, and literally carries me out," he says. "I carried myself out of there and drove away."

That self-rescue brought Caplash peace. "I got out of there. I'm alive. It's all right. I'm OK." For years, Caplash had experienced flashbacks, nightmares and insomnia from childhood trauma. He thought constantly about killing himself, he says.

His experiences while on MDMA changed his perspective. "I still have the memory, but that anger and pain is not there anymore."

Caplash's transcendent experiences, spurred by three therapy sessions on MDMA, happened in 2018 as part of a research project on PTSD. Along with a handful of other studies, that research suggests that when coupled with psychotherapy, mind-altering drugs bring some people immediate, powerful and durable relief.

Those studies, and the intense media coverage they received, have helped launch psychedelic medicine into the public conversation in the United States, England and elsewhere. Academic groups devoted to studying psychedelics have sprung up at Johns Hopkins, Yale, New York University Langone Health, the University of California, San Francisco and other research institutions. Private investors have ponied up millions of dollars for research on psychedelic drugs. The state of Oregon has started the process of legalizing therapeutic psilocybin, the key chemical in hallucinogenic mushrooms; lawmakers in other states and cities are considering the same move.

New ways to help people with PTSD, depression, anxiety and other mental health disorders are desperately needed. An estimated 30 percent of people with depression, for instance, don't get relief from current treatments. Psychedelics, some researchers and clinicians believe, may help.

"The promise is incredible," says Monnica Williams, a psychologist at the University of Ottawa, who ran the clinical trial Caplash participated in at UConn Health in Farmington. "Psychedelics have the potential to really completely revolutionize mental health and change everything."

But a cloud of questions hovers over the research. It's not known how the therapy works or who it might work for. Even if these new treatments perform well in clinical trials, the drugs, and the mind-bending experiences they bring, won't appeal to everyone. What's more, the drugs may not be available, or they may cost too much.

Psychedelic drugs, including MDMA, psilocybin and the hallucinogen LSD, which is also being studied as a treatment for depression and other mental health disorders, are illegal under federal law, classified as Schedule 1 substances by the U.S. government — with high potential for abuse and no currently accepted medical use. Many people may be reluctant to take an illegal drug that lowers their defenses and makes them vulnerable, no matter how great the promise of healing.

KASEY SCHEMPF

In 2018, Kanu Caplash participated in a clinical trial of MDMA as a treatment for PTSD. The experience brought him relief, he says. Today he is a college student who works as a mental health advocate.

Social and legal hurdles, barriers to access and scientific questions make it unlikely that psychedelics will replace current mental health treatments, many experts agree. More likely is that with enough research, psychedelic substances will become another tool for doctors and therapists.

Caplash remembers what MDMA did for him right after his sessions. "I wasn't as angry as I was before. My muscles were a lot less tense. I could literally see clearer," Caplash says. "As I went through the study, I was also becoming a different person."

The benefits are still with him. Caplash no longer thinks of suicide. A biology major at the University of Connecticut, he has big dreams and advocates for more accessible mental health care for others. "I feel like I'm at peace, to an extent," he says. "I know who I am and what I want to do."

A winding path

Psychedelic drugs are not new. Scientists at the pharmaceutical company Merck made MDMA in 1912. Swiss chemist Albert Hofmann synthesized LSD in 1938, and Aldous Huxley popularized the drug in his 1953 book *The Doors of Perception*. When people talk about the psychedelic renaissance, they often begin with Hofmann and Huxley, says Sutton King, who advocates to include Indigenous voices in discussions about psychedelics and is an Afro-Indigenous member of the Menominee and Oneida Nations of Wisconsin.

But the story of psychedelics starts long before then. Indigenous communities around the world have used psilocybin and other consciousness-changing compounds for healing for thousands of years.

"The traditional Indigenous Nations ... have had these connections to these medicines," says King, who is cofounder and president of the Urban

Indigenous Collective, a nonprofit advocacy group in New York City.

Belinda Eriacho, a wisdom carrier of Dine' (Navajo) and A:shiwi (Zuni) descent, believes that psychedelic drugs, called sacred plant medicines by some Indigenous groups, are catalysts to help align mental, physical, spiritual and emotional health. "We were the knowledge keepers," she says. "A lot of our understanding about these medicines is through practical experiences. They are not something you can read in a book."

But around the middle of the 20th century, medical researchers, dissatisfied with existing mental health treatments, began trying to quantify these drugs' effects on mental states. A flurry of research yielded promising hints, but many of those early attempts didn't yield solid data. Some experiments were poorly designed; worse, some were deeply unethical, forcing high doses of psychedelics on people who were incarcerated or experiencing psychosis. Many of those study subjects were people of color.

In the 1960s, social and political sentiments began turning against these drugs — and the counterculture they represented — in both non-Indigenous and Indigenous communities. The U.S. government criminalized the use of psychedelics to keep them out of the public's hands. The new restrictions kept the drugs out of researchers' hands, too.

That social shift stigmatized the drugs and whatever promise they held, says neuroscientist Rachel Yehuda, who has studied PTSD for decades at the Icahn School of Medicine at Mount Sinai in New York City. Current drug treatments for PTSD, such as antidepressants or sleep medications, don't work well for some people, she says. These medicines may help with symptoms, but don't get at the root of the problem. Psychedelics might do more, she's come to realize.

Two years ago, when Yehuda began studying psychedelic drugs, she faced a lot of skepticism. But those dismissals have disappeared. "The general attitude in academic medicine right now is, 'Gosh, let's try it. Let's see. Maybe it will be good. Wouldn't that be nice?' "

In some ways, psychedelics can outperform approved psychiatric drugs such as Prozac and other selective serotonin reuptake inhibitors, or SSRIs. And so far, the data suggest psychedelics work quickly, appear to be safe and have lasting effects, says Atheir Abbas, a psychiatrist and neuroscientist at Oregon Health & Science University in Portland. "That is hard to come by. I think that is extremely exciting."

In the last five years, a handful of high-quality, albeit small, studies have suggested tremendous benefits from the psychedelic psilocybin for depression, anxiety and PTSD. The studies differ in their details, but many follow a similar arc. Generally, the studies begin with talk therapy sessions, followed by several therapy sessions in which participants are under the influence of a psychedelic drug. More psychotherapy comes afterward. At certain points in the process, researchers measure the participants' symptoms.

Psilocybin-assisted therapy quickly reduced signs of depression among 24 participants with moderate or severe depression, scientists reported in 2020 in *JAMA Psychiatry*. Four weeks after two psilocybin sessions, 71 percent of the participants had maintained a drop of at least 50 percent in their scores on a depression rating scale called the GRID-HAMD.

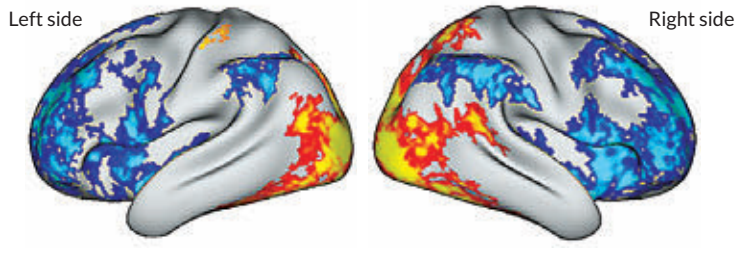
Earlier work showed psilocybin could help with depression and anxiety in patients facing life-threatening cancer; the benefits were still there about four years after the psilocybin treatment, researchers reported in the *Journal of Psychopharmacology* in 2020.

MDMA therapy seemed to have similar effects in an international study of 90 people with PTSD. Two-thirds of those who got MDMA no longer qualified for a PTSD diagnosis at the end of the trial, compared with about one-third of participants who received placebos. Those results appeared May 10 in *Nature Medicine*.

Collectively, the studies offer strong hints that psilocybin, MDMA and other psychedelic drugs can help in these research settings, says Scott Thompson, a neuroscientist at the University of Maryland School of Medicine in Baltimore. "All of them are giving the same sort of signal," he says.

Changing minds Psilocybin can change brain activity, but it's not clear if these shifts relate to mental health. In a study in healthy people, red and orange show where psilocybin boosted brain connectivity compared with a placebo. Those regions are important for handling information coming in from the senses. Blue shows where connections were weaker in people who took psilocybin than in those on a placebo.

The brain on psilocybin



K.H. PRELLER *ET AL/BIOLOGICAL PSYCHIATRY* 2020

We're in a moment when Western research is converging with the long history of Indigenous knowledge, King says. There is a place for both approaches, "two truths," as King puts it, when it comes to helping people with psychedelic drugs.

King adds that the excitement coming from laboratories is accompanied by fear for some Indigenous people: fear of their ceremonies being appropriated, fear of worsening access to their medicines and fear of these substances being misunderstood. "It's an exciting time, but it's also a scary time for Indigenous peoples," she says.

The healing components

One big question is how the various psychedelic drugs work. "If you look at all the knobs people are turning, it's really not known what's critical and what's not," Abbas says. The talk therapy that often goes with the drugs, the psychedelic trip or other drug effects could all be important.

Some people suspect that the psychotherapy is the healing component, not the drug itself. And plenty of data show that therapy works well for some people. Many of the key trials so far have been testing the drug in tandem with intense psychotherapy. Caplash, for instance, had multiple therapy sessions before, during and after his MDMA experiences. Similarly intense therapy sessions happened for people in the trial of psilocybin for depression. The drugs might make a person open to exploring some of the painful events of their past during therapy.

Others suspect that the psychedelic trip itself, the hallucinatory experience, is a crucial part of the treatment. That's a hard question to study, but not impossible, Yehuda says. "We need the science to understand what transformation looks like, and how a drug facilitates it," she says. "We've been afraid of studying the biology of altered states, or even consciousness, because it feels so wonky and so unscientific and so subjective and woo woo. But I think we should be up for this challenge."

Other scientists are focusing on the actions of the drugs themselves, by looking inside the brain. Thompson, for instance, suspects that it's possible to get the benefits and skip the trip by restricting cells' responses to serotonin, a chemical messenger that's thought to be involved in the hallucinations. His recent study in mice hints that this just might be possible.

In the mice, Thompson and colleagues blocked a sensor thought to spark psilocybin-related hallucinations. When this serotonin-detecting receptor, called 5-HT2A, was blocked, the mice appeared to stop tripping (their heads no longer twitched). Yet, psilocybin still had antidepressive effects on the mice, restoring a lost preference for sugar water. The result raises the idea that the antidepressant effects associated with psychedelics can come without the hallucinations, the researchers reported in the April 27 *Proceedings of the National Academy of Sciences*.

If a similar thing could happen in people, "you could retain the benefits but block the trip," Thompson says. "The trip is the thing that makes you have to spend all day in the hospital with a facilitator there, and makes it expensive, and keeps psychedelics from being widely used," Thompson says. "Being able to block the trip would lower the barriers in many ways."

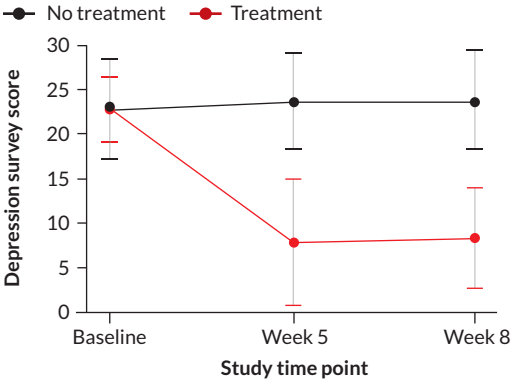
Eriacho, who has used psychedelics for her own healing, says the holistic experience is what matters. Psychedelic medicines allow a person to go within, to the pockets of the mind where traumas lurk, and begin to heal. "That is what it's done for me," she says. But the ceremony, the ritual and the wider context were all keys to her healing.

Who will benefit?

The trials completed so far have been small and included mostly white volunteers. Williams and colleagues tallied participants in psychedelic studies from 2008 to 2017. Of the 282 people who took part (and for whom race or ethnicity data were available), just 50 were not white, the researchers wrote in 2018 in *BMC Psychiatry*.

People of color have been underrepresented in these studies for many reasons, says Williams, who designed her study at UConn Health to specifically look at the effects of MDMA-assisted therapy in people of color. Caplash, who is Indian-American, was the first and only person to go through the process at UConn. Soon after his

Effects of immediate versus delayed psilocybin therapy on depression



Depression drop
People who received two psilocybin sessions with psychotherapy had fewer symptoms of depression one week after their second dose, at week 5, and at week 8 than people who had not yet received the treatment. Error bars show the variation among individual responses.
SOURCE: A.K. DAVIS *ET AL/JAMA PSYCHIATRY* 2020

C. CHANG

In a research setting, psychedelic drugs are paired with psychotherapy that involves cycles of introspection and supportive talking.

participation, the trial was stopped at that site. Other enrolled volunteers there were unenrolled, says Williams, now at the University of Ottawa.

"This is a very marginalized and vulnerable group," she says. "There were fears that if anything really bad happened [during the trial], it would reflect very badly on the university." UConn Health spokesperson Lauren Woods says that is false. The clinical trial was stopped for a "variety of reasons," she wrote in an e-mail to *Science News*, declining to provide specifics.

Without strong efforts to create inclusive studies that actively recruit a diverse group of people into the trials, train therapists of color and consider racial trauma, psychedelic drugs will not be accessible to everyone who might benefit from them, Williams says. "This needs to be an important part of what we do," she says. "We can't keep doing it the same way it was done in the past."

Yehuda aims to design treatments for "the populations who need it the most," she says. That includes combat veterans with PTSD. She and her colleagues are beginning to enroll 60 veterans in a clinical trial at the James J. Peters Veterans Affairs Medical Center in the Bronx, N.Y., where Yehuda directs the Mental Health Patient Care Center. "We are hoping to enroll a lot of ethnically diverse and racially diverse people, because we already serve them," Yehuda says. "We've done a lot of the trust work already."

As part of her studies, Yehuda plans to get at the question of who the drugs might work for, and why, in part by scrutinizing biological differences between people who get relief from the psychedelics and people who don't. "We're going to ask these somewhat tougher questions," she says. "There is going to be a science about who [MDMA] is particularly good for."

Meanwhile, the people making laws and policies are impatient for the science to yield answers. In 2020, Oregon voters approved Measure 109, which provides a sanctioned way to offer people psilocybin-assisted therapy. The state's Psilocybin Advisory Board, which includes doctors, scientists and even a mushroom biologist, has two years to figure out how the state will regulate that effort.

Abbas is on that advisory board. Speaking personally and not on behalf of that board, he says designing a system for psilocybin-based therapy is immensely complex. "It's not just who, but it's how you identify those folks, it's how you regulate the providers, how you regulate the psilocybin."

Though studies so far have mainly focused on the performance of psychedelic drugs from a scientific perspective, other considerations are important, too. Perspectives from Indigenous peoples will be sought out, Abbas says.

"There needs to be this meeting of the minds, and the openness that the scientific and Western way of thinking is not always the right way," Eriacho says. Clinical trials, for instance, often rely on narrowly defined clinical surveys to capture symptoms. "Those are Western concepts," she says, and from her perspective, those metrics miss a lot. "You don't have a very comprehensive way of looking at what an individual may be experiencing," she says.

What Oregon's psilocybin program will ultimately look like is still anyone's guess. The same is true for use of other psychedelics. There is no single story to be found amid all of these diverse and intersecting perspectives — Indigenous traditions, Western medicalization, social movements, eager private investors.

In the place of one story, we have many, including that of Kanu Caplash, who feels healed by an experience enabled by a psychedelic drug. His transformation was deeply personal. Yet it gives us a glimpse of something possible and powerful. ■

Explore more

■ Jamilah R. George *et al*. "The psychedelic renaissance and the limitations of a white-dominant medical framework: A call for Indigenous and ethnic minority inclusion." *Journal of Psychedelic Studies*. March 1, 2020.

If you or someone you care about may be at risk of suicide, call the National Suicide Prevention Lifeline, a free, 24/7 service that offers support, information and local resources: 1-800-273-TALK (8255).

MAPS

Tears From a Volcano

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BOOKSHELF

Animals are already coping with climate change

As a conservation biologist, Thor Hanson has seen firsthand the effects of climate change on plants and animals in the wild: the green macaws of Central America migrating along with their food sources, the brown bears of Alaska fattening up on early-ripening berry crops, the conifers of New England seeking refuge from vanishing habitats. And as an engaging author who has celebrated the wonders of nature in books about feathers, seeds, forests and bees (*SN: 7/21/18, p. 28*), he's an ideal guide to a topic that might otherwise send readers down a well of despair.

Hanson does not despair in his latest book, *Hurricane Lizards and Plastic Squid*. Though he outlines the many ways that global warming is changing life on our planet, his tone is not one of hand-wringing. Instead, Hanson invites the reader into the stories of particular people, places and creatures of all sorts. He draws these tales from his own experiences and those of other scientists, combining reporting with narrative tales of species that serve as examples of broader trends in the natural world.

After back-to-back hurricanes in Turks and Caicos, events expected to happen more often in a warmer world, natural selection favored *Anolis scriptus* lizards with longer front legs for clinging in high winds.

COLIN DONIHUE

A trip to La Selva Biological Station in Costa Rica, for example, has Hanson reliving the experience of tropical ecologist and climatologist Leslie Holdridge, who founded the research station in the 1950s and described, among other things, how climate creates different habitats, or life zones, as elevation increases. As Hanson sweats his way up a tropical mountainside so he can witness a shift in life zones, he notes, "I had to earn every foot of elevation gain the hard way." I could almost feel the heat that he describes as "a steaming towel draped over my head." His vivid descriptions bring home the reason why so many species have now been documented moving upslope to cooler climes.

Hanson doesn't waste much breath trying to convince doubters of the reality of climate change, instead showing by example after example how it is already playing out. The book moves quickly from the basic science of climate change to the challenges and opportunities that species face — from shifts in seasonal timing to ocean acidification — and the ways that species are responding.

As Hanson notes, the acronym MAD, for "move, adapt or die," is often used to describe species' options for responding. But that pithy phrase doesn't capture the complexity of the situation. For instance, one of his titular characters, a lizard slammed by back-to-back Caribbean hurricanes in 2017, illustrates a different response. Instead of individual lizards adjusting, or adapting, to increasingly stormy conditions, the species evolved through natural selection. Biologists monitoring the lizards on two islands noticed that after the hurricanes, the lizard populations had longer front legs, shorter back legs and grippier toe pads on average than they had before. An experiment with a leaf blower showed that these traits help the lizards cling to branches better — survival of the fittest in action.

In the end, the outcomes for species will probably be as varied as their circumstances. Some organisms have already moved, adapted or died as a result of the warming, and many more will face challenges from changes that are yet to come. But Hanson hasn't given up hope. When it comes to preventing the worst-case scenarios, he quotes ecologist Gordon Orians, who is in the seventh decade of a career witnessing environmental change. When asked what a concerned citizen should do to combat climate change, he responded succinctly: "Everything you can."

And as Hanson points out, this is exactly how plants and animals are responding to climate change: by doing everything they can. The challenge feels overwhelming, and as a single concerned citizen, much feels out of my hands. Yet Hanson's words did inspire me to take a cue from the rest of the species on this warming world to do what I can.

— Erika Engelhaupt

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STEM SUCCESS IN NEW MEXICO

The 2020–2021 school year was a challenging one for teachers around the world, including Nate Raynor (pictured above on the left with his student). But neither he nor his students let COVID-19 hold them back.

Nate has been teaching science at the Mescalero Apache School in New Mexico for 11 years. Last year, students in his research class did better than ever in science fair competitions. His students entered three projects in the Junior Science and Humanities Symposia; two projects in the International Virtual Science Symposium; and one project in the state science fair.

Nate participates in the Society for Science's Advocate Program, which provides support to educators who mentor students entering science research competitions. In particular, the program champions students from backgrounds underrepresented in STEM and from low-income households. Nate says the program played a significant role in helping him and his fellow educators learn more about how to help students successfully shift from classroom research projects to entering those projects in science competitions. When Nate first arrived at Mescalero they did not have a science fair. "Before then, they hadn't had a science fair for over five years or more," he says.

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OCTOBER 9, 2021 & OCTOBER 23, 2021

SOCIAL MEDIA

Holy cow!

Researchers trained cows to pee in a stall (shown below). Such "MooLoo training" on a large scale could help reduce pollution, **Maria Temming** reported in "Cows use stalls when nature calls" (*SN: 10/9/21 & 10/23/21, p. 24*). Twitter user **@Natas4President** was amused by the story, writing: "MooLoo trainer on your resume looks fabulous from the University of Mootivation."

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Worth the wait

*The James Webb Space Telescope, which has been in development for more than 30 years, will soon launch and explore new cosmic questions that have cropped up since the telescope was first conceived, **Lisa Grossman** reported in "The origami satellite" (*SN: 10/9/21 & 10/23/21, p. 26*).*

Once operational, the James Webb Space Telescope will survey planets orbiting small, cool stars called M dwarfs, **Grossman** reported. Reader **Bert Latamore** asked why the telescope will focus on those planets instead of ones orbiting stars similar to our sun.

Planets in the habitable zones of M dwarfs are easier to discover and observe, **Grossman** says. Since M dwarfs are smaller and cooler than sunlike stars, planets in their habitable zones cross in front of, or transit, the stars more frequently. When a planet does transit such a star, more starlight can filter through the planet's atmosphere (if it has one), allowing astronomers to measure the atmosphere's composition, she says.

Surveying M dwarf systems is only a first step, **Grossman** says. "Ultimately, scientists would like to look at rocky planets orbiting stars similar to our sun. Using Webb to study M dwarfs' planets will help scientists learn how to make important observations, and what to look for when we can study the really exciting worlds," she says.

Grossman reported that Webb's home in space will be a gravitationally fixed point called L2 that is about 1.5 million kilometers from Earth, beyond the reach of scientists if something were to go awry. Reader **Bruce Joffe** wondered how Webb will be able to orbit around this point since there is no massive celestial body nearby to keep the telescope in place.

Objects that orbit L2 are nearly — though not completely — stable, says astronomer **Scott Friedman** of the Space Telescope Science Institute in Baltimore, who is in charge of Webb's postlaunch choreography. Webb and other satellites that orbit L2 need propulsion to maintain their positions. "For Webb, we will execute what we call station-keeping maneuvers every 21 days," **Friedman** says. The telescope's thrusters will fire to correct its position and maintain its L2 orbit.

Reader **Malcolm K. Cleaveland** wondered why it would be impossible for scientists to service Webb if something were to go wrong, given our increasing space capabilities — including a proposed lunar base.

"L2 is about four times farther from Earth than the moon is, even at the moon's farthest distance," **Grossman** says. "Even if we have a lunar base someday, and I'm not convinced that we will during Webb's limited operational lifetime, it would still be a small step toward L2."

Cosmic cravings

*Astronomers may have pieced together the first firm evidence of a theorized type of supernova, in which a star gulps down a compact object — such as a black hole or neutron star — and the object engulfs the star's core, causing the star to explode, **Adam Mann** reported in "Double cannibalism sparks explosion" (*SN: 10/9/21 & 10/23/21, p. 6*).*

The purported black hole or neutron star in this binary system was the remnant of a star's supernova death, **Mann** reported. Reader **Richard Freeman** wondered how the living star in the binary survived its companion's explosive demise.

Though it might seem strange for anything to survive so close to a massive stellar explosion, it does happen, **Mann** says. "The majority of stars are born in double or even triple systems, and the evolution of each partner star affects its companions," he says.

"But stars are also pretty tough entities, and it's rather hard to blast them to smithereens from the outside," **Mann** says. This is because a star is made of an extremely dense core, surrounded by loosely held plasma and hot gas. A supernova may temporarily deform a nearby companion star's gaseous outer shell, but its core is not as easily shaken.

Brainless sponges may have echoes of a nervous system

Brains are like sponges, slurping up new information. But sponges may also be a little bit like brains.

Sponges, which are humans' distant evolutionary relatives, don't have nervous systems. But an analysis of sponge cells turns up what might just be an echo of our own brains: previously identified cells called neuroids that crawl around sponges' digestive chambers and send out messages, researchers report in the Nov. 5 *Science*.

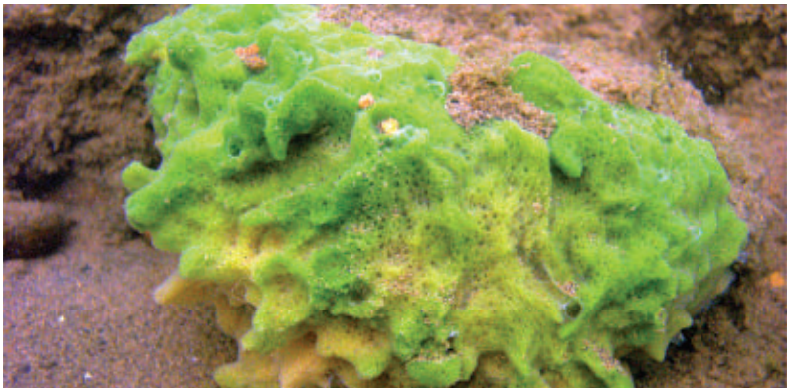
The cells were found lurking in *Spongilla lacustris* (top), a freshwater sponge that lives in lakes. The neuroids caught the attention of evolutionary biologists Jacob Musser and Detlev Arendt — both of the European Molecular Biology Laboratory in Heidelberg, Germany — and colleagues. They realized that the cells use genes essential to more evolutionarily sophisticated nerve cells in other organisms. In those organisms, those genes help control secretory vesicles, small blobs of cellular material that can carry information from cell to cell.

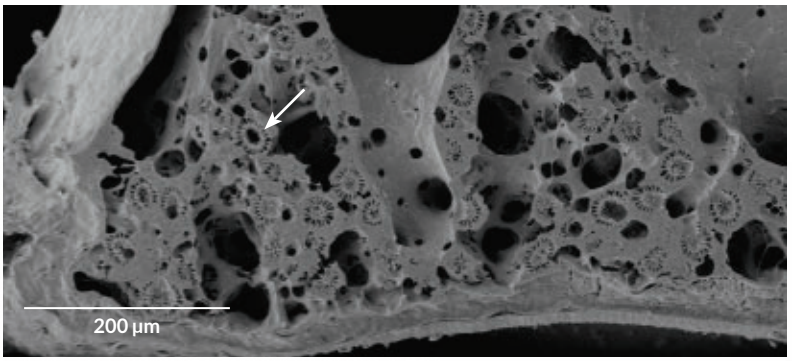
What's more, when the scientists took a closer look, the neuroids turned up in an unexpected locale, Musser says. "We realized, 'My God, they're in the digestive chambers.'"

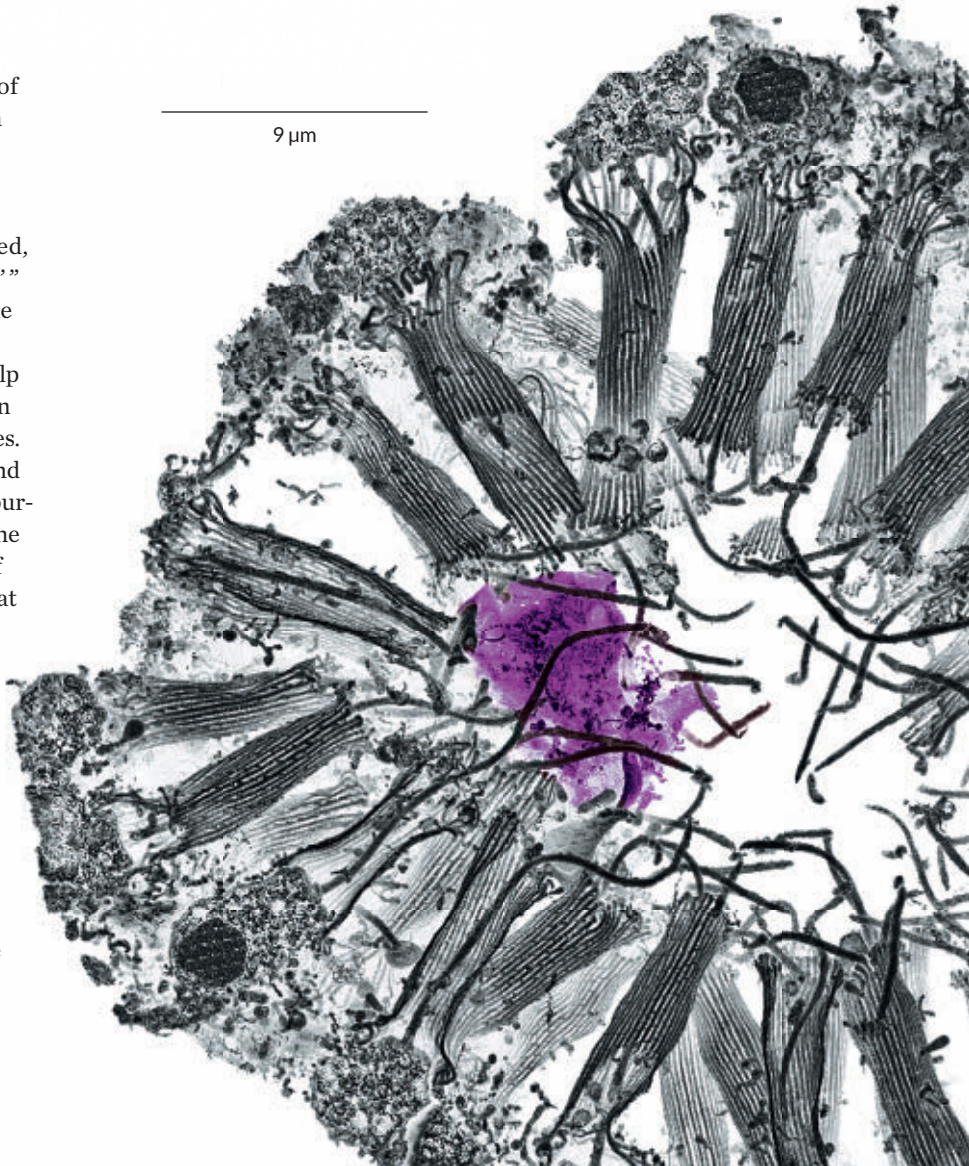
These circular "choanocyte chambers" (one indicated by an arrow in the electron micrograph of part of a sponge's body at middle) help move water and nutrients through sponges, in part by the beating of hairlike cilia appendages. The scientists found neuroids hovering around some of these cilia (one neuroid is shown in purple false color inside a digestive chamber in the electron micrograph at bottom). And some of the cilia near neuroids were bent at angles that suggested they were no longer moving.

Neuroids were sending signals to cells charged with keeping sponges fed, perhaps using secretory vesicles to stop the cilia's movement, the team suspects. If so, that would be a sophisticated level of control for an animal with no nervous system.

The finding suggests that sponges are using bits of communications systems that came together eventually to work as brains in other animals. Understanding the details may provide clues to how nervous systems evolved. — *Laura Sanders*







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