Igniting Nuclear Fusion | What Gives Blueberries the Blues

ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ MARCH 9, 2024

Totality

Why this year's eclipse will be a win for spectators and scientists

Robert Wood Johnson Foundation

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COVER The 2017 eclipse (shown) was the most recent total solar eclipse over North America. *Dominic Hart/NASA Ames Research Center*

FROM TOP: MIRECCA/ISTOCK/GETTY IMAGES PLUS; NEIL WEBB; NASA. ERIKA BLUMENFELD AND JOSEPH AEBERSOLD

Here comes the sun, the eclipsed version

Before modern astronomers and mathematicians figured out how to accurately predict solar eclipses, the extinction of the sun sparked terror. The god Zeus turned midday into night, the ancient Greek poet Archilochus wrote of a 647 B.C. eclipse, "and sore fear came upon men." Thanks to science, we can now skip the fear and go straight to awe. And on April 8, millions of people across North America will be treated to an awe-inspiring view.

In fact, almost 32 million people in the United States alone live in the zone of totality for next month's solar eclipse. The path runs from northern Mexico through the United States and then to southeastern Canada. As luck would have it, this will be an extra-special, superduper eclipse. If skies are clear, viewers will be treated to a blackout of nearly 4.5 minutes. That's almost two minutes longer than the August 2017 eclipse, which was the last total solar eclipse to pass over North America.

And the sun will be close to solar maximum, when its activity is greatest, so observers may see bright streamers of plasma and perhaps even a coronal mass ejection, freelance writer James R. Riordon reports (Page 24). Scientists are poised to make the most of this special eclipse to investigate a wide range of questions, Riordon writes, including how the sun's radiation generates the Earth's ionosphere and what gives rise to zippy solar winds — an important question for predicting the space weather that can disrupt communications and power grids on Earth.

Needless to say, we here at *Science News* have been looking forward to this eclipse since the 2017 one brushed by us. Back then, our staffers trekked from our office in Washington, D.C., to the National Mall, joining throngs of people enjoying a partial view of the eclipse. D.C. won't be in totality this year, either, but we'll get more than two hours of partial eclipse. Because the path of totality sweeps across so much of the United States, it's a great year for eclipse tourism. More than a few Science Newsers are planning to travel to catch the full show.

I may be a bit late for that. I just checked hotel listings in the path of totality, and a Holiday Inn Express in Painesville, Ohio, on Lake Erie, would cost me $1,899 a night. So I'll be content with the partial view at home.

Also in this issue, astronomy writer Adam Mann gets the latest on the space rocks collected from asteroid Bennu and delivered to Earth last year by NASA's OSIRIS-REx spacecraft (Page 7). Much to researchers' consternation, difficulties opening the sample canister kept their prize out of reach for months. It took clever work-arounds and making a new kind of ratchet wrench for them to get the job done.

And do check out molecular biology and senior writer Tina Hesman Saey's report on how ancient viruses helped make our sophisticated human brains possible (Page 6) and freelance writer Simon Makin's story on a new technology that let a person with a prosthetic hand sense hot and cold (Page 11). Science never ceases to amaze me in its ability to surprise and delight.

— *Nancy Shute, Editor in Chief*

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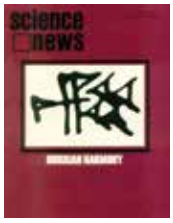


Excerpt from the March 16, 1974 issue of *Science News*

50 YEARS AGO

Superconductors inch upward

Superconductivity, the property by which certain metals lose all their electrical resistance, would be a grand thing to use technologically were it not for the extreme refrigeration necessary. Every superconductor has a transition temperature above which it becomes an ordinary conductor. Most transition temperatures are near absolute zero. [Scientists] are discovering metals with higher transition temperatures.

UPDATE: Transition temperatures continue to creep upward. In 2018, physicists reported that a compound of lanthanum and hydrogen under extreme pressure showed signs of superconductivity up to about −20° Celsius — the highest for any superconductor (*SN: 10/13/18, p. 6*). But the squeeze and relative chill makes these materials impractical for widespread use, so the hunt for a material that superconducts at room temperature and closer to atmospheric pressure continues. A debunked 2023 claim for such a material has some scientists advocating for new standards for identifying superconductivity (*SN: 12/16/23 & 12/30/23, p. 22*).

Traditionally, the extinct megalodon (bigger shark) has been viewed as a scaled-up version of the modern great white (smaller shark). But megalodon may have been shaped quite differently.

RETHINK

Megalodon may have been a long, slender giant

The largest shark discovered to date, *Otodus megalodon*, may have been a sleek leviathan.

A fresh look at the extinct predator's fossilized remains suggests its body was many meters longer and possibly more slender than previous reconstructions indicate, scientists report January 22 in *Palaeontologia Electronica*. The findings may offer clearer insights into megalodon's lifestyle, including how fast it swam and what it ate.

Reconstructing megalodon has been a challenge. Like all sharks, the giant had a cartilaginous skeleton that preserves poorly relative to bone. The species, which lived between 23 million and about 3 million years ago, is mostly known from teeth and vertebrae. Traditionally, great white sharks (*Carcharodon carcharias*) have been used as a model for megalodon's body shape because the sharks are somewhat closely related.

A 2022 reconstruction that extrapolated from great whites caught the attention of paleobiologist Kenshu Shimada of DePaul University in Chicago. That study based its reconstruction on a megalodon vertebral column at the Royal Belgian Institute of Natural Sciences in Brussels. Adding up the vertebrae end to end revealed a body length of over 11 meters. But Shimada noticed that work from the 1990s on the same specimen had calculated a 9-meter body length based on how vertebrae diameter scales with size in great whites, which top out at about 6 meters long.

In reassessments of the specimen and the 2022 reconstruction, Shimada and colleagues question relying on the shape of great white sharks to build our view of megalodon. Megalodon's vertebrae are thinner than those of great whites. The team offers a new interpretation: Because such a squat vertebral column would make more sense in a longer, leaner body shape, megalodon may have been built more like a bus than a van.

A svelter body may mean that megalodon wasn't as powerful a swimmer as great whites are. Previous work by the team on a megalodon's scale suggested the shark was a slow cruiser capable of short bursts of speed. This new view of body shape may hint at how it ate or how much it ate, says paleontologist Dana Ehret of the New Jersey State Museum in Trenton, who is not part of the team.

The new study takes an interesting approach, says Michael Gottfried, a vertebrate paleontologist who was involved in the calculation made in the '90s. But the team still relies on great whites as a model in some ways, such as for patterns of vertebrae size throughout the body. It's unclear how accurately the megalodon's vertebrae can be used to find total length because many of the fossils are incomplete, says Gottfried, of Michigan State University in East Lansing. "We are still speculating on body form and many other aspects of megalodon." —*Jake Buehler*

VICTOR HABBICK VISIONS/SCIENCE PHOTO LIBRARY/GETTY IMAGES PLUS

THE EVERYDAY EXPLAINED

Nanostructures give berries the blues

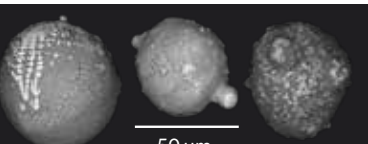
The secret to a blueberry's hue is in the structure of its wax coat.

Waxy coverings on blue-colored fruits such as blueberries, grapes and some plums contain nanostructures that scatter blue to ultraviolet light, researchers report in the Feb. 9 *Science Advances*. That makes these fruits look blue to people.

Few blue fruits contain pigments in that shade. Blueberries, for instance, contain anthocyanin, a pigment that should give each sphere a dark red color. So something else must influence the hue.

Physicist Rox Middleton of the University of Bristol in England and colleagues examined a variety of blue fruits with a scanning electron microscope. Not only did the team find molecular structures in all of the waxy coatings, but optical experiments also revealed that the structures scatter blue to UV light. What's more, wax taken off the fruits was transparent when dissolved. When the wax recrystallized after being spread on a black card, it regained its blue hue.

—Erin Garcia de Jesús



Microscopic Antarctic rocks (three shown) came from an asteroid that exploded in the atmosphere millions of years ago.

THE –EST

Rocks betray oldest known airburst

An asteroid exploded over Antarctica about 2.5 million years ago, tiny rocks in ice suggest. The timing, estimated from the age of the ice, makes the midair detonation the oldest known airburst, scientists report in the Feb. 1 *Earth and Planetary Science Letters*. Airbursts come with shock waves and heat but don't make craters, so there's scant proof of the explosions in the geologic record. The two other known ancient events date to about 450,000 years ago.

Cosmochemist Matthias van Ginneken of the University of Kent in England and colleagues chemically analyzed 116 rocks, each about the width of a human hair. Dominated by olivine and spinel minerals, the rocks' chemical composition is consistent with an asteroid. What's more, the rocks appear to be multiple pieces fused together, indicating that they formed in a dense cloud of material. *—Katherine Kornei*

SCIENCE STATS

How long might your dog live?

For a dog, it's good to be small and have a long nose.

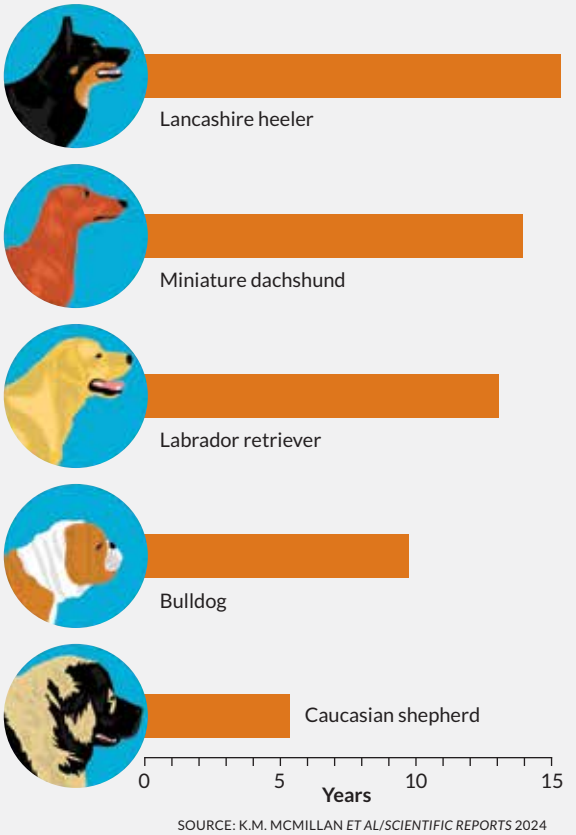
In the United Kingdom, breeds matching that description can expect to have the longest lives, researchers report February 1 in *Scientific Reports*. Medium and large dogs, especially those with flat noses, tend to have shorter lives.

Canine companions worldwide can expect to live roughly 10 to 14 years on average. But life span varies among breeds. While some studies show that small dogs tend to live longer than large dogs, myriad factors such as genetic history and body type can also influence life expectancy.

To explore how body and head size might influence life span, data scientist Kirsten McMillan of the London-based charity Dogs Trust and colleagues analyzed records for 584,734 dogs representing 155 pure breeds and mixes. Of pure breeds (selection shown, right), small dogs with longer noses tend to have the longest life expectancies. For instance, Lancashire heelers live 15.4 years—the longest of any breed—while large, long-nosed Caucasian shepherds live just 5.4 years, the shortest of any breed. Medium, flat-faced breeds, such as bulldogs, tend to live less than 10 years.

The findings apply only to dogs in the United Kingdom, McMillan says. Estimates from other countries would be helpful to see if there are places where breeds might live longer, she says. *—Erin Garcia de Jesús*

Median life spans of U.K. dog breeds



SOURCE: K.M. MCMILLAN *ET AL*/*SCIENTIFIC REPORTS* 2024

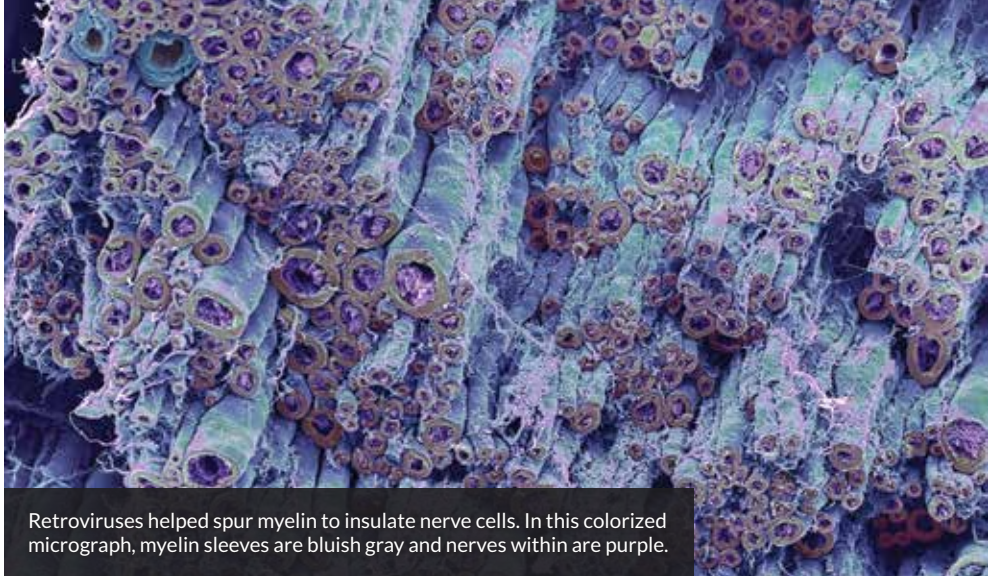
FROM TOP: COURTESY OF M. VAN GINNEKEN; R.TSUBIN/MOMENT/GETTY IMAGES PLUS; DOG ILLUSTRATIONS: NEIL WEBB

Explore the life spans of more dog breeds at **bit.ly/SN_DogsLife**

GENETICS

Ancient viruses shaped our brains

Speedy signals evolved with help from retroviral RNA



Retroviruses helped spur myelin to insulate nerve cells. In this colorized micrograph, myelin sleeves are bluish gray and nerves within are purple.

STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY/GETTY IMAGES PLUS

BY TINA HESMAN SAEY

Ancient viruses have really gotten on our nerves, but in the best of ways.

Remnants of retroviruses embedded in the DNA of jawed vertebrates help turn on production of a protein needed to insulate nerve fibers, researchers report in the Feb. 15 *Cell*. This insulation, called myelin, may have helped make speedy thoughts and complex brains possible.

The retrovirus trick was so handy that it shows up many times in the evolution of vertebrates with jaws, the team found.

Retroviruses are RNA viruses that make DNA copies of themselves to embed in a host's DNA. Rarely, these insertions can become permanent and pass down from parent to offspring. Scientists once thought these ancient viral remnants, known as jumping genes or retrotransposons, were genetic garbage. But that impression is changing, says Jason Shepherd, a neuroscientist at the University of Utah Spencer Fox Eccles School of Medicine in Salt Lake City. Researchers are increasingly finding that "these retrotransposons and retroviruses have influenced the evolution of life on the planet," he says.

Remains of retroviruses were already known to have aided the evolution of the placenta, the immune system and other important aspects of human biology (SN: 5/27/17, p. 22). Now, they're implicated in helping to produce myelin.

Myelin is a coating of fat and protein that encases long nerve fibers known as axons. The coating works a bit like the insulation around an electrical wire: Nerves sheathed in myelin can send electrical signals faster than uninsulated nerves can.

Coated nerve fibers can also be thinner and grow longer than they would without insulation, enabling animals to grow bigger, says Robin Franklin, a stem cell biologist at Altos Labs Cambridge Institute of Science in England. And thinner fibers can be packed into the nervous system more efficiently.

As a result, "brains became more complex, and vertebrates became more diverse," Franklin says. "If myelination hadn't happened in early vertebrate evolution, we wouldn't have the whole galaxy of vertebrate diversity that we see now."

Franklin and colleagues went digging in previously collected data for evidence of jumping genes, particularly those that may influence myelin production. The team hit pay dirt in data on the cells that wrap nerves in myelin, finding high levels of RNA from an ancient retrovirus.

That RNA, dubbed *RetroMyelin*, does not have instructions for making a protein. Rather, the RNA latches on to a protein called SOX10, and together they turn on production of myelin basic protein, which zips myelin into a sleeve around cells.

When the researchers used a genetic trick to reduce amounts of *RetroMyelin* in rats, zebrafish and frogs, production of myelin basic protein dropped. That finding suggests *RetroMyelin* is important for making myelin across different animal groups.

Other retrotransposons have shaped evolution by creating new switches in the genetic control panels of certain genes or by producing new versions of proteins that regulate activity of genes, says developmental neuroscientist Eirene Markenscoff-Papadimitriou of Cornell University. But producing RNA to influence activity of a gene is a newfound ability. The finding is "a very surprising and important demonstration … of a new type of developmental process being made possible by these retroviruses," she says.

Animals with vertebrae and jaws — some fish and all amphibians, birds, reptiles and mammals — have *RetroMyelin*. Jawless fish and invertebrates don't. While that would seem to suggest that the retrovirus jumped into the last common ancestor of jawed vertebrates, that doesn't appear to have been the case.

Each species the team examined had its own version of *RetroMyelin*, rather than related versions with minor changes. That pattern suggests retroviruses infected multiple lineages at different times yet resulted in the same outcome.

Why lampreys and other jawless vertebrates don't have *RetroMyelin* is unclear. One possibility is that the viruses didn't infect lampreys, says computational biologist Tanay Ghosh of Altos Labs. Or if one of the viruses did invade, perhaps it wasn't evolutionarily useful and so was lost.

For jawed vertebrates, having myelin basic protein already in place may have been important to take advantage of *RetroMyelin*. "We're getting infected constantly, and some of these [viruses] are conferring evolutionary advantage," Markenscoff-Papadimitriou says.

Scientists are increasingly recognizing that RNAs like *RetroMyelin* that don't code for proteins do important jobs, she says. "This paper will be an inspiration to other developmental biologists to really mine their data to look for the retrotransposons." ■

ASTRONOMY

OSIRIS-REx canister is finally opened

A geologist explains what the asteroid sample will teach us

BY ADAM MANN

It's official: NASA's OSIRIS-REx spacecraft snagged 121.6 grams of pristine space rock when it bopped the asteroid Bennu, more than double the mission's official science goal, the agency confirmed February 15.

Launched in 2016, OSIRIS-REx is NASA's first mission to collect bits of an asteroid and bring them to Earth. After performing its grab-and-go procedure, the spacecraft flew by Earth last year and dropped off a canister. Engineers swiftly shuttled it off to the Johnson Space Center in Houston, where it was placed in a hermetic glove box to prevent contamination.

Researchers have already analyzed some rock and dust that clung to the outside of the canister, but weighing the full sample had been delayed by a couple of stuck screws, which prevented access to the entire contents of the capsule for several months. Clever work-arounds finally unlocked the full sample on January 10. Now parts of Bennu will be distributed to scientists around the world to study our solar system's origins.

To learn how engineers got the canister open and what the sample will teach us, *Science News* spoke with geologist Harold Connolly of Rowan University in Glassboro, N.J., who oversees analysis of the Bennu material. The conversation has been edited for clarity and brevity.

What problems did you face opening the main sample container?

A bunch of fasteners or screws hold the container closed, approximately 32 of them. We couldn't loosen two of them enough with the equipment we had. But there's a Mylar flap that moves, which trapped the sample in a container. The curation team figured out it could just push down the flap. Without removing the plate that was stuck, the team could get sample out from inside the TAGSAM [Touch-and-Go Sample Acquisition Mechanism] head by literally pushing down the Mylar flap and scooping it out very gently. We got 70 grams of sample.

But to access the rest of the sample, the team had to create a new kind of ratchet wrench screwdriver.

Can you say anything about what you've found from the sample so far?

It's a serpentinite, an altered rock where the original rocky material has interacted with water. That rocky material must have been rich in olivine and pyroxene and some other common rock-forming minerals on Earth, but altered in a beautiful way. That's a geologic puzzle to figure out.

What have we suspected about Bennu that the sample can confirm?

Oh, there's a lot. Bennu itself is in a configuration that is not what it originally was. Once upon a time, the pieces that became Bennu were in a much different object, probably a heck of a lot bigger. We're talking soon after the solar system formed 4.5 billion years ago.

When that object formed, material came together, brought ices with it — and not just water ice, but carbon monoxide and ammonia ice — which means it had to accrete somewhere out past what we call the snow line, out past Mars in the outer solar system. At that distance from the sun, temperatures are low enough for those ices to form.

Eventually, the interior of the larger, original object started to heat up because of radioactivity that's naturally in the material, and that began to melt the ice and become fluid. Fluid began to interact with the parent body to form new minerals — like serpentinite — from the material that accreted.

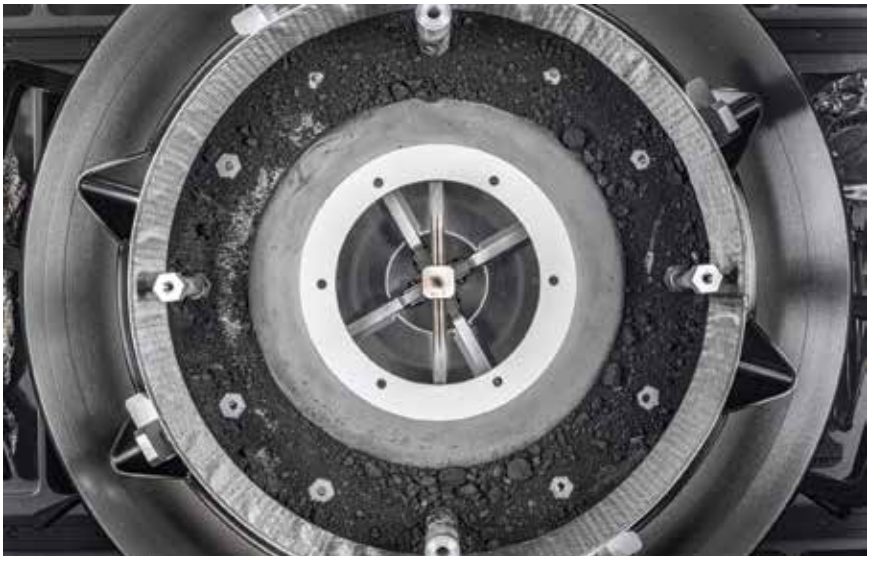
We'll be teasing out how much of it was altered, how much is relic from the pre-accretion stage, how much is actually from stars that died and injected dust into our solar system.

It sounds like a complicated history.

We're interested in what happened: How did that original parent body change? Was it impacted by another body and smashed apart to create the larger boulders that eventually came together to form Bennu? And how long has Bennu been in this current configuration? How much had it experienced interaction with the sun or with cosmic rays? All these kinds of processes we can tease out by analyzing teeny-tiny little bits of sample.

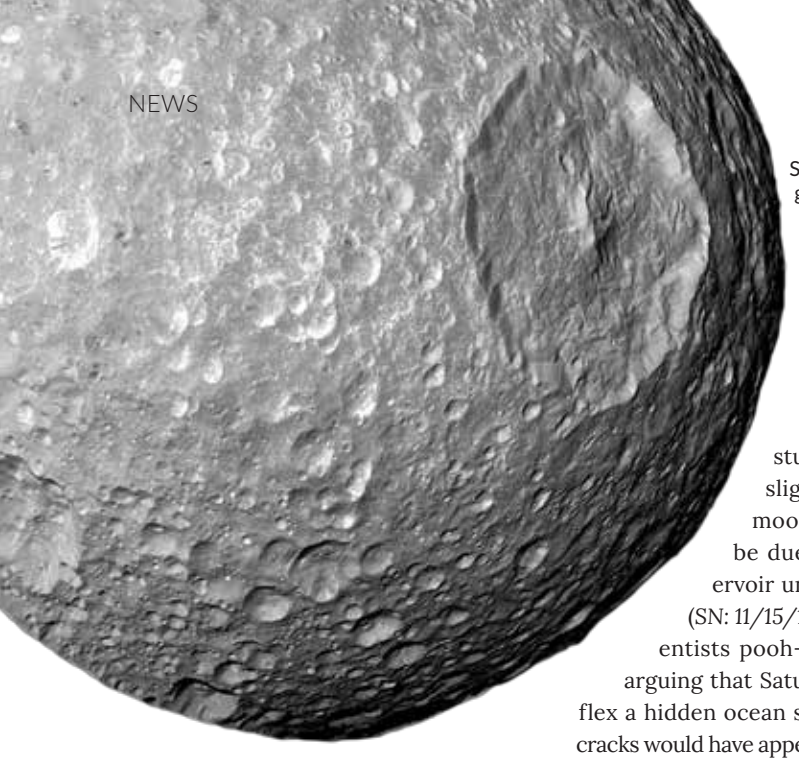
Do we have any answers to any of these questions yet?

Stay tuned. ■



NASA, ERIKA BLUMENFELD AND JOSEPH AEBERSOLD

Pieces of the asteroid Bennu fill the sample container (inside shown) of NASA's OSIRIS-REx mission. In January, engineers finally removed two stuck screws to access the full sample.



Saturn's moon Mimas gets its Death Star–like appearance from the enormous Herschel crater. New evidence suggests a large ocean might lurk beneath the moon's ice.

PLANETARY SCIENCE

This Saturn moon may harbor water

Evidence mounts for an ocean underneath Mimas' surface

BY ADAM MANN

An uncanny resemblance to the Death Star might not be the only intriguing thing about Saturn's moon Mimas. It could also harbor a vast ocean of liquid water beneath its pockmarked exterior.

A new look at data from NASA's Cassini probe reveals that the point in Mimas' orbit where it comes closest to Saturn changed slightly over 13 years, scientists report in the Feb. 8 *Nature*. Because Mimas' internal composition affects the gravitational dance between the moon and its planet, these orbital dynamics, along with some previously seen moon wobbles, point to a liquid interior, astronomer Valéry Lainey of the Paris Observatory and colleagues say.

"It's a very surprising result," says Francis Nimmo, a planetary scientist at the University of California, Santa Cruz. "When you look at Mimas, it does not look like a moon with an ocean."

This is not the first time that liquid water has been suspected on Mimas, which at 400 kilometers across is the smallest of Saturn's major moons. A 2014 study suggested that slight wobbles in the moon's rotation could be due to a watery reservoir under a frozen shell (*SN: 11/15/14, p. 16*). Other scientists pooh-poohed this idea, arguing that Saturn's gravity would flex a hidden ocean so much that large cracks would have appeared in Mimas' surface ice. Such cracks have not been seen.

The new calculations suggest that Mimas has a 70-kilometer-deep ocean underneath an ice shell that's roughly 30 kilometers thick. The team suspects the ocean may have formed between 5 million and 50 million years ago. That geologic eyeblink would explain why there are no large surface cracks—there hasn't been enough time to form them.

The evidence has converted some previous naysayers. "I was the most skeptical of Mimas having an ocean," says planetary scientist Alyssa Rhoden of the Southwest Research Institute in Boulder, Colo. "But you really have to go where the data takes you, and it seems like we're getting a new ocean world."

Nimmo, however, isn't entirely convinced. The presence of a relatively young ocean at the same epoch as humankind's exploration of the planets "would mean that we had to be seeing the solar system at an extremely special time," he says. And even if there hasn't been enough time for the putative ocean to fracture the surface, there should still be signs of contraction: Water takes up less space than ice, so a recently formed ocean would have created voids beneath Mimas' crust that left visible scars. There are no hints of that, he says.

Still, the possibility of a geologically young ocean is exciting, Lainey says. It's really the place to look "if you want to look at the beginning of conditions for life." ■

NEUROSCIENCE

A baby teaches an AI its first words

The finding could provide clues to how we learn language

BY LAURA SANDERS

The AI program was way less cute than a real baby. But like a baby, it learned its first words by seeing objects and hearing words.

After being fed dozens of hours of video of a growing tot exploring his world, an artificial intelligence model could more often than not associate words—*ball*, *cat* and *car*, among others—with their images, researchers report in the Feb. 2 *Science*. This AI feat, the team says, offers a new window into the mysterious ways that humans learn words.

Some ideas of language learning hold that humans are born with specialized knowledge that allows us to soak up words, says Evan Kidd, a psycholinguist at the Australian National University in Canberra. The new work is "an elegant demonstration of how infants may not necessarily need a lot of in-built specialized cognitive mechanisms to begin the process of word learning."

The model keeps things simple and small—a departure from many of the large language models, or LLMs, that underlie today's chatbots. Those models were trained on enormous pools of data. "These AI systems we have now work remarkably well but require astronomical amounts of data, sometimes trillions of words, to train on," says computational cognitive scientist Wai Keen Vong of New York University.

But that's not how humans learn words. "The input to a child isn't the entire internet like some of these LLMs. It's their parents and what's being provided to them," Vong says. He and colleagues built a more realistic model of language learning that relies on just a sliver of data. The question is, "Can [the model] learn language from that kind of input?" Vong says.

The team trained an AI program with the actual experiences of a real child, an Australian baby named Sam. A head-mounted camera recorded what Sam saw

JPL-CALTECH/NASA, SPACE SCIENCE INSTITUTE

and the words he heard as he learned English from age 6 months to 2 years.

The AI program — a type called a neural network — was given about 60 hours of Sam's recorded experiences, connecting objects in the videos to the words he heard caregivers speak as he saw them. From the data, which represented about 1 percent of Sam's waking hours, the model "learned" how closely aligned the images and spoken words were.

The model picked up some key words over time. Vong and colleagues tested their model in a similar way to a lab test used to find out words that babies know. When given a word and told to find the picture symbolizing the word out of a lineup of four images, the model landed on the right answer about 62 percent of the time. Random guessing would have yielded correct answers a quarter of the time.

Videos taken by a baby named Sam, shown wearing a head-mounted camera, served as the sight and sound input for an AI program.

"What they've shown is, if you can make these associations between the language you hear and the context, then you can get off the ground when it comes to word learning," Kidd says. But the results can't say if this is how children learn words.

The model, of course, made mistakes. The word *hand* proved to be tricky. Most of the training images involved a hand depicted at the beach, leaving the model confused over *hand* and *sand*.

Kids get tangled up with new words, too. A common mistake is overgeneralizing, Kidd says, such as calling all adult men "Daddy." If the model made the kinds of errors that children make, "then you know it's on the right track," he says.

Verbs might also pose problems, particularly for an AI system that lacks a body. The visuals for running come from Sam running, Vong says. "From the camera's perspective, it's just shaking up and down."

The team is now feeding more data to the model. "There should be more efforts to understand what makes humans so efficient when it comes to learning language," Vong says. ■

PALEONTOLOGY

3-D fossil tells of a forest's understory

A short, stout tree may be the earliest known subcanopy species

BY HELEN BRADSHAW

With a fluffed, spiraling top and thin trunk, the *Sanfordiacaulis densifolia* tree looks like it came straight out of Dr. Seuss' *The Lorax*. At least, that's what an analysis of a 3-D fossil of the tree suggests.

The 350-million-year-old specimen, described February 2 in *Current Biology*, preserves something that few other tree fossils have: both the trunk and leaves. "I was gobsmacked," says geologist Robert Gastaldo of Colby College in Waterville, Maine. "It made me think we should buy lottery tickets. That's how rare it is."

Known from an ancient lake bed in New Brunswick, Canada, *S. densifolia* lived during the early Mississippian — a fuzzy time period in plant history. The fossil's short height and preserved trunk and crown suggest Mississippian forests may have had more layers than previously known.

The study "fills a gap within our picture of what forest structure looked like in the Mississippian," says botanist Mihai Tomescu of California State Polytechnic University, Humboldt.

An earthquake probably sent the tree rolling to the bottom of the lake, the team says. But it wasn't flattened by the fossilization process. Using a computer program, Gastaldo and colleagues reconstructed what the tree looked like in life: about 3 meters tall with a 6-meter-wide crown and leaves as long as 3 meters. It's unclear whether the tree was fully mature, but it's unlikely that it would have ever neared the height of other known Mississippian trees, which reached upward of 20 meters.

The tree's short height and massive leaves suggest *S. densifolia* could be the earliest known subcanopy tree. Trees in the dark understory would have had to use large leaves to capture as much sunlight as possible, the team says.

Finding more *S. densifolia* fossils could shed light on how ancient plants adapted to changing environments, says study coauthor Patricia Gensel, a biologist at the University of North Carolina at Chapel Hill. That in turn could "help us understand how plants may modify themselves to survive in the future." ■

The preserved leaves and trunk of this fossilized *Sanfordiacaulis densifolia* tree, found in Canada, suggest the tree lived in a forest understory about 350 million years ago.

FROM TOP: COURTESY OF SAM'S DAD; MATTHEW STIMSON

HEALTH & MEDICINE

Newfound cells remember allergens

The finding may lead to new allergy treatments or even a cure

Scientists have found the immune cells that cause potentially lifelong allergies to things such as pet dander, pollen and peanuts.

BY TINA HESMAN SAEY

Allergy sufferers may one day be able to erase the source of their congestion, itchy skin, and swollen lips and throat thanks to two studies that have uncovered elusive immune cells that keep allergies going over the long haul, often for a lifetime.

A specialized type of immune cell holds the memory of proteins that cause allergies, two independent groups of researchers report in the Feb. 7 *Science Translational Medicine*. (One group calls it a type 2 memory B cell while the other group calls it an MBC2.) Memory B cells are important for long-lasting protection against infectious diseases, but the type 2 subset is primed to make the kind of antibodies that lead to allergies.

Unmasking the cells' identity might lead to new ways to diagnose, treat or even cure allergies.

In the United States, about a third of adults and a quarter of children have allergies, with symptoms ranging from seasonal sniffles to life-threatening reactions to food or insect stings. Allergies happen when the immune system unleashes a type of antibody called IgE on innocuous proteins. Usually, those antibodies are reserved for fighting parasitic worms, but in people with allergies, the antibodies target harmless things such as pollen, peanuts and pet dander (SN: 12/3/22, p. 10).

While some allergies disappear over time or with therapy, others last a lifetime. For decades, scientists have been searching for the source of the long-lived allergies.

Recently, researchers found that cells that help the immune system remember vaccinations and natural infections may be involved. These memory B cells produce a class of antibodies known as IgG, which ward off viral and bacterial infections and neutralize toxins. But no one had identified exactly which memory B cells were recalling allergens or how they switched to making the IgE antibodies responsible for allergies.

To solve the mystery, two teams took a deep dive into the immune cells of people with allergies and some without.

Joshua Koenig, an immunologist at McMaster University in Hamilton, Canada, and colleagues examined more than 90,000 memory B cells from 10 people with allergies and five people without. In the allergy group, six people had a birch allergy and four people had a dust mite allergy.

> Doctors could use the cells to tell whether a person's allergy will disappear with treatment.

Using a technique called RNA sequencing, the team identified specific memory B cells, dubbed MBC2s, that make antibodies and other proteins associated with the immune response that fights parasitic worms and causes allergies.

In another experiment, Koenig and colleagues used a peanut protein to fish for memory B cells in blood samples taken from people with peanut allergies. The team pulled out the same type of cells found in people with birch and dust mite allergies. In people with peanut allergies, those cells increased in number and produced IgE antibodies — the ones responsible for allergies — as the people started therapy to desensitize them to peanut allergens (SN: 9/28/19, p. 8).

"That's a smoking gun observation," Koenig says. "You find the cells present in the allergic people. [They're] not present in the nonallergic people.... These cells are the ones that are making these antibodies, and that's how this memory is being held."

Another group led by Maria Curotto de Lafaille, an immunologist at the Icahn School of Medicine at Mount Sinai in New York City, discovered similar cells — which the researchers call type 2 memory B cells. These cells were more abundant in 58 children allergic to peanuts than in 13 kids without allergies of any kind, the team found.

It's clear that both research groups have found the same cells, says Cecilia Berin, an allergist and immunologist at Northwestern University Feinberg School of Medicine in Chicago. There are "very consistent findings between the two groups," she says.

Lafaille's team found that the cells are poised to switch from making protective IgG antibodies to allergy-causing IgE antibodies. Even before the switch, the cells were making RNA copies of the IgE gene but didn't produce the protein. Making that RNA enables the cells to switch the type of antibodies they make when they encounter the allergen. "They are one step ahead of other cells to respond and to switch," she says.

The signal to switch partially depends on a protein called JAK, Lafaille's team discovered. Stopping JAK from sending the signal could prevent the memory cells from switching to IgE production, she says. Other researchers at Mount Sinai are testing a JAK inhibitor drug called abrocitinib in people with food allergies.

Lafaille also predicts that allergists may be able to examine aspects of these memory cells to forecast whether a patient's allergy is likely to last or disappear with time or treatment.

Knowing which population of cells enshrines allergies in long-term memory may eventually help scientists identify other ways to starve or kill the allergy cells, Berin says. "You could potentially get rid of not only your peanut allergy but also all of your allergies." ■

CLOCKWISE FROM TOP LEFT: SCIENCE ARTWORK/SCIENCE PHOTO LIBRARY/GETTY IMAGES; ALXEYPNFEROV/ISTOCK/GETTY IMAGES PLUS; OKSANA ERMAK/ISTOCK/GETTY IMAGES PLUS

NEUROSCIENCE

Prosthetic limb feels hot and cold

The new ability advances efforts to restore touch

BY SIMON MAKIN

A new device makes it possible for a person with an amputation to sense temperature with a prosthetic hand. The technology is a step toward prosthetic limbs that restore a full range of senses, improving both their usefulness and acceptance by those who wear them.

Researchers in Italy and Switzerland attached the device, called MiniTouch, to the prosthetic hand of a 57-year-old man named Fabrizio, who has an above-the-wrist amputation. In tests, Fabrizio could identify cold, cool and hot bottles of liquid with perfect accuracy, the team reports in the Feb. 9 *Med*. Fabrizio could also tell the difference between plastic, glass and copper significantly better than chance, and he could sort steel blocks by temperature with around 75 percent accuracy.

"It's important to incorporate these technologies in a way that prosthesis users can actually use to perform functional tasks," says neuroengineer Luke Osborn of Johns Hopkins University Applied Physics Lab in Laurel, Md. "Introducing new sensory feedback modalities could help give users more functionality they weren't able to achieve before."

The device also improved Fabrizio's ability to tell whether he was touching an artificial or human arm. His accuracy was 80 percent with the device turned on, compared with 60 percent with it off. "It's not quite as good as with the intact hand, probably because we're not giving [information about] skin textures," says neuroengineer Solaiman Shokur of EPFL, the Swiss Federal Institute of Technology in Lausanne.

Work to give prosthetic limbs a sense of touch has advanced greatly over the last decade (SN: 10/12/19 & 10/26/19, *p.* 8). But the ability to detect temperature has lagged behind. "Temperature is almost the last modality that needs to be solved in order to then put all the results together and be able to make an artificial limb really feel as the biological one," says EPFL engineer Jonathan Muheim.

Fabrizio, a 57-year-old man whose right hand was amputated above the wrist, tests a temperature-sensing device for prosthetic hands by separating warm metal cubes (left) from cool ones (right).

JAMANI CAILLET/EPFL

The study builds on work the group published last May in *Science*, which found that people who have had amputations often have spots on their residual arms that, when heated or cooled, generate temperature sensations in their missing hand. The effect is caused by stimulating nerves originally destined for the missing hand. The researchers showed they could reliably elicit phantom temperature sensations in 63 percent of amputees.

In the new work, Shokur, Muheim and colleagues first mapped Fabrizio's phantom temperature sensations to match a spot on his arm to the corresponding sensation in the index finger of his missing hand. The team then attached a temperature sensor to the fingertip of Fabrizio's prosthetic hand, which was connected via a controller unit to a device on his arm that delivered appropriate temperature signals.

Currently the device employs just one sensor on the index finger. The team plans to add sensor-stimulator pairs to create more temperature-sensitive locations on the prosthetic hand. The researchers also want to develop a prosthesis that combines the ability to sense touch and temperature. "In the coming year or so, hopefully that's where we'll be," Shokur says.

The speed at which the device relays temperature may become an issue when combining multiple senses. Osborn and colleagues have developed a device that delivers realistic cooling sensations nearly as quickly as natural responses, that team reported in July in *Nature Biomedical Engineering*.

In the immediate term, the new device needs to be tested in larger groups of participants, as well as real world settings, to ensure it isn't adversely affected by air temperature or humidity. "We still need to do those crash tests outside the lab," Shokur says.

Once the device leaves the lab, Fabrizio already knows how he'd put it to use. "With these new technologies, I can understand better what I am touching," Fabrizio said in a prerecorded video interview. "Certainly, my priority would be to use it in a kitchen to cook." ■

PHYSICS

How to ignite nuclear fusion

Physicists reveal the secret to their energy breakthrough

BY EMILY CONOVER

One of nuclear fusion's biggest advances wouldn't have happened without some impeccable scientific artistry.

In December 2022, researchers at Lawrence Livermore National Laboratory in California created fusion reactions that produced an excess of energy — a first. In the experiment, 192 lasers blasted a small chamber, setting off fusion reactions — in which smaller atoms merge to form larger ones — that released more energy than initially kicked them off (SN: 1/14/23, *p.* 6). It's a milestone known as "ignition," and it had been decades in the making.

Now, researchers have released details of that experiment in five papers published February 5 in *Physical Review Letters* and *Physical Review E*. The feat demanded an extraordinary level of finesse, tweaking conditions just so to get more energy out of the lasers and create the ideal conditions for fusion.

The work is "exquisitely beautiful," says physicist Peter Norreys of the University of Oxford, who was not involved in the research. He compares the feat to conducting a world-class orchestra: Different experimental elements had to be meticulously coordinated and precisely timed.

Fusion, the same process that takes place in the sun, is an appealing energy source. Nuclear fusion power plants wouldn't emit greenhouse gases or produce the dangerous radioactive waste that nuclear fission power plants do. Ignition is the first step toward harnessing such power.

Generating fusion requires extreme pressures and temperatures. In the experiment, the lasers at Lawrence Livermore's National Ignition Facility, or NIF, pelted the inside of a small hollow cylinder called a hohlraum. The blast heated the hohlraum to 3 million degrees Celsius — so hot that it emitted X-rays. Inside this X-ray oven, a diamond capsule contained the fuel: two heavy varieties of hydrogen called deuterium and tritium. The radiation vaporized the capsule's diamond shell, triggering the fuel to implode at speeds of about 400 kilometers per second, forming the hot, dense conditions that spark fusion.

Previous experiments have come tantalizingly close to ignition. To push further, the researchers increased the energy of the laser pulse from 1.92 million joules to 2.05 million joules by lengthening the pulse by a fraction of a nanosecond.

The team also thickened the capsule's diamond shell by about 7 percent — a difference of just a few micrometers — which slowed down the capsule's implosion, allowing the scientists to fully capitalize on the longer laser pulse.

But these tweaks altered the implosion's symmetry, which meant other adjustments were needed. It's like trying to squeeze a basketball down to the size of a pea, says Annie Kritcher, a physicist at Lawrence Livermore, "and we're trying to do that spherically symmetric to within 1 percent."

That's particularly challenging because of the mishmash of electrically charged particles, or plasma, that forms in the hohlraum during the laser blast. This plasma can absorb the laser beams before they reach the walls of the hohlraum, messing with the implosion's symmetry.

So Kritcher and colleagues slightly altered the wavelengths of the laser beams in a way that allowed them to transfer energy from one beam to another. The fix required tweaking the beams' wavelengths by tenths of a billionth of a meter.

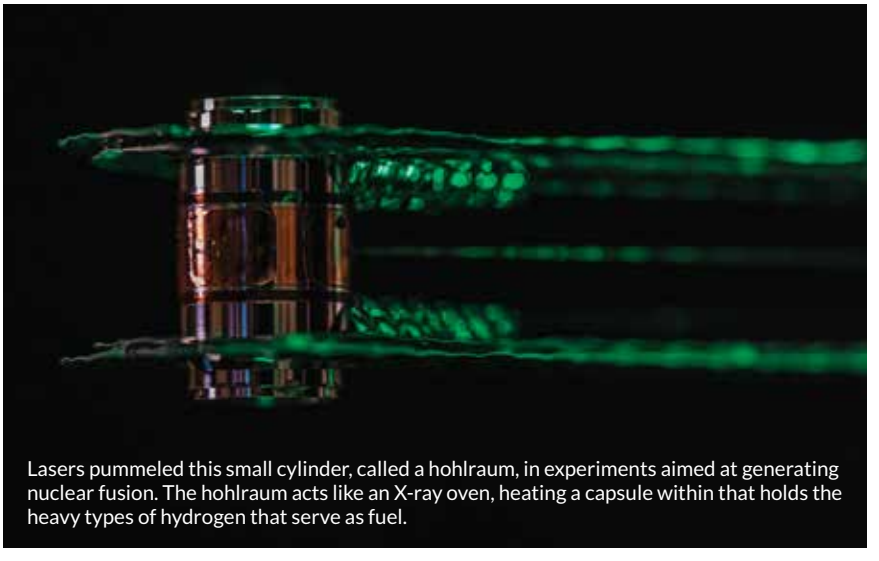
"Engineering-wise, that's amazing they could do that," says physicist Carolyn Kuranz of the University of Michigan in Ann Arbor. "These tiny, tiny tweaks make such a phenomenal difference."

After all the adjustments, the ensuing fusion reactions yielded 3.15 million joules of energy — about 1.5 times the input energy, Kritcher's team found. The total energy needed to power NIF's lasers is around 350 million joules. So fusion is still far from a practical power source.

Another experiment in July 2023 used a higher-quality diamond capsule to obtain an even larger gain, releasing nearly twice as much energy as went into the reactions (SN: 9/23/23, *p.* 4). NIF scientists hope to boost the laser's energy from about 2 million joules to 3 million, which could kick off fusion reactions that would release 10 times the energy that went into them.

NIF is not the only fusion game in town. Other teams aim to kick off fusion by confining plasma into a torus, or doughnut shape, using a device called a tokamak. The Joint European Torus in Abingdon, England, generated 69 million joules, researchers reported February 8. That's a record for total fusion energy produced, though it didn't exceed the input energy.

After decades of slow progress on fusion, scientists are beginning to get their atomic orchestras in sync. ■



Lasers pummeled this small cylinder, called a hohlraum, in experiments aimed at generating nuclear fusion. The hohlraum acts like an X-ray oven, heating a capsule within that holds the heavy types of hydrogen that serve as fuel.

JASON LAUREA/LLNL

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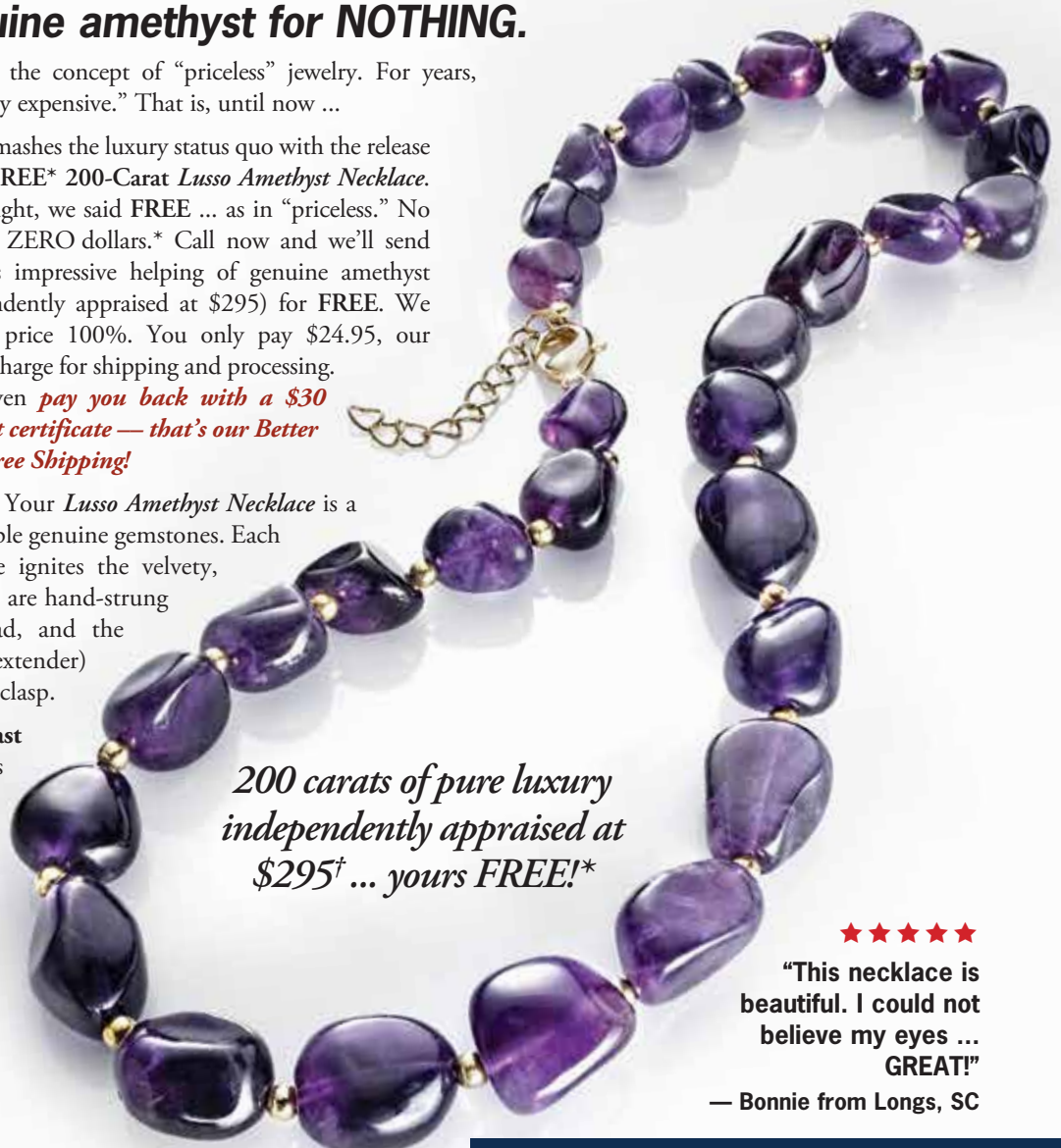

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SCIENCE & SOCIETY

Social media hurts teens' mental health

An emerging causal link now has scientists trying to explain why

BY SUJATA GUPTA

In January, Mark Zuckerberg, CEO of Facebook's parent company Meta, appeared at a United States congressional hearing to answer questions about whether social media harms children. Zuckerberg opened by saying: "The existing body of scientific work has not shown a causal link between using social media and young people having worse mental health."

But many social scientists disagree with that statement. In recent years, studies have, in fact, started to show a causal link between teen social media use and reduced well-being or mood disorders, chiefly depression and anxiety.

Ironically, one of the most cited studies showing cause and effect focused on Facebook's staggered rollout across U.S. college campuses in the early to mid-2000s. Researchers delved into whether the platform's introduction increased symptoms of depression and anxiety among students. The answer was a clear yes, the team reported in 2022 in *American Economic Review*. "There is still a lot to be explored," says MIT economist Alexey Makarin, a coauthor of that study. But to say "there is no causal evidence that social media causes mental health issues, to that I definitely object."

The concern, and the impetus for the studies, come from statistics showing that social media use in teens ages 13 to 17 is now almost ubiquitous. In one survey, two-thirds of teens reported using TikTok, and some 60 percent reported using Instagram or Snapchat. (Only 30 percent said they use Facebook.) Another recent survey showed that girls, on average, allot roughly 3.4 hours per day to TikTok, Instagram and Facebook combined, compared with roughly 2.1 hours among boys. At the same time, more teens are showing signs of depression than ever, especially girls (SN: 7/1/23, *p.* 18).

As more studies show a strong link between social media and declines in teen mental health, some researchers are shifting their attention to identifying possible mechanisms. These researchers are asking: Why are the mental health effects unevenly distributed among different groups, such as girls vs. boys and young vs. older adults? And can the positives of social media be teased out from the negatives to provide more targeted guidance to teens, their caregivers and policy makers?

"You can't design good public policy if you don't know why things are happening," says economist Scott Cunningham of Baylor University in Waco, Texas.

Increasing rigor

Concerns over the effects of social media use in children have been circulating for years, resulting in a massive body of scientific literature. But until recently, most studies have been correlational, meaning they couldn't show if teen social media use harms mental health or if teens with mental health problems use social media more.

> Talking to teens and those in their orbit is the best way to get at the mechanisms by which social media influences well-being.

The findings from such studies were often inconclusive, or the effects on mental health so small as to be inconsequential. In one study that received considerable media attention in 2019, psychologists in England combined data from three surveys to look for a link between technology use, including social media, and reduced well-being. The researchers gauged the well-being of over 355,000 teenagers by focusing on questions around depression, suicidal thinking and self-esteem.

Digital technology use was associated with a slight decrease in adolescent well-being, Amy Orben of the University of Cambridge and Andrew Przybylski of the University of Oxford reported in *Nature Human Behaviour*. But the pair downplayed that finding, noting that researchers have observed similar drops in adolescent well-being correlated with drinking milk, going to the movies or eating potatoes.

But Orben and Przybylski have since changed their thinking. In one longitudinal study, researchers including Orben and Przybylski used survey data on social media use and well-being from over 17,400 teens and young adults to look at how individuals' responses to a question gauging life satisfaction changed between 2011 and 2018. And the researchers dug into how the responses varied by gender, age and time spent on social media.

Social media use was associated with a drop in well-being among teens during certain developmental periods, chiefly puberty and young adulthood, the team reported in 2022 in *Nature Communications*. That translated to lower well-being scores for girls around ages 11 to 13 and for boys ages 14 to 15. Both groups also reported a drop in well-being around age 19. And among the older adolescents, the team found evidence for the Goldilocks hypothesis: the idea that either too much or too little time spent on social media can harm mental health.

"There's hardly any effect if you look over everybody. But if you look at specific age groups, at particularly what [Orben] calls 'windows of sensitivity'… you see these clear effects," says L.J. Shrum, a consumer psychologist at HEC Paris who was not involved in the research. His review of studies related to teen social media use and mental health is forthcoming in the *Journal of the Association for Consumer Research*.

Cause and effect

That longitudinal study hints at causation, scientists say. But one of the clearest ways to pin down cause and effect is through natural or quasi-experiments. For these in-the-wild experiments, researchers must identify situations where the rollout of a societal "treatment" is staggered across space and time. They can then compare

outcomes among members of the group who received the treatment with those still in the queue — the control group.

That was the approach Makarin and his colleagues used in their study of Facebook. The researchers homed in on the staggered rollout of Facebook across 775 U.S. college campuses from 2004 to 2006. The team combined that rollout data with student responses to the National College Health Assessment, a widely used survey of college students' mental and physical health.

To understand if those survey questions captured diagnosable mental health problems, the researchers had roughly 500 undergraduate students respond to questions both in the National College Health Assessment and in validated screening tools for depression and anxiety. Mental health scores on the assessment predicted scores on the screenings, the team found. That suggested that a drop in well-being on the college survey was a good proxy for a corresponding increase in diagnosable mental health disorders.

Makarin and colleagues controlled for time of Facebook rollout and differences in demographic makeup at selective vs. less-selective colleges, among other factors. On average, 25 percent of students were clinically depressed and 16 percent had generalized anxiety disorder before Facebook's rollout. After the platform's introduction, depression and anxiety each went up by about 2 percentage points, the team found.

When it comes to showing a causal link between social media use in teens and worse mental health, "that study really is the crown jewel right now," says Cunningham, who was not involved in that research.

A need for nuance

The social media landscape today is vastly different than it was 20 years ago. Facebook is now optimized for maximum addiction, Shrum says, and newer platforms, such as Snapchat, Instagram and TikTok, have copied and built on those features. Paired with the ubiquity of social media in general, the negative effects on mental health may well be larger now.

Social media research tends to focus on young adults — an easier cohort to study than minors. That needs to change, Cunningham says. "Most of us are worried about our high school kids and younger."

And so, researchers must pivot accordingly. Crucially, simple comparisons of social media users and nonusers no longer make sense. As Orben, Przybylski and colleagues' 2022 work showed, a teen not on social media might well feel worse than one who briefly logs on.

BRENDAN SMIALOWSKI/AFP VIA GETTY IMAGES

Meta CEO Mark Zuckerberg testified at a U.S. congressional hearing in January in Washington, D.C. He claimed that science hasn't found that social media use harms teen mental health.

Researchers must dig into why, and under what circumstances, social media use can harm mental health, Cunningham says. Possible explanations for this link abound. For instance, social media is thought to crowd out other activities or increase people's likelihood of comparing themselves unfavorably with others. But big data studies, with their reliance on existing surveys and statistical analyses, cannot address that question of why. "These kinds of papers, there's nothing you can really ask … to find these plausible mechanisms," Cunningham says.

One ongoing effort to identify possible mechanisms is the SMART Schools study out of the University of Birmingham in England. Pedagogical expert Victoria Goodyear and colleagues are comparing mental and physical health outcomes among children who attend schools that have restricted cell phone use with those attending schools without such a policy. The researchers described the protocol of that study of 30 schools and more than 1,000 students last July in *BMJ Open*.

Goodyear's team is also combining that natural experiment with qualitative research. The scientists met with 36 focus groups, each consisting of all students, all parents or all educators from six schools. The team hopes to learn how students use their phones during the day, how usage practices make students feel and what the various parties think of restrictions on cell phone use during the school day.

Talking to teens and those in their orbit is the best way to get at the mechanisms by which social media influences well-being — for better or worse, Goodyear says. Moving beyond big data to this more personal approach, however, takes considerable time and effort.

"Social media has increased in pace and momentum very, very quickly," Goodyear says. "And research takes a long time to catch up with that process."

Until that catch-up occurs, though, researchers cannot dole out much advice. "What guidance could we provide to young people, parents and schools to help maintain the positives of social media use?" Goodyear asks. "There's not concrete evidence yet." ■

ARCHAEOLOGY

Stone Age wall led prey to their doom

Hunters likely built the wall to make reindeer easier to kill

BY ANNA GIBBS

These stones in the Baltic Sea were part of an ancient hunting trap in Germany, scientists say.

If this underwater wall could talk, it might reveal that it once helped Stone Age people in Europe hunt reindeer.

Now submerged about 20 meters below the surface of the Baltic Sea off the coast of Germany, the wall stretches for almost a kilometer and contains nearly 1,700 stones, making it among the largest human-made megastructures from Stone Age Europe, scientists report in the Feb. 20 *Proceedings of the National Academy of Sciences*.

The team suspects the wall was used similarly to ancient hunting traps found in the Middle East and North America. If so, it would be the first known trap of its kind in the southern Baltic region.

Researchers discovered the structure, dubbed the Blinkerwall, in 2021 while using sonar to map the seafloor. The data revealed odd protrusions down below, so the team returned with underwater cameras to get a better look.

"When we found the rocks, I realized it's possibly not a natural process that put these rocks together," says Jacob Geersen, a marine geologist at the Leibniz Institute for Baltic Sea Research Warnemünde in Rostock, Germany.

It's unlikely that glaciers, ice floes or construction of nearby underwater infrastructure could have positioned the rocks into their flattened S-like shape, Geersen and colleagues say. The rocks seem to have been intentionally placed, with the largest boulder (estimated to weigh over 11,000 kilograms) sitting in the middle. Most of the other rocks weigh less than 100 kilograms — light enough to have been moved by people to connect the larger rocks scattered along the wall's length.

Radiocarbon dating of sediment cores taken from near the Blinkerwall suggest that a lake bordered the structure around 10,000 years ago, before the Baltic Sea rose 8,500 years ago and submerged the area. The wall probably funneled Eurasian reindeer — which last occupied the area around the time the wall was built — toward the nearby lake, where the trapped prey could have been easily killed. At that time, the only people in the region who could have constructed such a large wall were nomadic hunter-gatherers, says archaeologist Marcel Bradtmöller of Rostock University.

Humankind has a long history of enhancing natural topography to obtain resources, says archaeologist Geoff Bailey of University of York in England. The team's interpretation of the findings "sounds, to me, to be very plausible," he says. ■

ARCHAEOLOGY

Patagonian cave kept culture alive

Near the southernmost tip of South America, people may have started cave painting nearly 8,200 years ago, several millennia earlier than previous evidence suggests. Dating of comblike depictions in an Argentinian cave in the region of Patagonia indicates that the designs belonged to a rock art tradition that lasted over 3,000 years, ending around 5,100 years ago, archaeologists report in the Feb. 16 *Science Advances*. The designs (shown left) probably preserved cultural knowledge shared by hunter-gatherers, the team says. The cave, called Cueva Huenul 1, displays 895 paintings — including geometric shapes, cross-shaped lines and figures of humans and llama relatives. Of four radiocarbon-dated paintings, three yielded reliable age estimates. Dating of butchered animal bones indicate that people reached the cave around 11,700 years ago. But there are no signs of such daily activities dating to when the art was made, the scientists say, underscoring the cave's transition to a place for cultural recordkeeping. — *Bruce Bower*

FROM TOP: PHILIPP HOY (CC BY); GUADALUPE ROMERO VILLANUEVA

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So far, scientists have cataloged more than 1,000 species of sound-producing fish, including the quillback rockfish.

WHAT DOES THE FISH SAY?

Researchers are on a quest to log all fish sounds **By McKenzie Prillaman**

Ashlee Lillis' interview subjects don't talk. But they have plenty to say through grunts, growls, clicks and other odd noises.

"I put my hydrophone — which is our underwater microphone — on the end of a long pole and keep sticking it into fish faces," says Lillis, a marine ecologist who leads Sound Ocean Science, an organization based in Gqeberha, South Africa, focused on international marine research and conservation.

Lillis is among a vanguard of researchers around the world cataloging fish sounds, aiming to put a species name to each underwater call. Eavesdropping on — and understanding — all that chatter is a powerful way to reveal under-the-surface secrets. The idea isn't novel: Whale songs have long been used to track cetacean behavior and migrations. But now researchers want to tap into the far broader symphony of fish sounds.

It's a whale of a task. For instance, take ray-finned fishes. More than 34,000 species make up this largest group of bony fish, including salmon, eels, herring and the like. But only about 1,000 of these species have been documented in published research to make a ruckus. Those fish span about 130 families, but a 2022 analysis estimates that 175 families — representing nearly 85 percent of all species in the ray-finned group — could have soniferous species that communicate via sound.

Fish clamor can reveal a lot: Is there the hubbub of biodiversity? Has an invasive fish species moved in? When do conservationists need to put up a "do not disturb" sign to ensure that human activity doesn't disrupt mating season?

Sound recordings can complement more traditional ways of monitoring, such as catching fish to examine abundance and health. But beyond deepening our understanding of a largely hidden realm, there's an urgency to the task. "We need to log these sounds as quickly as we can before climate change and anthropogenic stressors affect the aquatic world" even more than they already have, says acoustician Miles Parsons of the Australian Institute of Marine Science in Perth. Warming waters can push fish to new places and even alter their sounds, he notes. Listening in can help track those shifts. "From a science point of view, the world is changing very quickly."

Sounds fishy

Humans have known for millennia that fish are noisy creatures; many age-old common names like drum and croaker come from the fish's distinctive cries.

The Greek philosopher Aristotle pondered fish grunts and squeaks back in the fourth century B.C. Even then, he noted that these animals' "voices" aren't generated in the traditional sense. Instead, fish may rub or click their bony structures together, contract certain muscles to drum the gas-filled swim bladder or vibrate stretched tendons in fins like a stringed instrument. Some fish even expel air out of their rear ends, aptly named fast repetitive tick, or FRT, sounds. These numerous ways to produce sounds evolved independently about 33 times in ray-finned fishes, a 2022 study in *Ichthyology & Herpetology* suggested.

> "We need to log these sounds as quickly as we can before climate change and anthropogenic stressors affect the aquatic world."
>
> **MILES PARSONS**

Fish "probably have the greatest diversity of sound-producing mechanisms across the tree of life," says marine ecologist Audrey Looby of the University of Florida Nature Coast Biological Station in Cedar Key. Many known fish sounds are within human hearing range, but they're relatively quiet and occur in an environment where we're not suited to hear well.

Fish hear each other thanks to tiny stones in their heads, which move in response to sound vibrations, triggering signals to the brain. It's similar to how human hearing works. The animals also have specialized sensory cells running down their bodies that detect movement, including sound waves, in the water.

Fish sounds can serve different purposes. Some are distress signals, warning others of danger

Ashlee Lillis (shown) and other marine researchers are matching fish grunts, growls and clicks to specific species to better monitor ecosystems and fish behavior.

OPPOSITE PAGE: MIRECCA/ISTOCK/GETTY IMAGES PLUS; THIS PAGE: ANDY CAMPBELL/BIG BLUE TECH DIVING

In the wake of World War II, Marie Poland Fish (shown listening to catfish) began documenting which underwater creatures produce noise. By the end of her career, she had studied the sounds of over 300 species.

LYNN PELHAM/GETTY IMAGES

or attempting to scare away a predator — noises well-known to fishers, Looby says. "A lot of the fish that you catch will make grunting sounds when they're caught."

Other cries indicate aggression, produced when fish mark territory or get into fights. Some of the most ear-piercing noises deal with reproduction. For instance, certain male plainfin midshipman (*Porichthys notatus*), which live off the North American west coast, advertise their reproductive quality to picky females through an incessant foghorn-like hum (*SN*: 10/29/16, *p.* 4).

"They're vibrating their swim bladder like crazy," says marine community ecologist Kieran Cox of Simon Fraser University in Burnaby, Canada. When he worked on a project involving the species, the males' eerie hum would surround him during late nights in the dark fish tank–filled lab. The louder the mating call, Cox says, the greater the number of females drawn in to lay eggs in the male's cavelike nest for him to fertilize and guard.

Still, there's an ocean (and lake, river and pond) full of fish sounds with unknown sources and purposes. Simply noting the variety of sounds, even if the specific sources are mysterious, can give glimpses into biodiversity and ecosystem health. But the lure of learning more intimate details of fish lives is spawning new efforts to solve those mysteries.

Spying on species

The modern field of underwater bioacoustics had a fraught start. During World War II, the ocean served as a battlefield, where submarines kept an ear out for enemy vessels.

"The technicians that were listening on the submarines were hearing all these weird things," says marine bioacoustician Michelle Schärer-Umpierre of HJR Reefscaping, an environmental consulting group based in Cabo Rojo, Puerto Rico. "They thought it was enemy warships, but they were really animals."

After the war ended, the U.S. Navy hired marine biologist Marie Poland Fish to investigate. She began cataloging the sounds of fish and other sea creatures both in their natural habitats and in laboratory tanks at the University of Rhode Island's campus in Narragansett. More than two decades later, in 1970, she published a book — accompanied by audio recordings — with colleague William Mowbray containing analyses of 153 fish species' sounds out of 220 described species. By the end of her career, Fish had recorded and examined the sounds of more than 300 marine species.

But that's merely a drop in the bucket.

Other researchers, including Schärer-Umpierre, have resumed that work. For almost 20 years, Schärer-Umpierre has been studying the sounds made by groupers, an assortment of large-mouthed, stout-bodied fishes. She figured out what behaviors certain noises match up with. Using passive acoustic monitoring, she now uses that link to track what the fish are doing in the wild. Listening to their underwater calls helps her spy on these fish without disturbing them.

Most of the time, groupers are solitary animals whose sole sounds are alarm calls produced when in danger. But at specific times of the year, many species travel long distances — up to hundreds of kilometers — to tropical waters to reproduce. That includes to the Caribbean, where Schärer-Umpierre studies the fish. The massive, sometimes monthslong gatherings that happen there result in a symphony of diverse grouper sounds associated with reproduction.

Most of the ruckus comes from males. Male red hind groupers (*Epinephelus guttatus*), for example, make distinct noises when fighting over territory, courting females and preparing to release sperm to fertilize eggs. The latter sound consists of nonstop singing for a few hours on nights around the full moon, Schärer-Umpierre says. Females make just one noise. "It's a very short grunt that doesn't really ring very well."

Groupers are both ecologically and commercially important in the Caribbean, and sex-specific sounds can help fishery managers better understand what's going on during aggregations, as well as the ratio of males to females. Poor weather can prevent visual surveys, and determining the timing of breeding seasons often relies on cutting open females to assess egg development.

The sounds can also signal when the groupers are easy targets, leading to overfishing: Many species are

so focused on reproduction that they don't swim away when danger is near, Schärer-Umpierre explains.

To protect groupers during this vulnerable period, the Caribbean Fishery Management Council, CFMC, forbids fishing certain species during breeding. The red hind's closed season lasts from December through February, and it was first implemented in 1993 based on the fish's physical characteristics measured throughout multiple breeding seasons. But more recent passive acoustic monitoring off of western Puerto Rico has shown that this period doesn't quite align with the species's reproductive schedule, Schärer-Umpierre reported at a meeting of the management council in 2021.

"We have never seen in Puerto Rico, since we started doing this in 2007, that the red hind aggregated during the month of December," she says. The fish have, however, remained gathered in early March. Using that data, she's urging the CFMC, which creates regional fishery management plans for approval by the U.S. Department of Commerce, to shift the species's closed fishing season.

Tracking an interloper

Fish sounds aren't just good for tracking species we want to protect; they can help solve other environmental challenges, too.

In 2003, ichthyologist Rodney Rountree, then at the University of Massachusetts Dartmouth, was presenting preliminary data at a scientific meeting in San Antonio. When he played a mystery sound recorded in the Hudson River in New York, it struck a chord with a fellow researcher. The listener suspected it was a type of drum, belonging to a collection of fishes known for their deep rumble.

The suggestion surprised Rountree; he wasn't aware of any drum species living in the freshwater area where the sound was recorded. But he later found documentation that the freshwater drum (*Aplodinotus grunniens*, whose species name means "grunting" in Latin) had made its way into the river.

"It's going to change the dynamics of the Hudson River tremendously because it is a very successful river species," Rountree thought at the time.

Scientists weren't sure how established the drums were in the river system, or how they got there. Some speculated that the drums came from the Great Lakes' native populations. Rountree eyed another potential source: Lake Champlain, which lies north of the Hudson River. Perhaps, he thought, the roughly 100-kilometer-long Champlain Canal connecting the two bodies of water might be a fish passageway. As a source, it had largely been ignored, Rountree says, possibly because the Great Lakes' drums were more well-known and the Erie Canal is a prominent connector to the Hudson River.

In July 2010, he drove south along Lake Champlain and the Champlain Canal for three days, stopping roughly every 10 kilometers to assess the soundscape, the cacophony of noises below the water's surface. "I would drop the hydrophone into the water and listen for a few minutes—and *brr*, *brr*, *brr* or silence was out there," Rountree says.

Based on those recordings, he and a colleague reported in 2017 in *Biological Invasions* that Lake Champlain's drum population probably played a large part in the migration into the Hudson River. The project also showed how quickly and easily such passive sound recordings could be used to snoop on species.

"I did it based on just my free time in a few days," says Rountree, who is now primarily an independent bioacoustics consultant known as the Fish Listener based in Waquoit, Mass.

Catching fish, rather than listening for them, is one of the main traditional ways to survey an aquatic environment. Scientists can make direct measurements

Place of origin After discovering an influx of freshwater drums into the Hudson River, scientists wanted to know where the nonnative species came from. Based on where the sounds of freshwater drums were recorded in the region, scientists pinpointed Lake Champlain as a source.

SOURCE: R.A. ROUNTREE AND F. JUANES/*BIOLOGICAL INVASIONS* 2017

MATTHEW PETERS AND B. PRICE

on fish, though it sometimes requires killing the animals. More technologically advanced approaches include using sonar to estimate biomass or tagging the animals to track their locations.

Such operations can be time-consuming and costly. And, while useful, many represent "a snapshot at one point in time," says acoustician Xavier Mouy of the National Oceanic and Atmospheric Administration's Northeast Fisheries Science Center in Woods Hole, Mass.

Passive acoustic monitoring, on the flip side, can record sounds for months at a time, and it's become easier and more accessible in recent years. Simple underwater recording devices can cost as little as $135 while more advanced versions start at around $3,000.

"We've got a situation where now we can very easily collect terabytes and terabytes of data," says marine biologist Tim Lamont of Lancaster University in England. "So there's all this data that we've never been able to get before."

A deep dive into these underwater symphonies will allow scientists to learn more about changes in fish populations over time and across broad areas, adding a new dimension to traditional survey methods. Scientists expect that data will help track large-scale shifts induced by climate change and other human influences.

For instance, Schärer-Umpierre suspects that the Caribbean's warming waters are pushing the red hind's aggregation period even later, as the fish prefer to spawn when the sea cools to around 26.5° Celsius. And a 2023 study in *PeerJ* suggests that increasing water temperatures and ocean acidification will enhance how sound travels in some ocean regions worldwide, making ship noise there up to seven decibels louder by the end of the century.

Such human-caused discord can harm a fish's ability to find food, reproduce, escape predators and even induce hearing loss, according to an analysis that Cox and colleagues published in 2018 in *Global Change Biology* (SN: 3/14/20, p. 13). Listening in may help scientists document some of these changes and push for policies to limit noise pollution. Canada, for instance, is developing the Ocean Noise Strategy as a road map for addressing the problem.

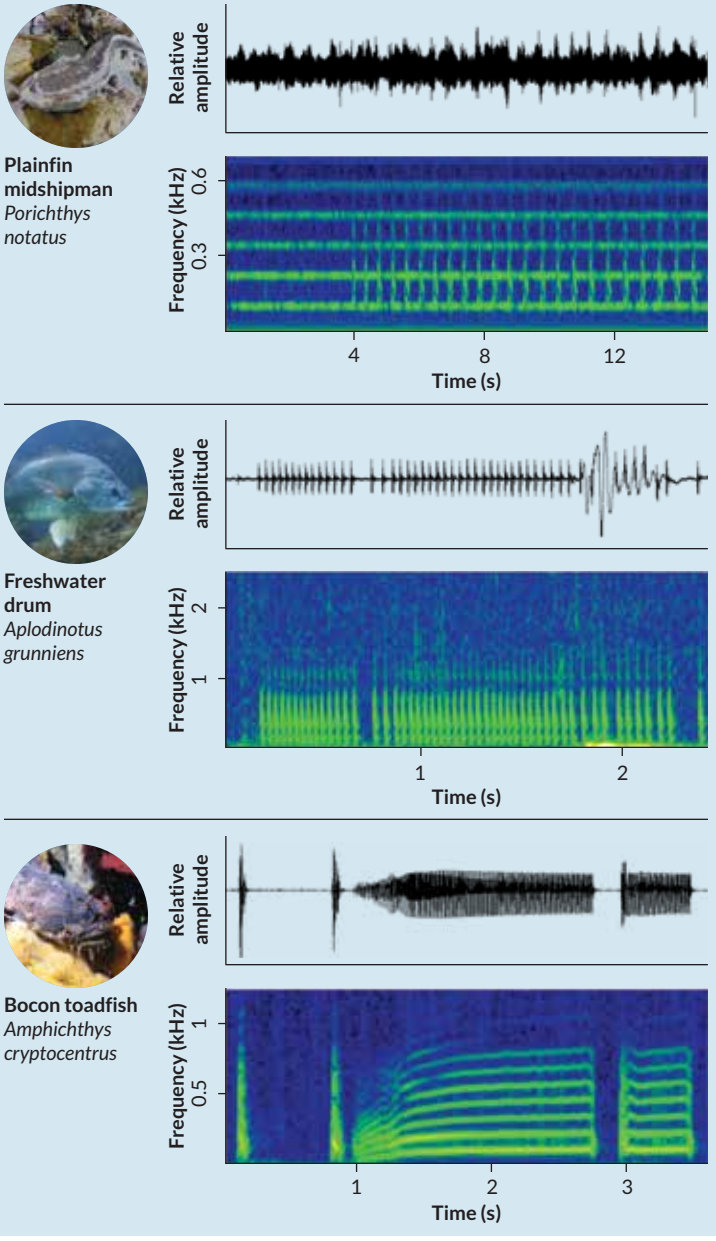
Modern mysteries

Efforts to build repositories of underwater animal sounds are growing. In 2021, Looby, Cox, Rountree and others joined forces to launch the first library of every known fish that produces sound, according to published research. Today, the library documents more than 1,000 soniferous fish and holds more than 1,200 audio recordings.

In 2022, scientists sounded the call for a global library of underwater biological sounds to detail the ruckus made by every underwater species, from fish and mammals to invertebrates. The scientists behind this effort, known as GLUBS, also hope to create a data repository for soundscape recordings, a community science platform where anyone can upload underwater animal sounds, and an AI-based system to detect different calls from these recordings.

Researchers are now collecting so much data that

Signature sound For every distinct fish call, scientists characterize the pattern of changing frequency, or pitch, and amplitude, or volume, over time. Visual representations of the sounds of three different species are shown.

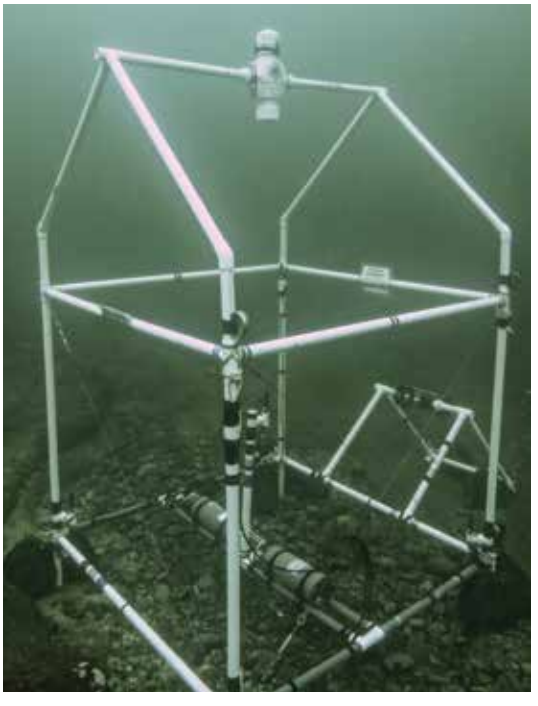


GRAPHS: FISHSOUNDS.NET (CC BY-NC 4.0 DEED); PHOTOS, FROM TOP: MARISA AGARWAL/INATURALIST (CC BY-NC 4.0 DEED); © BELOW BLUE WATER DIVER/INATURALIST (CC BY-NC 4.0 DEED); © EWOUT KNOESTER (CC BY-NC 4.0 DEED)

"the old manual techniques that people used to use to look for specific calls just aren't appropriate anymore," says Parsons, who is a leader of the GLUBS effort. Some scientists and companies have already developed algorithms that can detect specific sounds in large soundscape recordings. Parsons hopes to have GLUBS up and running in two years, depending on funding.

Still, much of what's recorded leaves people puzzled. "In acoustics, you come across hundreds and hundreds of mystery sounds," says Jill Munger, who until recently worked as a marine acoustic analyst at Conservation Metrics, a company in Santa Cruz, Calif., that develops wildlife monitoring tools. The company has a YouTube channel dedicated to unknown marine animal sounds, hoping that people around the world can listen and help identify the cryptic creatures.

New innovations to simplify matching sounds with species in the wild may also provide crucial clues. Mouy and colleagues, for instance, have developed easy-to-assemble audio-video arrays. A large version consists of an open house-shaped structure built from PVC pipes, measuring 2 meters wide, 2 meters long and 3 meters high, that fish and other critters can swim through. Six hydrophones sit at different locations, and their simultaneous recordings can help pinpoint the source of a sound produced inside the structure. Two video cameras point inward to identify the noisemaker. The devices can record two weeks of data at a time.



New innovations are helping scientists ID more soniferous species. This array of hydrophones and cameras simultaneously records audio and video of critters swimming through.

One of the most recent additions to the list of sound-making fish is the lingcod, which inhabits rocky reefs and ocean bottoms off the west coast of North America.

When testing the array and two smaller versions off the coast of British Columbia, Mouy recorded the sounds of a lingcod (*Ophiodon elongatus*), a species not previously documented in research to be soniferous. How the fish, which doesn't have a swim bladder, produces its pulsating grunt remains unknown.

Such great unknowns can both frustrate and delight. It was Lillis' annoyance with the lack of research on fish sounds that led her down the "shrimp hole" of "interviewing" fish, she says, which she started doing a little over a year ago. She's currently testing various eavesdropping techniques, including her own version of one of Mouy's arrays, to match species to their calls.

Meanwhile, Munger, who's now at the University of New Hampshire in Durham, has been obsessed with a bugling sound heard near both Hawaii and the Palmyra Atoll farther south. She and colleagues dubbed the noise "cascading saw" for its shape when graphed as pitch over time, which resembles saw-like teeth that rapidly tumble downward. People have been weighing in, whittling away possible species. But the call's origin still eludes Munger.

"It's definitely a mystery," she says. "Everybody loves a good mystery." ■

Explore more

- Browse the Fish Sounds library at fishsounds.net
- Help identify mysterious ocean sounds at youtube.com/@conservationmetrics

McKenzie Prillaman is a freelance science journalist based in Washington, D.C.

FROM TOP: MAURICIO HANDLER/GETTY IMAGES; K. COX

All Eyes on the SUN

This year's total solar eclipse offers a rare opportunity for scientists **By James R. Riordon**

The moon passes in front of the sun over Wyoming during the 2017 total solar eclipse.

Solar eclipses are dramatic events as a rule. But the total solar eclipse crossing North America on April 8 is going to ratchet up the experience.

Compared with the last total eclipse that crossed the United States, in 2017, this year's total eclipse will last longer, the sky will fall darker, and the sun itself will put on a much livelier show. And millions more people will be able to step outside their front doors to see one of the most astounding astronomical events of their lives.

It will also be the last major eclipse to cross North America for 20 years. All of that means that it's an especially rare opportunity for casual observers and scientists alike.

A longer eclipse, a more active sun

The moon will be at a point in its orbit that's relatively close to Earth in April, making the moon appear particularly large. As a result, for anyone fortunate enough to make it to the path of totality, where the moon completely blocks out the sun's disk, the eclipse will last for nearly 4½ minutes. That's almost two minutes longer than the Great American Eclipse of 2017 (*SN: 8/20/16, p. 14*).

32 million
Number of people in the United States who will be inside the path of totality

What's more, the sun will be close to solar maximum. That's the peak of its roughly 11-year activity cycle (*SN: 11/2/13, p. 22*). As a result, lots of bright, petal-like streamers of plasma will extend from the solar corona, the sun's outer atmosphere. The increase in solar activity also ups the chances of a coronal mass ejection, a large puff of plasma trapped in a loop of magnetic field that's blasted away from the sun's surface.

A longer time to observe the eclipse and a more active sun will make it both a better show and a boon for scientists who have more telescopes, sensors and satellites available to study the sun than ever before. Even viewers without other equipment should be able to see the streamers and a coronal mass ejection, if one occurs.

Crossing North America

Nearly 32 million people in the United States will be inside the path of totality, says cartographer Michael Zeiler. That's about 2½ times as many as during the 2017 eclipse. And "the major East Coast metros from Baltimore to Boston are all about 200 miles from the path of totality," he says.

That means that the path of totality is going to be very accessible to the bulk of the U.S. population, says Zeiler, founder of GreatAmericanEclipse.com. The eclipse will be visible to some degree in every U.S. state and portions of Mexico and southeastern Canada.

The eclipse path will be particularly helpful for researchers who use radar to study charged particles high in the atmosphere. Unlike the last two North American eclipses, this year's path passes within the observing range of a few radars in the worldwide Super Dual Auroral Radar Network, says space scientist Bharat Kunduri of Virginia Tech in Blacksburg.

Those radars monitor a gaslike plasma of positively charged atoms and negatively charged electrons in Earth's atmosphere, created when the sun's rays kick electrons off atoms. The plasma makes up the ionosphere, which can act like a mirror for radio signals and bounce signals from terrestrial transmitters back down to receivers, instead of letting the signals head out to space. That extends the range that transmitters can reach. The ionosphere also modifies the transmission of signals down to Earth from GPS satellites. Taking that effect into account is crucial for ensuring that GPS systems are accurate.

During a solar eclipse, as at nighttime, radiation from the sun goes away, and the atmosphere becomes less dense and less ionized. "Radio waves

OPPOSITE PAGE: JOEL KOWSKY/NASA

can behave differently," Kunduri says. Using the instruments in the radar network during an eclipse can help scientists better understand how the sun generates the ionosphere and how the plasma layer affects satellite and radio transmissions.

An eclipse, Kunduri says, "gives you an excellent opportunity to study what happens when there is a sudden change in the upper atmosphere."

Spying on a coronal mass ejection

Because of the sun's elevated activity during this eclipse, the chances are unusually high that terrestrial eclipse observers and space satellites could have the opportunity to simultaneously study a coronal mass ejection. Both the European Space Agency's Solar Orbiter and NASA's Parker Solar Probe will be looking at the sun from the side while the eclipse is happening.

That means that ground-based observers would be able to watch a coronal mass ejection traveling out from the sun, while the satellites would see the event head on, if they happen to lie in the path of an ejection, and could take samples as the solar material goes blasting past. It's the only time in the lifetimes of the two satellites that the arrangement will coincide with an eclipse at solar maximum.

If we would be so lucky to have one, says astrophysicist Nour Raouafi of Johns Hopkins Applied Physics Laboratory in Laurel, Md., and it's "propagating toward the spacecraft … it will be fascinating to see it during a total solar eclipse."

Scientists want to know more about coronal mass ejections because the solar eruptions, when aimed at Earth, can disrupt communications and power grids, and potentially threaten satellites or astronauts in orbit around Earth.

In addition to observing any coronal mass ejections, the satellites' observations could help confirm the source of particularly speedy solar winds — the stream of charged particles that flow from the sun — which seem to be accelerated by kinks that develop in magnetic fields near the surface of the sun.

Insights into the solar wind, in turn, help explain how coronal mass ejections can affect Earth. That's because the ejections pile up material in the solar

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wind, which "will affect the arrival time of these events to Earth," Raouafi says. "Knowing the conditions of the solar wind before the [ejections] is extremely important to predict when they are arriving or how potent they will be."

Eclipse day science

Several experiments planned for 2024 are repeats from past eclipses. Some feature updated instrumentation. Others will benefit from observations gathered while the sun is near its solar maximum, allowing for comparisons to the more quiescent phase that the sun was in during the 2017 eclipse. All of this year's experiments should enjoy the improvement in data quality and quantity that comes with the longer viewing time.

Take the WB-57F jet planes that carried instruments to observe the 2017 eclipse while flying along its path of totality. They will be in the air again in April, says physicist Amir Caspi of the Southwest Research Institute in Boulder, Colo. "It's a big improvement because we're flying new instruments [that provide] better information. The fact that it's solar maximum will give us a lot more things to look at."

Improved cameras and spectrometers, for example, will offer detailed views of the corona relatively close to the sun's surface. "This eclipse is also twice as long as the last one. On the ground, it's 4.5 minutes," Caspi says, "In the air, we're going to get 6.5 minutes per airplane."

If all goes well, he says, the instruments could also discover some asteroids thought to exist within the orbit of Mercury, which are difficult to detect without the moon blocking the sun's glare.

Astronomer Shadia Habbal of the University of Hawaii in Honolulu is leading a team that will fly updated cameras and spectrometers on the jets as well. She's also setting up ground-based observations at sites in Mexico, Texas and Arkansas.

Habbal is even planning to send a spectrometer up to four kilometers aloft on a kite from a location near Kerrville, Texas, to get above any clouds that might block the view. The spectrometer collects light from the sun to determine the composition of material in the corona. "There are changes in the corona that occur on timescales of seconds to minutes to hours," she says. "So the longer duration [of the eclipse] also enables us to capture [more] time variable events and their impact on the corona and solar wind."

Other repeat experiments include weather balloons that will measure waves of pressure in the atmosphere that ripple away from the passing shadow of the eclipse. And a redesigned spectrometer will ride aboard a Gulfstream jet chasing the eclipse over Texas.

There's also a number of new or improved ways that amateurs and citizen scientists can contribute to the effort, including taking pictures of the event (*SN: 11/18/23, p. 32*).

Two of NASA's WB-57F jets (one shown) will fly along the path of the eclipse on April 8, 2024, to extend the time that instruments on board can collect data and ensure the view isn't obstructed by clouds.

NASA

An astronomical event to remember

Once this year's eclipse wraps up, that will be it for North America for a while. In 2033, Alaska will get an exclusive show in the western part of the state, which might partly make up for it having the worst seat in the house, as far as U.S. states go, this time around. (Only a sliver of the state will be within range to see a portion of the sun covered up.) After that, there will be an eclipse primarily over Canada in 2044, and another that will cross the United States and northeastern South America in 2045.

While the astronomical event on April 8 will be both livelier and longer than many eclipses, Habbal says that it doesn't diminish the importance of studying other eclipses. "Every total solar eclipse yields new discoveries."

If you're one of the lucky tens of millions of people who will have a chance to enjoy totality in person, or among of the hundreds of millions within range of the partial eclipse, this is an astronomical event you won't want to miss. ■

Explore more

- For information on how to help photograph the eclipse for science, visit sunsketcher.org
- Help researchers track how the eclipse affects animals at eclipsesoundscapes.org

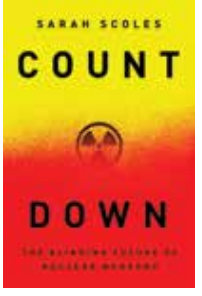
James R. Riordon is a freelance science writer based in Maryland and coauthor of Ghost Particle.

BOOKSHELF

The past, present and future of nuclear bombs

The United States is on a mission to modernize its aging nuclear weapons stockpile. And physicists have feelings about it — and the future of nuclear weapons more broadly.

In *Countdown*, science writer Sarah Scoles dredges up all the feels in interviews with physicists at the national laboratories dedicated to maintaining the U.S. nuclear stockpile and with researchers, activists and others who orbit that lab system. The researchers grapple with the legacy of their field's most infamous invention and their roles as stewards of the planet's most destructive weapons.



Countdown
Sarah Scoles
BOLD TYPE BOOKS, $30

To work on nuclear weapons, Scoles' conversations reveal, is to embrace seemingly contradictory ideas. The weapons promote peace by deterring countries from attacking each other, but the weapons also make possible the destruction of civilization. The researchers see their work — on a variety of topics, from computer simulations of nuclear weapons to nonproliferation research — as necessary and even find beauty in it, but some also dream of a world without these bombs.

The United States has not tested nuclear weapons since the 1990s, when it signed the Comprehensive Nuclear-Test-Ban Treaty. To maintain confidence in its roughly 3,700 nuclear weapons, the country aims to replace the steadily degrading nuclear material at their hearts. These bowling ball–sized pits are hollow spheres of plutonium that kick off the nuclear explosion when a bomb detonates. Currently, the United States is stuck with its aging pits, but by 2030, the plan is to produce 80 pits per year.

Yet some activists oppose the pit production and other modernization efforts — the details of which are classified and thus unknown to the public. While proponents see updating the weapons as essential to shore up the deterrent, others think the deterrent is effective as is and worry modernizing could kick off a dangerous arms race.

Countdown also delves into the history and culture of the national labs focused on nuclear work. While some of it seems like inside baseball — this or that management change — there is serious tea spilled. One scientist says Los Alamos "is in a 1950s bubble," lamenting the lab's seeming focus on the "cult of genius" — the outdated model in which a lone researcher transforms a field. And Scoles recounts drama from decades prior, of employees at Los Alamos National Laboratory in New Mexico and Lawrence Livermore National Laboratory in California rebelling against management the best way they knew how: angry blog posts and at least one snarky limerick.

With witty attention to detail, Scoles inserts moments of levity, pointing out the small absurdities surrounding this otherwise heavy topic. (She meets a scientist at Los Alamos' Hot Rocks Java Cafe, "a place whose name suggests the 1990s came up with it.") And the scientists' passion for their field shines through, like the feeling of exhilaration that comes with taming plasma, a feral state of matter consisting of electrically charged particles.

At times the book leaves the reader craving more scientific details, perhaps unavoidable when dealing with a classified subject. But some topics are glossed over more than necessary. The discussion of quantum computing — a technology that might eventually be useful for simulating nuclear weapons — is so abbreviated as to be confusing.

Throughout the book, Scoles highlights the deep connections that run between basic scientific research and nuclear applications. The conditions in an atomic bomb are similar to those elsewhere in the universe, such as in exploding stars. That means that even physicists who set out to reveal basic features of the universe might inadvertently advance knowledge about nuclear weapons. Like it or not, physics and nuclear weapons are inseparable.

The researchers Scoles profiles hope that, by understanding nuclear weapons better, we might protect ourselves from them. One research team aims to improve the detection of nuclear blasts, making it easier to verify that other countries aren't setting them off. But such knowledge could also teach a government how to hide its own tests from prying eyes. Like so much else in nuclear weapons research, there are two sides. — *Emily Conover*

The United States is working to modernize its aging nuclear weapons, such as the nuclear intercontinental ballistic missile (shown).

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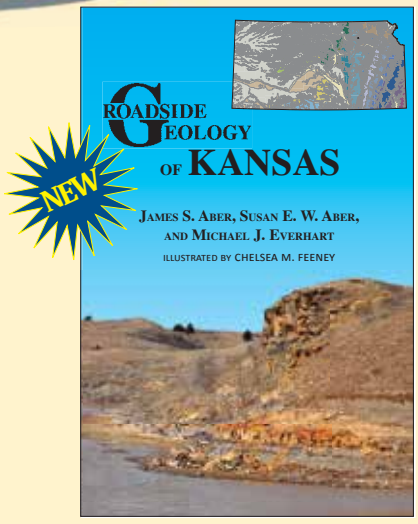

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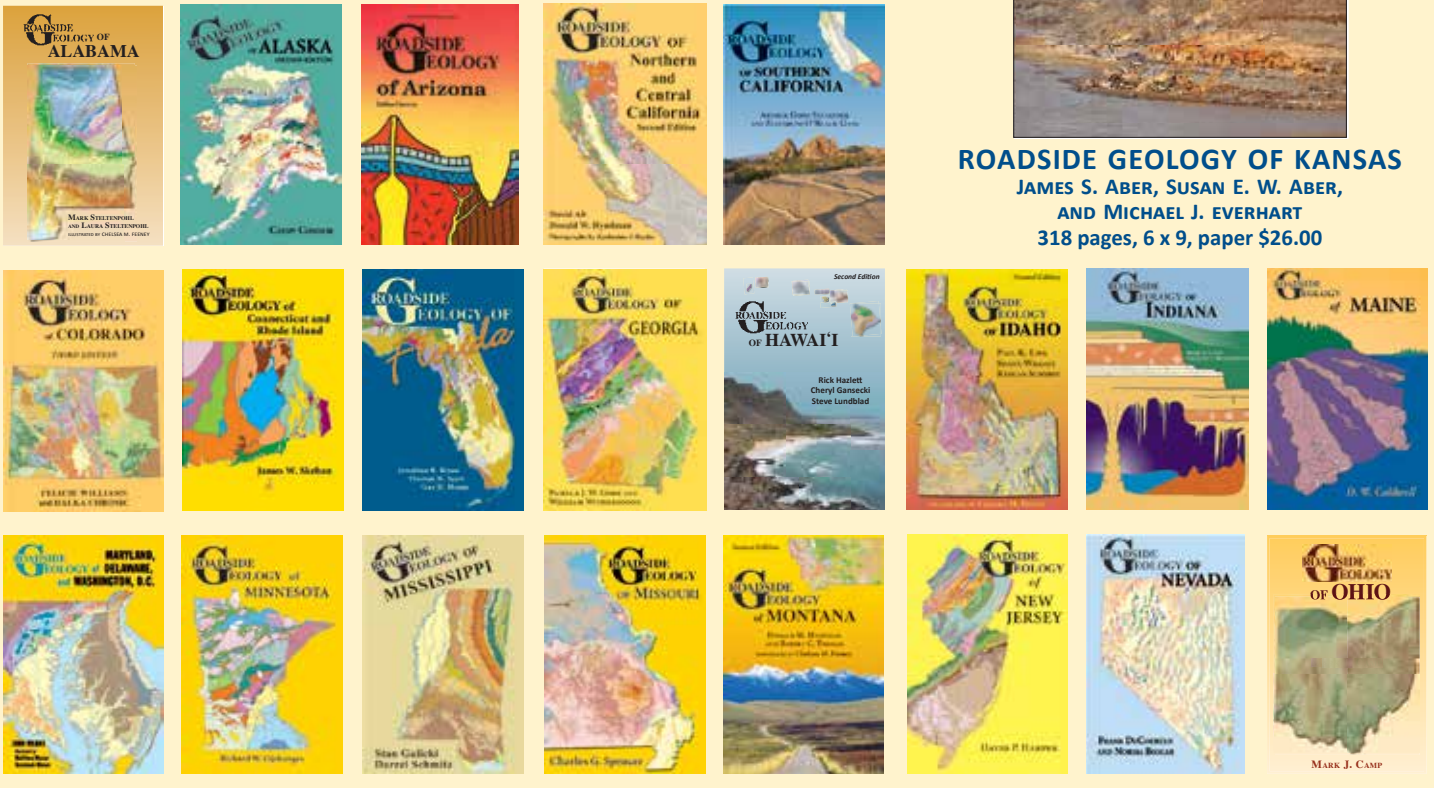

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Loree Harvey (pictured above), a teacher at Monte Vista High School in Monte Vista, Colo., is now in her third year as an Advocate. "The Advocate Program is helping to bring research opportunities to deserving, underserved students in our remote location. Our students can conduct authentic scientific research and develop to their fullest potential," she says.

Learn more about the Society's Advocate Program:
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JANUARY 27, 2024

Get low (cholesterol's version)

An experimental genetic treatment called VERVE-101 can deactivate a cholesterol-raising gene in people with hypercholesterolemia, ***Meghan Rosen*** *reported in "Base editing can lower cholesterol"* (SN: 1/27/24, p. 8).

Rosen wrote that researchers are testing to see what dosage of VERVE-101 is most effective. Given that the treatment edits a gene, reader **Linda Ferrazzara** wondered why the dose matters.

Too low a dose may mean that not enough VERVE-101 makes it to the liver, where it turns off the gene, **Rosen** says. If too few cells have the gene switched off, patients will not experience the drug's cholesterol-lowering effects. If cholesterol levels remain high after an initial treatment, a second infusion of the drug may help, **Rosen** says. But the developers prefer for the treatment to be one dose.

Reader **Jack Miller** asked whether VERVE-101 affects germ cells, which give rise to sperm and egg cells.

In mice, scientists have found that most of the drug ends up in the liver, and none goes to the germ line, **Rosen** says. The offspring of treated mice are also unaffected by the drug. So if the children of treated patients also have hypercholesterolemia, those kids would still need their own treatment, she says.

AI etiquette

To develop better safeguards, scientists are studying how people have tricked AI chatbots into answering harmful questions that the AI have been trained to decline, such as how to build a dangerous weapon, ***Emily Conover*** *reported in "Chatbots behaving badly"* (SN: 1/27/24, p. 18).

Reader **Linda Ferrazzara** wondered if AI chatbots have been trained on languages other than English.

AI chatbots like ChatGPT are based on large language models, or LLMs, a type of generative AI typically trained on vast swaths of internet content. Many of the biggest, most capable LLMs right now are tailored to English speakers, **Conover** says. Although those LLMs have some ability to write in other languages, most of their training data is in English. But there are language models designed to use other languages, she says. Efforts so far have focused on languages that are widely spoken and written, and for which large amounts of training data are available, such as Mandarin.

Ferrazzara also asked if boosting computing power could help the bots better defend against trickery.

LLMs already use a lot of computing power, and it will only increase as people use LLMs more and more, **Conover** says. But even if increased power would make establishing safeguards easier, we need to recognize that greenhouse gas emissions linked to such energy-intensive calculations contribute to climate change, she says. "The time and energy needed to respond to a chatbot query is not something we want to overlook while waiting for computers to improve."

Many of the defensive techniques described in the story screen for harmful questions. Reader **Mike Speciner** wondered if filtering the responses to those questions would be easier.

Some filters like this are already applied on some chatbots, **Conover** says. For example, Microsoft's Bing AI tends to cut off its answers if it wades into forbidden territory. These filters are more general, rather than targeted specifically at one kind of attack. "To avoid letting bad stuff slip through, they may cast too wide of a net, filtering out innocuous answers as well as dangerous ones and making the user's experience worse," **Conover** says. What's more, an attacker who knows how the LLM's self-filtering works may figure out a way to fool that filter.

Correction

"Saving lives with safe injection" incorrectly described Elizabeth Samuels of UCLA as an epidemiologist and emergency medicine physician (SN: 2/10/24, p. 16). She is an emergency and addiction medicine physician. That story also mistakenly stated that drug policy consultant Edward Krumpotich helped write the 2023 legislation in Minnesota that authorized funding for an overdose prevention center. He advocated for that legislation but did not help write it.

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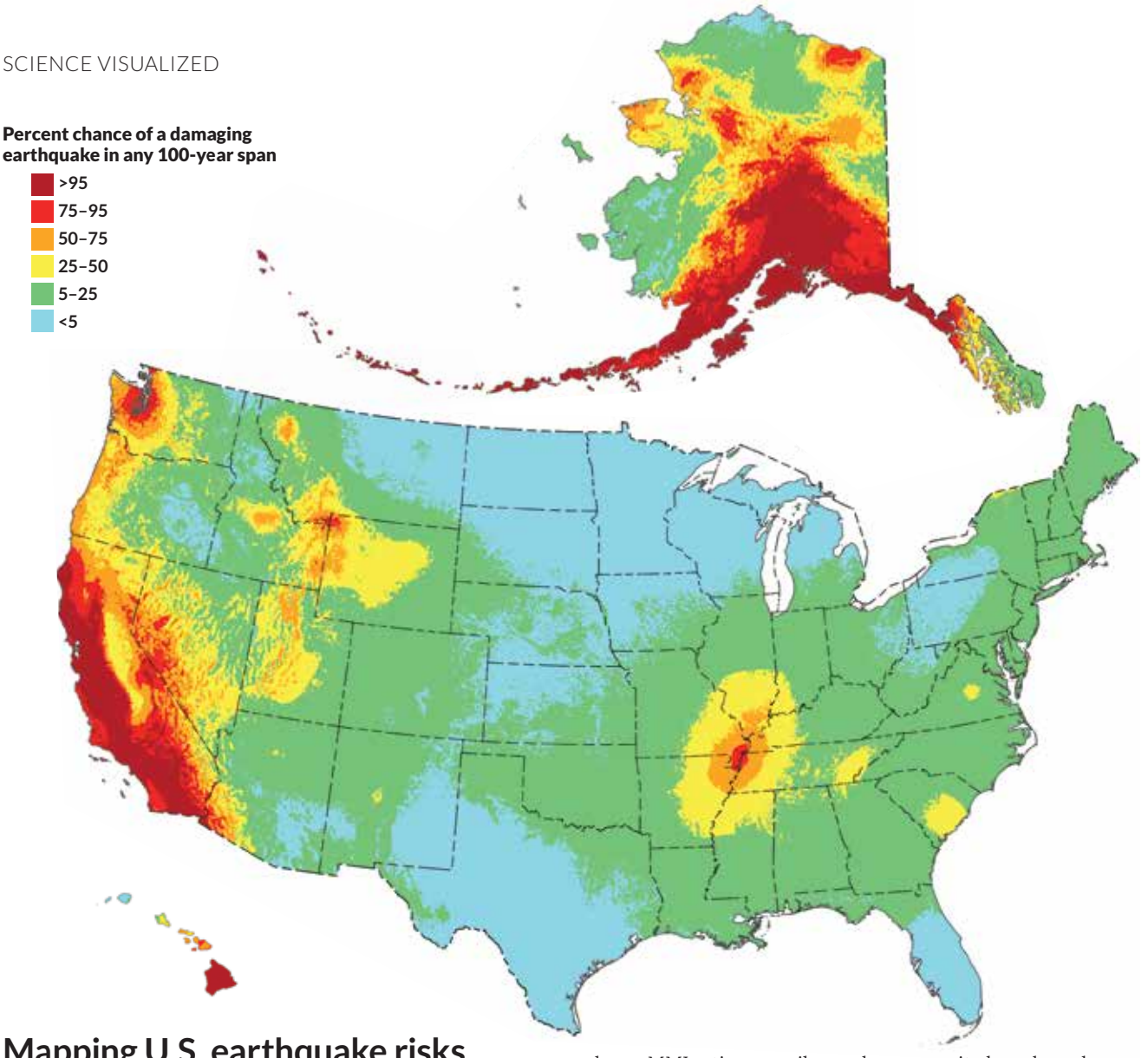

Mapping U.S. earthquake risks

Some 230 million people in the United States face the potential of experiencing a damaging earthquake, according to the latest U.S. National Seismic Hazard Model. That's about 40 million more people than the NSHM previously suggested.

"This hazard model forecasts where we think the future earthquakes will occur," and where there's "the chance of having any damage from an earthquake," says geophysicist Mark Petersen of the U.S. Geological Survey in Golden, Colo.

The NSHM draws from data on some 130,000 quakes recorded in seismic catalogs and the geologic record, as well as nearly 500 new active faults. It also incorporates new ground motion models that estimate the shaking at a site during a quake. These updates contributed to an increase in the mean earthquake hazard across the country, Petersen and colleagues report December 29 in *Earthquake Spectra*.

As part of the study, the team developed the map above, which shows the probability of a damaging earthquake in different parts of the country in any 100-year span. A damaging quake is one with a Modified Mercalli Intensity rating of VI or above. MMI ratings ascribe quakes a severity based on observable effects. An earthquake rated as MMI VI is felt by all people in a given area, frightens many, moves some heavy furniture and causes a few instances of fallen plaster.

The updated model includes an improved characterization of shaking in sedimentary basins, Petersen says. Basins with deep soil can amplify some of the waves generated by an earthquake. Accounting for that amplification elevated the hazard in some major cities, including Seattle, Los Angeles and Portland, Ore.

The new NSHM also incorporates updated ground shaking models of the subduction zones in the Pacific Northwest and southern Alaska. These are earthquake-prone areas where one tectonic plate pushes under another. In general, those changes increased the hazard very close to subduction zones and decreased the hazard away from them.

That doesn't mean that quakes are restricted to plate boundaries, though. Ground shaking hot spots also occur in southwestern Missouri and eastern South Carolina, where tectonic stresses sometimes trigger rumbling in ancient rifts in Earth's crust. — *Nikk Ogasa*

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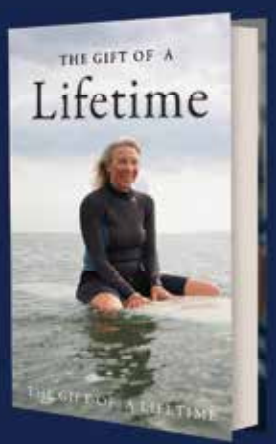

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