Why Orca Moms Play Favorites | The Milky Way's Star Power

Science News

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ MARCH 11, 2023

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As water runs low in the U.S. West, fruit and vegetable growers turn to dry farming

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VOL. 203 | NO. 5

ScienceNews


22

Features

News


10


4

Departments

COVER A lot of produce can be dry-farmed, such as these Native Sun and Marmande tomatoes grown near Portland, Ore. *Catherine Nguyen*

FROM TOP: PAUL SHEMISI/DNDI; S. CHOWDHURY, HOBYS KEY PROGRAMME CONSORTIA/PACS & SPIRE CONSORTIUM/ESA

Good with tools? You may be a cockatoo

We humans pride ourselves on our superior smarts, given our ability to make fire, use tools and subscribe to Netflix. But if other animals could counter that presumption, they might say they're doing just fine, thank you.

The latest entrant in the animal smarts sweepstakes is the Goffin's cockatoo. Birds in a laboratory in Vienna deployed both a pointy stick and a straw to extract a cashew from a clear box. They used the stick to poke a hole in a paper barrier erected by the scientists, then the straw to knock the cashew free. When scientists removed the paper barrier, some birds left the pointy stick home, staff writer Erin Garcia de Jesús reports on Page 12. Why tote around more tools than you need?

Wild cockatoos in Indonesia wield three different sticks to break open fruit pits. Other animals, including crows, also use tools but don't use multiple objects as a toolkit. That puts these cockatoos in the rarefied realm along with chimpanzees as the only nonhuman animals known to use tool sets.

Last year, Garcia de Jesús reported on another epic cockatoo skill—outwitting humans trying to keep the birds from raiding trash cans (SN: 10/8/22 & 10/22/22, *p.* 10). Many people, myself included, have resorted to using a brick or a bungee to prevent nocturnal snacking by raccoons and opossums. The cockatoos of Sydney would scoff at such a paltry effort. They quickly figured out they could push off a brick. But they were thwarted, at least for now, when humans wedged water bottles or sticks into the bins' back handles. The birds appear to be learning as the humans invent new defenses.

And lest you think bird brains have a lock on animal smarts, fish may be able to recognize themselves in photos or a mirror. Researchers in Japan found that when looking in a mirror, bluestreak cleaner wrasses would try to scrape off marks that researchers had put on their bodies. The fish could also distinguish their faces in photos from those of other cleaner fish (Page 13). Not all scientists are convinced that the fish are self-aware, but piscine partisans say it's time to give aquatic vertebrates their due, freelance contributor Betsy Mason reports.

That makes sense, given that goldfish can drive. Researchers in Israel taught six goldfish how to drive a water-filled tank to destinations around a room, we reported last year (SN: 2/12/22, *p.* 4). The fish were trained to steer toward a pink board on one side of the room and could find it even when researchers moved the board to another wall.

We loved the driving goldfish story so much that we turned it into a comic for *Science News Explores*, our magazine and website for younger readers. Evidently we weren't the only people who were charmed. The navigating fish comic, along with another on the garbage bin–raiding cockatoos and a third about pandas' camouflage skills, won the top award for science journalism for children in the 2022 AAAS Kavli Science Journalism Awards.

Thank you, animals, for continuing to amaze us, even as you chip away at our smug sense of superiority. Some animals even use computers, including nonhuman primates who have been trained to use touch screens. It's only a matter of time before they're writing editor's notes. —*Nancy Shute, Editor in Chief*

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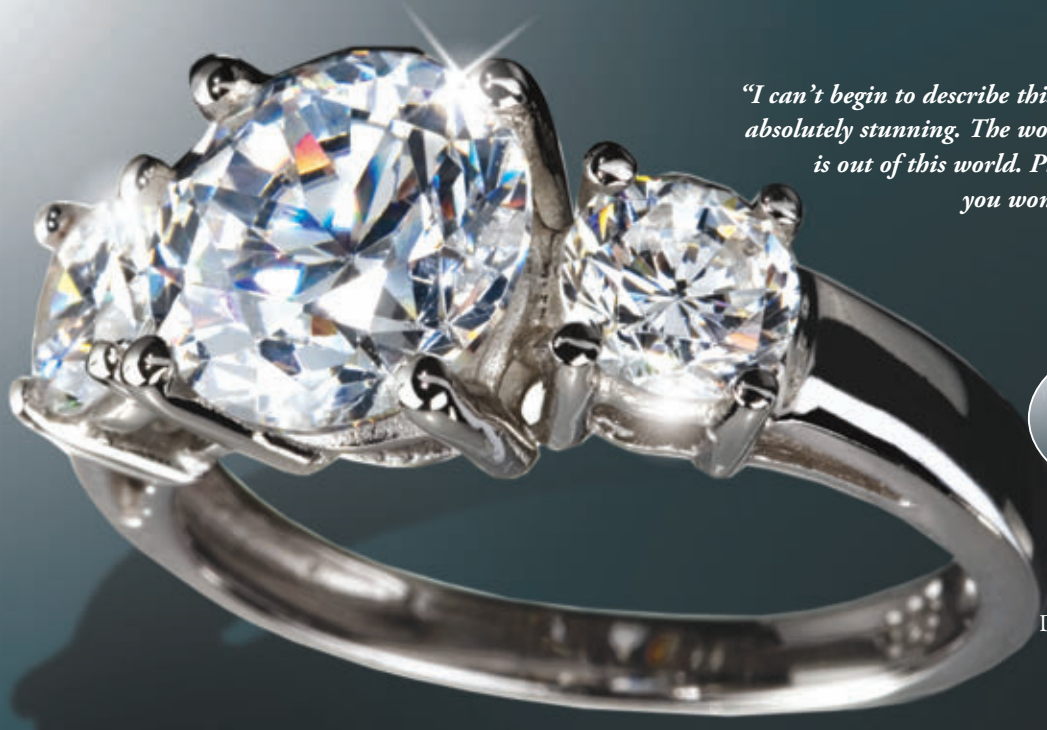
See *Science News Explores*' comic about goldfish drivers at **bit.ly/SNE_GoldfishComic**



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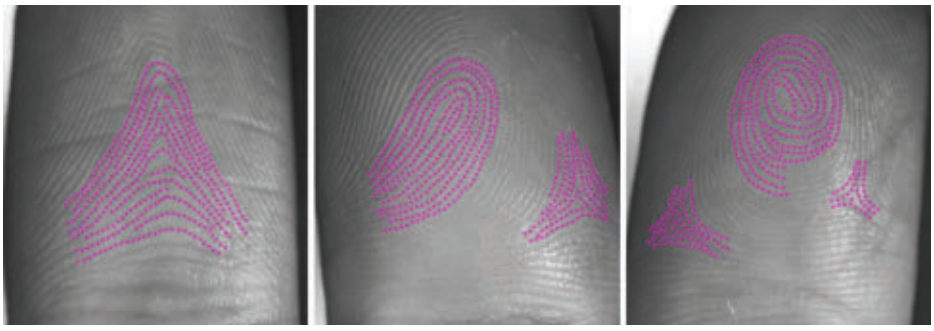
Excerpt from the March 10, 1973 issue of *Science News*

50 YEARS AGO

Oceans may be shrinking

The oceans of the world may be gradually shrinking, leaking slowly away into the Earth's mantle.... Although the oceans are constantly being slowly augmented by water carried up from Earth's interior by volcanic activity ... some process such as sea-floor spreading seems to be letting the water seep away more rapidly than it is replaced.

UPDATE: Scientists traced the oceans' leaks to subduction zones, areas where tectonic plates collide and the heavier of the two sinks into the mantle. It's still unclear how much water has cycled between the deep ocean and mantle through the ages. A 2019 analysis suggests that sea levels have dropped by up to 130 meters over the last 230 million years, in part due to Pangaea's breakup creating new subduction zones. Meanwhile, molten rock that bubbles up from the mantle as continents drift apart may "rain" water back into the ocean, scientists reported in 2022. But since Earth's mantle can hold more water as it cools (*SN: 7/12/14, p. 9*), the oceans' mass might shrink by 20 percent every billion years.



Three of the most common fingerprint shapes — arch, loop and whorl (from left, traced in purple) — can be explained in part by a theory proposed by British mathematician Alan Turing.

MYSTERY SOLVED

Turing pattern explains fingerprint formation

Scientists have finally figured out how those arches, loops and whorls formed on your fingertips.

In the womb, print-defining ridges expand outward in waves starting from three different regions on each fingertip. The skin arises in a striped pattern thanks to interactions between three molecules that follow what's known as a Turing pattern, scientists report February 9 in *Cell*. How those ridges spread from their starting sites — and merge — determines the overarching fingerprint shape.

Fingerprints are unique to each person and last for a lifetime. Scientists knew that fingerprint ridges begin forming as downward growths into the skin, like trenches. Over a few weeks, quickly multiplying cells in the trenches start growing upward, resulting in thickened bands of skin.

In the new study, researchers looked at cells from these budding fingerprint ridges and identified three chemical messengers that transfer information between cells: WNT, EDAR and BMP. Further experiments revealed that WNT tells cells to multiply, forming ridges in the skin, and to produce EDAR, which in turn further boosts WNT activity. BMP thwarts these actions, stunting ridge growth.

To examine how these messengers might interact to form patterns, the team adjusted the molecules' levels in mice. Mice don't have fingerprints, but their toes have striped ridges in the skin comparable to human prints. "We turn a dial, or molecule, up and down, and we see the way the pattern changes," says developmental biologist Denis Headon of the University of Edinburgh.

Increasing EDAR resulted in wider, more spaced-out ridges, while decreasing it led to spots rather than stripes.

That switch between stripes and spots is a signature change seen in systems governed by Turing reaction-diffusion, Headon says. This mathematical theory, proposed in the 1950s by British mathematician Alan Turing, posits how chemicals interact and spread to create patterns seen in nature. Though, when tested, the theory explains only some patterns, such as zebrafish stripes (SN: 2/22/14, p. 9).

Since mouse digits are too tiny to give rise to the elaborate shapes seen in human fingerprints, the team used a computer model to simulate a Turing pattern spreading from the three known ridge initiation sites: the center of the finger pad, under the nail and at the joint crease nearest the fingertip.

Altering the relative timing, location and angle of these starting points led to each of the three most common patterns — arches, loops and whorls. Arches, for instance, can form when finger pad ridges get a slow start, allowing ridges originating from the crease and under the nail to occupy more space.

"It's a very well-done study," says Sarah Millar, a developmental and stem cell biologist at the Icahn School of Medicine at Mount Sinai in New York City. Controlled competition between molecules also determines hair follicle distribution, Millar says. "The formation of fingerprints follows along some basic themes that have already been worked out for other types of patterns that we see in the skin."

— *McKenzie Prillaman*

J.D. GLOVER *ET AL*/*CELL* 2023

INTRODUCING

This 'croakless' frog may communicate via touch

A newfound species of frog doesn't ribbit. In fact, it doesn't make any sound at all.

Many frogs have unusual characteristics, from turning translucent to being clumsy jumpers (SN: 7/16/22 & 7/30/22, p. 5). The recently discovered amphibian lacks a voice, researchers report February 2 in *PLOS ONE*. It joins a group of seven other voiceless frog species called spiny-throated reed frogs that reside in East Africa.

Instead of listening for croaks, females may touch the spines on male frogs' throats to recognize mates, sort of like reading braille, says conservation biologist Lucinda Lawson of the University of Cincinnati.

Lawson and colleagues spotted the little frog, only about 25 millimeters long, while surveying wildlife in Tanzania's Ukaguru Mountains. The team immediately recognized the animal, now named *Hyperolius ukaguruensis*, as a spiny-throated reed frog. But something seemed off. Most spiny-throated reed frogs are green and silver; this one was gold and brown.

Instead of croaking, this newfound frog might use the spines on its throat to communicate with mates.

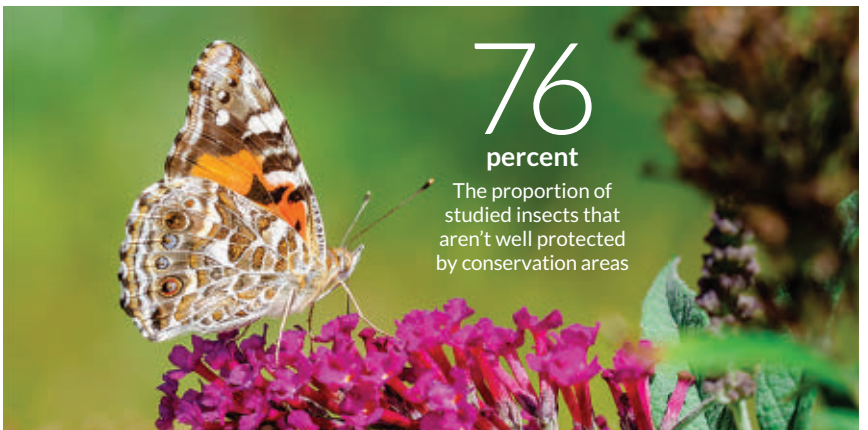
Some quick measurements revealed that the frog's eyes were smaller than other spiny-throated reed frogs', which raised the possibility that it could be a new species. So the team compared the DNA from two frogs that looked like they belonged to the suspected new species with the DNA of 10 individuals from known spiny-throated species. The golden frogs' genetic makeup was distinct.

Since the frog species in this voiceless group so far are endangered or vulnerable, it is vital to distinguish any new species and get them added to the conservation priority list, Lawson says. —*McKenzie Prillaman*

SCIENCE STATS

Conservation areas are short on insect habitats

Protected areas can provide safe havens for insects, including the Australian painted lady (*Vanessa kershawi*, below), but many existing areas fall short. National parks and other habitat preserves aren't enough to protect more than three-quarters of the world's well-studied insect species, scientists report February 1 in *One Earth*. That's a problem because the world's insect populations are plummeting. Setting aside habitat can help, but the ranges for only about 100,000 of the estimated 5.5 million species are known. To see how well preserves aid insects, ecologist Shawan Chowdhury of the German Centre for Integrative Biodiversity Research in Leipzig and colleagues compared the ranges of about 89,000 species with the World Database on Protected Areas. These spaces don't safeguard enough habitat for 76 percent of the species. Roughly 2 percent of the species don't overlap preserves at all. —*Freda Kreier*



FROM TOP: M. DEMMENIE *ET AL/PHYSICAL REVIEW APPLIED* 2023; CHRISTOPH LIEDTKE; S. CHOWDHURY

Blue dye shows how icicles grow without salt (left) and with salt (right). Salty icicles are rippled and covered in liquid water. Salt-free ones are smooth and have only small droplets.

THE EVERYDAY EXPLAINED

Why pure water icicles don't form ripples

Icicles made from pure water used to give scientists brain freeze.

In nature, most icicles are made from water with a hint of salt. But lab-made icicles free from salt disobey a prominent theory of how icicles form, and it wasn't clear why. Now, a study is helping to melt away the confusion.

Natural icicles tend to look like skinny cones with rippled surfaces—the result of a thin film of water that coats the ice, researchers think. As icicles grow, the film freezes. Any preexisting small bumps in the icicle get magnified into large ripples because the water layer is thinner above the bumps and can freeze more readily. But this theory fails to explain the salt-free variety, which has more irregular shapes reminiscent of drippy candles, says physicist Menno Demmenie of the University of Amsterdam.

Demmenie and colleagues grew icicles in the lab, adding a blue dye that was visible only when the water was liquid. Salted icicles not only had ripples, but they also were covered in a thin, blue film. Icicles made from pure water had no such film, and instead sported only small droplets of blue, the team reports in the February *Physical Review Applied*.

In icicles with salt, the temperature at which the water on the surface freezes is lowered, allowing a liquid layer to coat the entire icicle. Without the salt, icicles must build up drop by drop.
—*Emily Conover*

ANTHROPOLOGY

Early hominids butchered animals

Newly reported kits push stone-tool use back by 300,000 years

The oldest known Oldowan toolkits, dating to roughly 2.9 million years ago, consist of sharp-edged stone flakes (left), angular, palm-sized stones (center), and rounded stones (right).

T.W. PLUMMER, J.S. OLIVER AND E.M. FINESTONE/HOMA PENINSULA PALEOANTHROPOLOGY PROJECT

BY BRUCE BOWER

Nearly 3 million years ago, hominids employed stone-tool kits to butcher hippos and pound plants along what's now the shores of Kenya's Lake Victoria, researchers say.

Evidence of those activities pushes back hominids' use of these kits, consisting of Oldowan stone tools, by about 300,000 years, say paleoanthropologist Thomas Plummer of Queens College, City University of New York and colleagues. That makes these finds possibly the oldest known stone tools.

Several dating techniques place the discoveries at the Kenyan site, known as Nyayanga, at between around 2.6 million and 3 million years old. Based on where artifacts lay in dated sediment layers, these finds are probably close to about 2.9 million years old, the team reports in the Feb. 10 *Science*.

Until now, the oldest Oldowan tools, from an Ethiopian site, date to roughly 2.6 million years ago (SN: 7/6/19 & 7/20/19, *p.* 6). Excavations at another site in Kenya, called Lomekwi 3, have yielded large, irregularly shaped rocks dating to about 3.3 million years ago (*SN: 6/13/15, p.* 6). But the claim that these finds, which include some sharp edges, are actually tools is controversial.

Similarities of the Nyayanga artifacts to those found at sites dating to as late as around 1.7 million years ago "reinforce the long trajectory of Oldowan technology in the early stages of human evolution," says Manuel Domínguez-Rodrigo, an archaeologist at Rice University in Houston and the University of Alcalá in Madrid who was not involved in the work.

Skeletal remains of at least three hippos unearthed near 56 stone artifacts at Nyayanga display butchery marks, Plummer's team says. Wear patterns on another 30 stone tools indicate these items were used to cut, scrape and pound animal tissue and a variety of plants. And antelope fossils found at the site display damage from hominids removing meat with sharp stones and crushing bones with large stones to remove marrow.

The discoveries are among 330 Oldowan artifacts and 1,776 animal bones unearthed at Nyayanga from 2015 through 2017. Oldowan finds included three parts of an ancient toolkit—rounded hammerstones, angular or oval cores and sharp-edged flakes. Toolmakers struck a core held in one hand with a hammerstone held in the other hand, splitting off flakes that could be used to cut or scrape.

Whoever wielded the tools "had access to a well-balanced diet for hunter-gatherers," says coauthor Rick Potts, a paleoanthropologist at the Smithsonian Institution in Washington, D.C.

The evolutionary identity of ancient Nyayanga toolmakers remains a mystery. Plummer's team unearthed two large, peg-shaped molars belonging to *Paranthropus*, a big-jawed, small-brained hominid line that inhabited eastern and southern parts of Africa until around 1 million years ago. The Nyayanga teeth are the oldest known *Paranthropus* fossils. But there is no way to confirm that *Paranthropus* made and used the newly recovered stone tools.

Members of the *Homo* genus appeared in East Africa as early as around 2.8 million years ago and could have made Oldowan tools at Nyayanga, says archaeologist Sileshi Semaw of the National Research Center for Human Evolution in Burgos, Spain. But *Paranthropus* can't be discounted as a toolmaker. For instance, a large male *Paranthropus* skull, dubbed Nutcracker Man, lay near 1.89-million-year-old Oldowan artifacts in Tanzania, says Semaw, who was not part of the new work.

Previous discoveries indicated that Oldowan toolmakers eventually occupied much of Africa, Asia and Europe, either via the spread of toolmaking groups or through independent inventions.

Discoveries at Nyayanga fit a current consensus that stone-tool making must have begun shortly after hominids evolved smaller canine teeth around 5 million years ago, says archaeologist John Shea of Stony Brook University in New York, who was not involved in the work. Stone tools did the work formerly performed by big canines, including slicing prey carcasses, mashing edible plants and helping individuals communicate anger or dominance over others, Shea suspects.

If that tool-crafting timeline is correct, then even *Australopithecus afarensis*, known for Lucy's famous partial skeleton, may have made and used stone tools by around 3.4 million years ago. ■

NEUROSCIENCE

How psychedelics boost mental health

In rodents, the drugs get inside neurons and promote cell growth

BY MCKENZIE PRILLAMAN

Psychedelics go beneath the cell surface to unleash their potentially therapeutic effects.

These drugs are showing promise in clinical trials as treatments for mental health disorders (*SN: 12/4/21, p. 20*). Now, studies in rodents might show why. These substances can get inside nerve cells in the cortex — the brain region important for consciousness — and tell the neurons to grow, researchers report in the Feb. 17 *Science*.

Several mental health conditions, including depression and post-traumatic stress disorder, are tied to chronic stress, which contributes to neuron degradation in the cortex over time. Scientists have long thought that repairing the cells could provide therapeutic benefits, like lowered anxiety and improved mood.

Psychedelics — including psilocin, which comes from psilocybin mushrooms, and LSD — do that repairing by promoting the growth of neuron branches that receive information, called dendrites. The behavior might explain the drugs' positive outcomes in research for mental health treatments. But how they trigger cell growth has been a mystery.

Scientists already knew that, in cortical neurons, psychedelics activate a certain protein that receives signals and gives instructions to cells. This protein, called the 5-HT2A receptor, is also stimulated by serotonin, a chemical made by the body and implicated in mood. But a study in 2018 determined that serotonin doesn't make cortical neurons grow. That finding "was really leaving us scratching our heads," says chemical neuroscientist David Olson, director of the Institute for Psychedelics and Neurotherapeutics at the University of California, Davis.

To figure out why these two types of chemicals affect neurons differently, Olson and colleagues tweaked serotonin and several similar compounds to change how well they activated the receptor. Compounds that could turn it on more easily didn't make rat neurons grow. But the team noticed that "greasy" substances similar to LSD that easily pass through cells' fatty outer layers resulted in neurons branching out.

Serotonin and other polar compounds didn't induce growth because they have unevenly distributed electric charges and can't get into cells without the help of transporter proteins, which are virtually nonexistent in rat cortical neurons. Further experiments showed that most cortical neurons' 5-HT2A receptors are located inside the cell, not at the surface where scientists have mainly studied them.

But serotonin given access to the cortical neurons' interior — via artificially added gateways in the cell surface — led to growth. It also induced antidepressant-like effects in mice. A day after receiving a surge in serotonin, animals whose brain cells contained the added gateways didn't give up as quickly as normal mice when forced to swim. In this test, the longer the mice tread water, the more effective an antidepressant is predicted to be. Thus, this result suggests that inside access to 5-HT2A receptors is key for possible therapeutic effects.

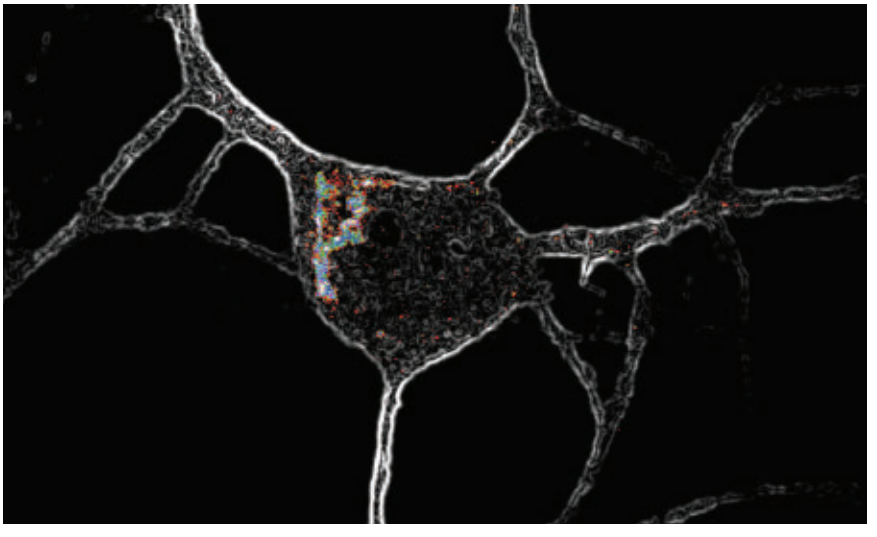
"It seems to overturn a lot about what we think should be true about how these drugs work," says neuroscientist Alex Kwan of Cornell University, who was not involved in the study. "Everybody, including myself, thought that [psychedelics] act on receptors that are on the cell surface."

That's where most receptors that function like 5-HT2A are found, says biochemist Javier González-Maeso of the Virginia Commonwealth University in Richmond, who was also not involved in the work.

Because serotonin can't reach 5-HT2A receptors inside typical cortical neurons, Olson proposes that the receptors might respond to a different chemical made by the body. "If it's there, it must have some kind of role," he says. DMT, for example, is a naturally occurring psychedelic made by plants and animals, including humans, and can reach a cell's interior.

Kwan disagrees. "It's interesting that psychedelics can act on them, but I don't know if the brain necessarily needs to use them when performing its normal function." Instead, he suggests that the internal receptors might be a reserve pool, ready to replace those that get degraded on the cell surface.

Either way, understanding the cellular mechanisms behind psychedelics' potential therapeutic effects could help scientists develop safer, more effective treatments. "Ultimately, I hope this leads to better medicines," Olson says. ■



D. OLSON/UC DAVIS

Psychedelic compounds activate a protein called the 5-HT2A receptor (highlighted with colors in this microscope image of a rat neuron) located inside nerve cells, causing the neurons to grow.

CLIMATE

Weak spots found under Antarctic ice

Thwaites Glacier melts in unexpected ways, scientists report

BY DOUGLAS FOX

Antarctica's most vulnerable climate hot spot is a remote, hostile place — a sliver of seawater beneath a slab of floating ice more than half a kilometer thick. Scientists have now explored it and uncovered something surprising.

"The melt rate is much weaker than we would have thought, given how warm the ocean is," says Peter Davis, an oceanographer at the British Antarctic Survey who was part of a team that drilled a narrow hole into this nook and lowered instruments into it. "Despite those low melt rates," he says, "we're still seeing rapid retreat" as the ice vanishes faster than it's being replenished.

Davis and about 20 other scientists conducted this research at Thwaites Glacier, a massive conveyor belt of ice that flows off the coastline of West Antarctica. Thwaites is losing ice more quickly today than at any time in the last few thousand years, hemorrhaging over 1 trillion metric tons of ice since 2000. The glacier's ice loss currently accounts for about 4 percent of all global sea level rise.

Much of Thwaites' ice loss is driven by warm, salty ocean currents that destabilize the glacier at its grounding zone, where the ice lifts off the seafloor and begins to float. This first look at the glacier's underbelly in the grounding zone shows that the ocean is attacking the ice in previously unknown ways.

Evidence gathered by a remotely operated vehicle, or ROV, sent down the borehole shows that much of the melting is concentrated where the glacier is already under mechanical stress — within massive cracks called basal crevasses. These openings slice up into the underside of the ice.

Even a small amount of melting at these weak spots could inflict a disproportionately large amount of structural damage on the glacier, the researchers report in two papers in the Feb. 16 *Nature*.

The results are "a bit of a surprise," says Ted Scambos, a glaciologist at the University of Colorado Boulder who wasn't part of the team. Glaciers are monitored mostly with satellites, which make the thinning and melting hidden under the ice seem uniform.

With global warming, the shrinking glacier has the potential to raise global sea level by 65 centimeters over a period of centuries. Its collapse could destabilize nearby glaciers and cause about three meters of sea level rise over thousands of years.

Simply getting these new observations "is kind of like a moon shot, or even a Mars shot," Scambos says. Thwaites sits on a bed that is hundreds of meters below sea level. The floating front of the glacier, the ice shelf, extends many kilometers out onto the ocean, creating a roof of ice that makes the grounding zone nearly inaccessible.

The researchers used a hot water drill to melt a hole, not much wider than a basketball, through the ice. Below the ice is a layer of water only 54 meters thick.

The underside of the ice seems to be melting at a rate of only 5 m/yr, less than what previous calculations have suggested, the researchers report. The team calculated the melt rate based on the water's salinity, which reveals the ratio of salty seawater to fresh glacial meltwater.

The reason for that slow melt: Just beneath the ice sits a layer of cold, buoyant fresh meltwater that shields the ice from warmer salty water below.

But the ROV also revealed that the walls of the crevasses are scalloped rather than smooth, suggesting a higher rate of melting than that of the flat icy ceiling. In these places, the ROV's video feed became blurry as the light refracted through swirling eddies of saltwater and freshwater. The higher melt appears to be driven by increased turbulence, which breaks up the top cold layer and draws warmer water from below into contact with the ice.

Britney Schmidt, a Cornell University glaciologist, and colleagues calculated that the walls of the crevasses are melting at rates of up to 43 m/yr.

The greater turbulence and higher melt appear driven by ocean currents within the crevasses, which move up to twice as fast as the currents outside of crevasses.

The fact that melting is concentrated in crevasses could accelerate the yearslong process by which some of these cracks propagate up through the ice and break through the top, calving off an iceberg, says team member Peter Washam, a Cornell oceanographer. It could cause the ice shelf, which presses against an undersea mountain and buttresses the ice behind it, to break apart more quickly than predicted and cause the glacier to spill ice into the ocean more quickly.

The new data will improve the ability to predict the retreat of Antarctic glaciers, says Eric Rignot, a glaciologist at NASA's Jet Propulsion Laboratory in Pasadena, Calif., who provided satellite measurements to the team. But more work is needed to fully understand how Thwaites will change. For one, a "fast lane" where the ice moves faster than the rest of the glacier wasn't visited by the team due to safety concerns, but scientists need to investigate this area too, Rignot says. Its upper surface is even more cracked with crevasses. ■

Scientists on Antarctica's Thwaites Glacier melted a hole through over 500 meters of ice to study melting near the glacier's grounding zone, where the ice lifts off the seafloor and starts to float.

P. DAVIS/BAS

CLIMATE

Climate syncs up droughts, wildfires

'Teleconnections' link dry spells or fires across continents

BY NIKK OGASA

Large-scale climate patterns that can impact weather across thousands of kilometers may have a hand in synchronizing multicontinental droughts and stoking wildfires around the world, two new studies find.

These profound patterns, called climate teleconnections, typically occur as recurring phases that can last from weeks to years. "They are a kind of complex butterfly effect, in that things that are occurring in one place have many derivatives very far away," says Sergio de Miguel, an ecosystem scientist at Spain's University of Lleida and the Joint Research Unit CTFC-Agrotecnio in Solsona, Spain.

Droughts in various regions across the globe tend to arise around the same time, and the world's major climate teleconnections may be behind the synchronization, researchers report in one study. What's more, these profound patterns may also regulate the scorching of more than half of the area burned on Earth each year, de Miguel and colleagues report in the other study.

The research could help countries around the world forecast and collaborate to deal with widespread drought and fires, the scientists say.

The El Niño-Southern Oscillation, or ENSO, is perhaps the most well-known climate teleconnection (SN: 9/14/19, *p.* 7). ENSO entails a phase of warm surface waters known as El Niño, which is caused by weakening trade winds, and an opposite phase of cooler waters called La Niña, caused by strengthening trade winds, in the eastern tropical Pacific Ocean.

These phases influence global wind, temperature and precipitation patterns, says Samantha Stevenson, a climate scientist at the University of California, Santa Barbara who was not involved in either study. "If you change the temperature of the ocean in the tropical Pacific ... that energy has to go someplace," she says. For instance, the 1982–1983 El Niño caused severe droughts in Indonesia and Australia and heavy rains and floods in parts of the United States.

Previous research has predicted that human-caused climate change will provoke more intense droughts and worsen wildfire seasons in many regions (SN: 3/28/20, *p.* 6). But few studies have looked at how shorter-lived climate teleconnections influence these events globally.

In one of the new studies, climate scientist Ashok Mishra of Clemson University in South Carolina and colleagues tapped drought data from 1901 to 2018. They used a computer to simulate the world's drought history as a network of drought events, drawing connections between events that occurred within three months of each other.

The team identified major drought hot spots across the globe — places where droughts appeared simultaneously or within a few months of each other. Hot spots included the U.S. West and Midwest, the Amazon, the eastern slope of the Andes, South Africa, the Arabian deserts, southern Europe, Scandinavia and Australia.

"When you get a drought in one, you get a drought in others," says climate scientist Ben Kravitz of Indiana University Bloomington, who was not involved in the study. "If that's happening all at once, it can affect things like global trade, [distribution of humanitarian] aid, pollution and numerous other factors."

A subsequent analysis of sea surface temperatures and precipitation patterns suggests that major climate teleconnections were behind the synchronization of droughts on separate continents, Mishra and colleagues report January 10 in *Nature Communications*. El Niño appeared to be the main driver of simultaneous droughts spanning parts of South America, Africa and Australia.

ENSO is known to exert a widespread influence on precipitation patterns. So that finding is "a good validation of the method," Kravitz says.

In the second study, de Miguel and colleagues investigated how climate teleconnections influence the amount of land burned globally. Scientists already knew that the climate patterns can influence the frequency and intensity of wildfires. De Miguel's team compared satellite data on global burned area from 1982 to 2018 with data on the strength and phase of the globe's major climate teleconnections.

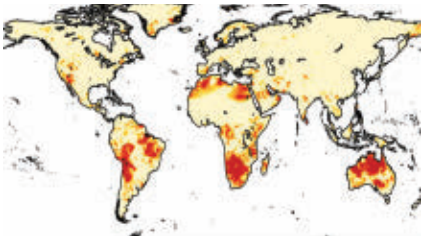
Variations in the yearly pattern of burned area aligned with the phases and range of climate teleconnections. In all, these climate patterns regulate about 53 percent of the land burned worldwide each year, the team reports January 26 in *Nature Communications*. Teleconnections directly influence the growth of vegetation and other conditions such as aridity, soil moisture and temperature that prime landscapes for fires, de Miguel says.

The Tropical North Atlantic teleconnection, a pattern of shifting sea surface temperatures just north of the equator in the Atlantic Ocean, was associated with about one-quarter of the global burned area — making it the most powerful driver of global burning.

These researchers are showing that wildfire scars around the world are tied to these climate teleconnections, and that's very useful, Stevenson says. "Studies like this can help us prepare how we might go about constructing larger-scale international plans to deal with events that affect multiple places at once." ■

In sync Climate teleconnections may spur droughts to arise on multiple continents at about the same time. Hot spots where droughts are linked are shown on the map, with redder shades indicating areas that are more prone to drought synchronization.

Where drought hot spots are found



Drought synchronization

Less — More

S. MONDAL ET AL/NATURE COMMUNICATIONS 2023

ASTRONOMY

Milky Way's star power gets a boost

The galaxy makes 10 to 20 new stars each year, a study finds

BY KEN CROSWELL

The Milky Way is churning out far more stars than previously thought, a new estimate of its star-formation rate suggests.

Gamma rays from aluminum-26, a radioactive isotope that arises primarily from massive stars, reveal that the Milky Way converts four to eight solar masses of gas and dust into new stars each year, researchers report in a paper posted January 24 at arXiv.org. That range is two to four times the conventional estimate and corresponds to an annual birthrate in our galaxy of about 10 to 20 stars, because most stars are less massive than the sun.

At this rate, every million years — a blink of the eye in astronomical terms — our galaxy spawns 10 million to 20 million new stars. That's enough to fill roughly 10,000 star clusters like the Pleiades cluster in the constellation Taurus. In contrast, many galaxies, including most of the ones that orbit the Milky Way, make no new stars at all.

"The star-formation rate is very important to understand for galaxy evolution," says Thomas Siegert, an astrophysicist at the University of Würzburg in Germany.

The more stars a galaxy makes, the faster it enriches itself with oxygen, iron and the other elements that stars create. Those elements then alter star-making gas clouds and can change the relative number of large and small stars that the gas clouds form.

Siegert and colleagues studied the observed intensity and spatial distribution of gamma-ray emissions from aluminum-26 in the Milky Way. A massive star creates this isotope during both life and death. During its life, the star blows the aluminum into space via a strong wind. If the star explodes when it dies, the resulting supernova forges more. The isotope, with a half-life of 700,000 years, decays and gives off gamma rays.

The Milky Way spawns stars in places such as the Rosette Nebula, shown in this far-infrared telescope image, and may do so with more vigor than astronomers had thought.

Like X-rays, and unlike visible light, gamma rays penetrate the dust that cloaks the youngest stars. "We're looking through the entire galaxy," Siegert says. "We're not X-raying it; here we're gamma-raying it."

The more stars our galaxy spawns, the more gamma rays emerge. The best match with the observations, the team found, is a star-formation rate of four to eight solar masses a year. That is much higher than the standard estimate for the Milky Way of about two solar masses a year.

Pavel Kroupa, an astronomer at the University of Bonn in Germany who was not involved in the work, thinks the new rate is realistic. "I'm very impressed by the detailed modeling of how they account for the star-formation process," Kroupa says. "I can see some ways of improving it, but this is really a major step in the absolutely correct direction."

Siegert cautions that it is difficult to tell how far the gamma rays have traveled before reaching our vicinity, which could affect estimates of aluminum-26 and thus the Milky Way's star-formation rate. If some of the observed gamma rays arose within a few hundred light-years of us, then the galaxy has less aluminum-26 than the team calculated. That would mean the rate is on the lower side of the new range, but it is still unlikely to be as low as two solar masses per year, Siegert says.

In any event, the Milky Way is the most vigorous star creator in a collection of more than 100 nearby galaxies called the Local Group. Andromeda, the largest galaxy in the group, converts only a fraction of a solar mass of gas and dust into new stars a year. The Milky Way ranks second in size, but its high star-formation rate means that it definitely tries a lot harder. ■

PARTICLE PHYSICS

Electron property precisely gauged

Magnetic moment confirms a standard model prediction

BY EMILY CONOVER

No one has ever probed a particle more stringently than this.

In a new experiment, scientists measured a magnetic property of the electron more carefully than ever before, making the most precise measurement of any property of an elementary particle, ever. Known as the electron magnetic moment, it's a measure of the strength of the magnetic field carried by the particle.

That property is predicted by the standard model of particle physics, the theory that describes particles and forces on a subatomic level. In fact, it's the most precise prediction made by that theory.

By comparing the new ultraprecise measurement with the prediction, scientists confirmed the theory to extremely high precision, giving the theory one of its strictest tests yet. The new measurement agrees with the standard model's prediction to about 1 part in a trillion, or 0.1 billionths of a percent, physicists report in the Feb. 17 *Physical Review Letters*.

When a theory makes a prediction at high precision, it's like a physicist's Bat Signal, calling out for researchers to test it. "It's irresistible to some of us," says physicist Gerald Gabrielse of Northwestern University in Evanston, Ill.

To measure the magnetic moment, Gabrielse and colleagues studied a single electron for months on end, trapping it in a magnetic field and observing how it responded when tweaked with microwaves. The team determined the electron magnetic moment to 0.13 parts per trillion, or 0.000000000013 percent.

A measurement that exacting is a complicated task. "It's so challenging that nobody except the Gabrielse team dares to do it," says physicist Holger Müller of the University of California, Berkeley.

The new result is more than twice as

HOBYS KEY PROGRAMME CONSORTIA/PACS & SPIRE CONSORTIUM/ESA

precise as the previous measurement, which stood for over 14 years, and which was also made by Gabrielse's team. Now the researchers have finally outdone themselves. "When I saw the [paper] I said, 'Wow, they did it,'" says Stefano Laporta, a theoretical physicist associated with the University of Padua in Italy who works on calculating the electron magnetic moment according to the standard model.

The new test of the standard model would be even more impressive if it weren't for a conundrum in another painstaking measurement. Two recent experiments, one led by Müller and the other by physicist Saïda Guellati-Khélifa of Kastler Brossel Laboratory in Paris, disagree on the value of a number called the fine-structure constant, which characterizes the strength of electromagnetic interactions (SN: 4/28/18 & 5/12/18, p. 24). That number is an input to the standard model's prediction of the electron magnetic moment. So the disagreement limits the new test's precision. If that discrepancy were sorted out, the test would become 10 times as precise as it is now.

The stalwart standard model has stood up to a barrage of experimental tests for decades. But scientists don't think it's the be-all and end-all. That's in part because the standard model doesn't explain observations such as the existence of dark matter, an invisible substance that exerts gravitational influence on the cosmos. And it doesn't say why the universe contains more matter than antimatter. So physicists keep looking for cases where the standard model breaks down.

One of the most tantalizing hints of a failure of the standard model is the magnetic moment not of the electron, but of the muon, a heavy relative of the electron. In 2021, a measurement of this property hinted at a possible mismatch with standard model predictions (SN: 5/8/21 & 5/22/21, p. 6).

"Some people believe that this discrepancy could be the signature of new physics beyond the standard model," says Guellati-Khélifa, who wrote a commentary on the new result in *Physics* magazine. If so, any new physics affecting the muon could also affect the electron. Future measurements of the electron magnetic moment might also deviate from the prediction, finally revealing the standard model's flaws. ■

PLANETARY SCIENCE

This dwarf planet hosts an odd ring

Quaoar's ring extends farther out than theory allows

BY LISA GROSSMAN

The dwarf planet Quaoar has a ring that is too big for its metaphorical finger. While all other rings in the solar system lie within or near a mathematically determined distance of their parent bodies, Quaoar's ring is much farther out.

"For the ring to be outside this limit is very, very strange," says astronomer Bruno Morgado of the Federal University of Rio de Janeiro. The finding may force a rethink of the rules governing rings, Morgado and colleagues report in the Feb. 9 *Nature*.

Quaoar, an icy body about half the size of Pluto, resides in the Kuiper Belt at the solar system's edge. To get a clear view of the world, the team watched it block the light from distant stars, a process called stellar occultation. The timing of the stars' blinking can reveal details about Quaoar, like whether it has an atmosphere.

An analysis of occultation data from 2018 to 2020 found no sign of an atmosphere, but it did find a ring. Quaoar is the third dwarf planet or asteroid in the solar system known to have a ring, after the asteroid Chariklo and the dwarf planet Haumea. However, Quaoar's ring "is not where we expect," Morgado says.

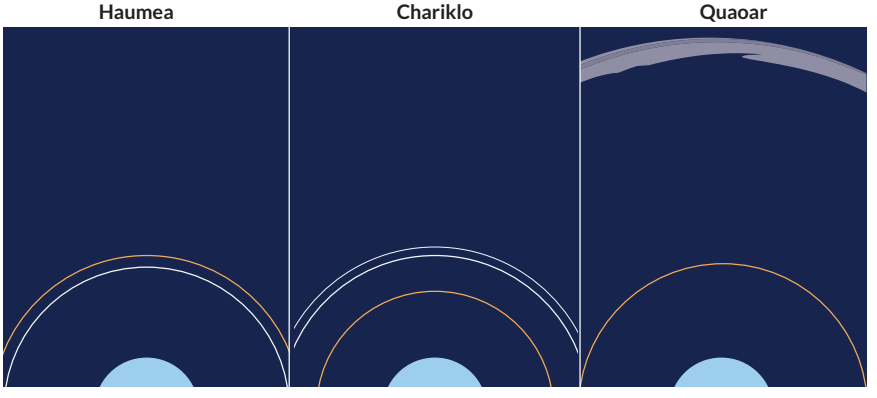
Known rings around other objects lie within or near what's called the Roche limit, an invisible line where the main body's gravitational force peters out. Inside the limit, that force can rip a moon to shreds, turning it into a ring. Outside the limit, the gravity between smaller particles is stronger than that from the main body, and rings will coalesce into moons.

"We always think of [the Roche limit] as straightforward," Morgado says. A moon forms on one side, and on the other, a ring is stable. "Now this limit is not a limit."

Perhaps the team caught the ring before it turns into a moon, Morgado says, or maybe gravity from the dwarf planet's known moon holds its ring stable. Or maybe the ring material is colliding in such a way that it avoids coalescing.

Though the finding is solid, it's unclear whether any of the hypotheses are correct, says UCLA planetary scientist David Jewitt. Predictions for such far-out rings to compare with Quaoar's situation don't yet exist. But more observations could help reveal what's going on. ■

Far-out ring Dwarf planet Haumea (left) and asteroid Chariklo (center) both have rings (white) that are close to their Roche limits (orange), an imaginary line beyond which rings aren't thought to be stable. Dwarf planet Quaoar (right), in contrast, has a ring that is clearly well beyond its Roche limit. SOURCE: M.M. HEDMAN/*NATURE* 2023



E. OTWELL

ANIMALS

Captive cockatoos can use toolkits

The birds know when two rods are better than one

BY ERIN GARCIA DE JESÚS

Forget screwdrivers or drills. A stick and a straw make for a great cockatoo toolkit.

Some Goffin's cockatoos (*Cacatua goffiniana*) know whether they need to have more than one tool in claw to topple an out-of-reach cashew, scientists report February 10 in *Current Biology*. By recognizing that two items are necessary to access the snack, the birds join chimpanzees as the only nonhuman animals known to use tools as a set.

The study is a fascinating example of what cockatoos are capable of, says Anne Clark, a behavioral ecologist at Binghamton University in New York, who was not involved in the study. A mental awareness that people often attribute to our close primate relatives can also pop up elsewhere in the animal kingdom (see Page 13).

A variety of animals including crows and otters use tools but aren't known to deploy multiple objects together as a kit. Chimpanzees from the Republic of Congo's Nouabalé-Ndoki National Park, on the other hand, recognize the need for both a sharp stick to break into termite mounds and a slender stick to fish out an insect feast (SN: 10/23/04, p. 269).

Researchers knew wild cockatoos could use three different sticks to break open fruit in the birds' native range in Indonesia. But it was unclear whether the birds might recognize the sticks as a set or instead as a chain of single tools that became useful as new problems arose, says evolutionary biologist Antonio Osuna Mascaró of the University of Veterinary Medicine Vienna.

Osuna Mascaró and colleagues first tested whether captive cockatoos could learn to smack loose a cashew placed inside a clear box and behind a thin paper barrier, akin to a chimpanzee's hunt for termites. Six of 10 cockatoos reliably knocked the nut out of the box using a stick to poke through the membrane and a plastic straw to fish for the cashew.

Two birds—a male named Figaro and a female named Fini—managed the task in less than 35 seconds on the first try. Both were already experienced tool users, Osuna Mascaró says.

Figaro, Fini and three fellow cockatoos were more likely to use both stick and straw only when the box had a paper barrier inside. If the team removed the barrier, the birds selected the straw instead of the stick as their tool.

In another test, when the cockatoos had to walk or fly to reach the box, they brought along both tools almost every time the box had a barrier. If there was no barrier, the birds usually brought only one tool, a sign they recognized when they needed their entire toolkit to get a snack.

Three of the cockatoos even learned to put the stick inside the straw to carry both at the same time, which saved the birds a trip and energy. Two birds named Kiwi and Pippin transported both tools together every time the box had a barrier rather than make two trips. Kiwi rarely brought along both tools if there wasn't paper, and Pippin did so half as often.

Trading off which tools to bring may have to do with strength. After Figaro learned to transport the tools together, he grabbed the set in 16 of 18 trials, whether the box had a membrane or not. That may be because he's one of the stronger birds in the group, Osuna Mascaró says. For Figaro, grabbing both tools at once isn't a big deal. Kiwi and Pippin, on the other hand, are weaker than he is.

Cockatoos raised in the lab probably display more abilities than a wild bird might use on an average day, Clark says. "Nevertheless, this means they can do it," she says. "That doesn't mean that the wild adult male…can do the same thing as Figaro. But he would have probably been capable of doing that had he been raised like Figaro." ■

Figaro, a Goffin's cockatoo, carries a stick within a straw as part of his toolkit to nab a cashew placed behind a thin piece of paper inside a box.

THOMAS SUCHANEK (CC BY-SA)

Watch a video of a cockatoo using tools to snag a snack at **bit.ly/SN_CockaTools**

ANIMALS

Fish recognize themselves in photos

Self-awareness may be more widespread than we realized

Bluestreak cleaner wrasses can recognize photos of themselves, suggesting that the fish have self-awareness.

MARRIO31/ISTOCK/GETTY IMAGES PLUS

BY BETSY MASON

Some fish can recognize their own faces in photos and mirrors, scientists report. The ability is usually attributed to humans and other animals considered particularly brainy, such as chimpanzees. Finding the ability in fish suggests that self-awareness may be far more widespread among animals than researchers once thought.

"It is believed widely that the animals that have larger brains will be more intelligent than animals of the small brain," such as fish, says animal sociologist Masanori Kohda of Osaka Metropolitan University in Japan. It may be time to rethink that assumption, Kohda says.

Kohda's previous research showed that bluestreak cleaner wrasses (*Labroides dimidiatus*) can pass the mirror test, a controversial cognitive assessment that purportedly reveals self-awareness, or the ability to be the object of one's own thoughts. The test involves exposing an animal to a mirror and then surreptitiously putting a mark on the animal's face or body to see if they will notice it on their reflection and try to touch it on their body. Until now, only a handful of large-brained species, including chimpanzees, dolphins, elephants and magpies, have passed the test (SN: 9/13/08, p. 10).

In a new study, cleaner fish that passed the mirror test were then able to distinguish their own faces from those of other cleaner fish in still photographs. This suggests that the fish identify themselves the same way humans are thought to, by forming a mental image of one's own face, Kohda and colleagues report in the Feb. 14 *Proceedings of the National Academy of Sciences*.

"It's truly remarkable that they can do this," says primatologist Frans de Waal of Emory University in Atlanta. "It's an incredible study."

Failing the mirror test should not be considered evidence of a lack of self-awareness, de Waal says. Still, scientists have struggled to understand why some species that are known to have complex cognitive abilities, such as monkeys and ravens, have not passed. Researchers have also questioned whether the test is appropriate for species like dogs that rely more on scent, or like pigs that may not care enough about a mark on their bodies to try to touch it.

The mixed results in other species make it all the more astonishing that a small fish can pass. In Kohda and colleagues' previous mirror test studies, published in 2019 and 2022, the team exposed wild-caught cleaner fish in separate tanks to mirrors for a week.

The researchers then injected brown dye just beneath the scales on the fish's throats, making a mark that resembles parasites that these fish eat off the skin of larger fish in the wild. When the marked fish saw themselves in a mirror, they began striking their throats on rocks or sand in the bottom of the tank, apparently trying to scrape off the marks.

In the new study, 10 fish that passed the mirror test were then shown a photo of their own face and a photo of an unfamiliar cleaner fish face. All the fish acted aggressively toward the unfamiliar photo, as if it were a stranger, but were not aggressive toward the photo of their own face.

When another eight fish that had spent a week with a mirror but had not previously been marked were shown a photo of their own face with a brown mark on the throat, six of them began scraping their throats just like the fish that passed the mirror test. But they did not scrape when shown a photo of another fish with a mark.

Animals that recognize their reflection in the mirror probably learn to identify themselves by seeing that the movement of the animal in the mirror matches their own movement, researchers think. Because the cleaner fish were also able to recognize their own faces in still images, they, and possibly other animals that have passed the mirror test, may be able to identify themselves by developing a mental image of their own face that they can compare to what they see in the mirror or photos, the team says.

"I think it's a great next step," says comparative cognitive psychologist Jennifer Vonk of Oakland University in Rochester, Mich., who wasn't involved in the work.

Vonk would like to see more research before drawing conclusions about what's being represented in the mind of a nonverbal being like a fish. "As with most other studies, it still leaves some room for further follow-up," she says.

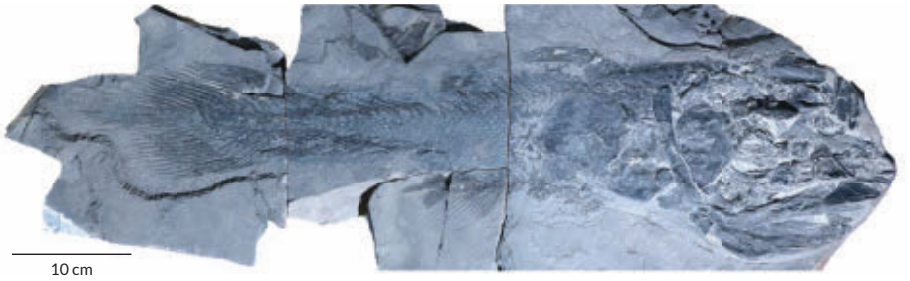
Kohda's lab has more experiments planned to continue to probe what's going on in the brain of the cleaner fish, and to try the new photo-recognition method with another popular research fish, the three-spined stickleback (*Gasterosteus aculeatus*).

Animal behaviorist Jonathan Balcombe, author of the book *What a Fish Knows*, is already convinced. People shouldn't be surprised that fish could be self-aware given that they have already been shown to have complex behavior including tool use, planning and collaboration, Balcombe says. "It's time we stopped thinking of fishes as somehow lesser members of the vertebrate pantheon." ■

PALEONTOLOGY

Great Dying didn't keep oceans down

Marine ecosystems bounced back just a million years later



A trove of fossils in China, including this bony fish called a coelacanth, provides evidence that marine life may have rapidly recovered after a mass extinction event about 252 million years ago.

BY NIKK OGASA

Following the most severe known mass extinction in Earth's history, vibrant marine ecosystems may have recovered within just a million years, researchers report in the Feb. 10 *Science*. That's millions of years faster than previously thought. The evidence, which lies in a diverse trove of pristine fossils discovered near the city of Guiyang in southern China, may represent the early foundations of today's marine ecosystems.

The conventional story was that the ocean was kind of dead for millions of years after this mass extinction, says paleontologist Peter Roopnarine of the California Academy of Sciences in San Francisco, who was not involved in the research. "Well, that's not true. The ocean [was] very much alive."

The Great Dying, also called the Permian-Triassic mass extinction, occurred roughly 252 million years ago after a series of massive volcanic eruptions (*SN Online*: 12/6/18).

"The oceans warmed significantly, and there's evidence for acidification, deoxygenation [causing widespread dead zones], as well as poisoning," Roopnarine says. "There [were] a lot of toxic elements like sulfur entering into parts of the ocean."

Life in the seas suffered. More than 80 percent of marine species went extinct. Some researchers have even proposed that entire trophic levels — functional groupings of organisms in an ecosystem's food web — may have vanished.

Figuring out how long it took for life to fully recover in the wake of all that loss has been challenging. In 2010, researchers studying an assemblage of fossils called the Luoping biota in China proposed that complex marine ecosystems fully rebounded within 10 million years. Later, other fossil finds, such as the Paris biota in the western United States and the Chaohu biota in China, led scientists to suggest that marine ecosystems re-established themselves within just 3 million years.

Then in 2015, a serendipitous discovery narrowed the gap again. Paleontologist Xu Dai, then an undergraduate student at the China University of Geosciences in Wuhan, was studying rocks from the early Triassic Period during a field trip near the city of Guiyang. When he split open a piece of black shale, he discovered within it a surprisingly well-preserved fossil of a primitive lobster.

The arthropod's immaculate condition sparked a series of return trips. From 2015 to 2019, Dai, now at the University of Burgundy in Dijon, France, and colleagues uncovered a bricolage of fossilized life: Predatory fish as long as baseball bats. Ammonoids in swirled shells. Eel-like conodonts. Early shrimps. Sponges. Bivalves. Even fossilized poo.

And the prizes kept coming. Both under and within the Guiyang biota, Dai and colleagues discovered beds of volcanic ash. An analysis of the amounts of uranium and lead in the ash revealed that the Guiyang biota dates to roughly 250.8 million to 250.7 million years ago. The types of fossils and an analysis of the different forms of carbon in the surrounding rocks further supported the dating.

Finding a potpourri of life of this age suggests that marine ecosystems rebounded quickly after the Great Dying, within just 1 million years or so, Dai says.

Alternatively, it may indicate that the extinction event failed to wipe out entire trophic levels, says paleontologist William Foster of the University of Hamburg in Germany. "You have this really environmentally stressful world, but some former marine ecosystems survive," says Foster, who was not involved in the work.

Regardless, these ecosystems were apparently hardy. Due to the motion of tectonic plates, the community preserved in the Guiyang biota was located in the tropics during the early Triassic. At that time, the sea surface was nearly 35° Celsius, and past research had suggested that many organisms migrated away to escape the heat.

But the discovery of the Guiyang biota challenges that hypothesis, Foster says. Sea creatures "are tolerating it somehow, they're adapting," he says.

The fossils may be evidence that the roots of today's marine ecosystems took hold shortly after the Great Dying, Dai says. "These groups are related to modern fish, lobsters and shrimps. They're ancestors," he says. "The oldest time we can find similar seafood to today is [in the time of] the Guiyang biota."

Roopnarine is skeptical. Exactly how the Guiyang biota connects to today's ecosystems is unclear, he says. The fossil assemblage could represent an ephemeral collective of life rather than a stable community, Roopnarine says, pointing out that ammonoids and conodonts eventually went extinct.

Further work will help resolve the many questions unearthed with the Guiyang biota, Dai says. He and colleagues plan to head back into the field this summer for the first time since 2019. When asked if he'll be keeping his eyes peeled for another lobster, he responds: "Of course." ■

X. DAI ET AL/*SCIENCE* 2023

ANIMALS

Why orca moms baby their adult sons

Catching and sharing food boosts the chances of grandwhales

BY SUSAN MILIUS

Among some killer whale moms, lifelong feeding for adult sons but not daughters could be a long-term investment play. The payoff? Greater grandmother glory.

Females in a quirky population of killer whales (*Orcinus orca*) off the Pacific coast of North America let their grown mama's boys share fish that mom catches. Biologists have known that this pampering continues throughout a son's life, which can last decades. Grown daughters, often feeding their own offspring, however, typically don't get such a bonus.

Scrutinizing decades of data has now revealed what moms sacrifice to lavish a lifetime of food on a son, scientists report February 8 in *Current Biology*. A mother's yearly chance of success—keeping a calf alive to its first birthday—drops by about half if she's feeding an older son, says behavioral ecologist Michael Weiss of the Center for Whale Research in Friday Harbor, Wash.

For the moms, "it's a huge, huge cost that they're taking on," Weiss says. It "emphasizes kind of the uniqueness and the intensity of this mother-son bond in killer whales." For creatures that bear young more than once in their lives, he says, this finding is "our first kind of direct evidence of any animal showing lifetime parental investment."

These killer whales off the coast of Washington state and British Columbia, in "the southern resident" population of orcas, don't migrate. Instead they specialize in feeding year-round on the region's fish, such as chinook salmon.

When moms catch a fish, "they do this huge head jerk, and one half of the fish stays in the mouth and the other half kind of trails behind them as they swim on," Weiss says. A son swimming with her can then grab that other half. "It's not the son coming up and grabbing the fish out of her mouth," he says.

The son's company looks consensual to Weiss. Mothers and sons "spend a lot of time kind of floating at the surface together … just kind of enjoying each other's company." Whale watchers need to take care reading interpretations into behavior, he says, but his "intuition from watching them is more about the mom wanting to provide for the son."

Weiss doesn't think the decline in new births after producing a son comes from a lack of opportunity to mate. "These whales are really social," he says. "They're usually in quite large groups, and usually with at least one sexually mature male around."

When watching them from drones, "we see that social behavior in these whales often involves a lot of sexual behavior," Weiss says. Nevertheless, all those halved fishes may not give a mom enough nutrition for the demands of whale pregnancy.

Mom's grandchild tally, however, can make up for her own limited reproduction as she coddles her sons, the whale records suggest. Sons don't have to parent. They just deliver sperm to the right address. Plus, the longer that males live, the better, Weiss says. Genetic analyses suggested that for a few years, the two oldest males in the southern resident population were siring more than half of the new calves.

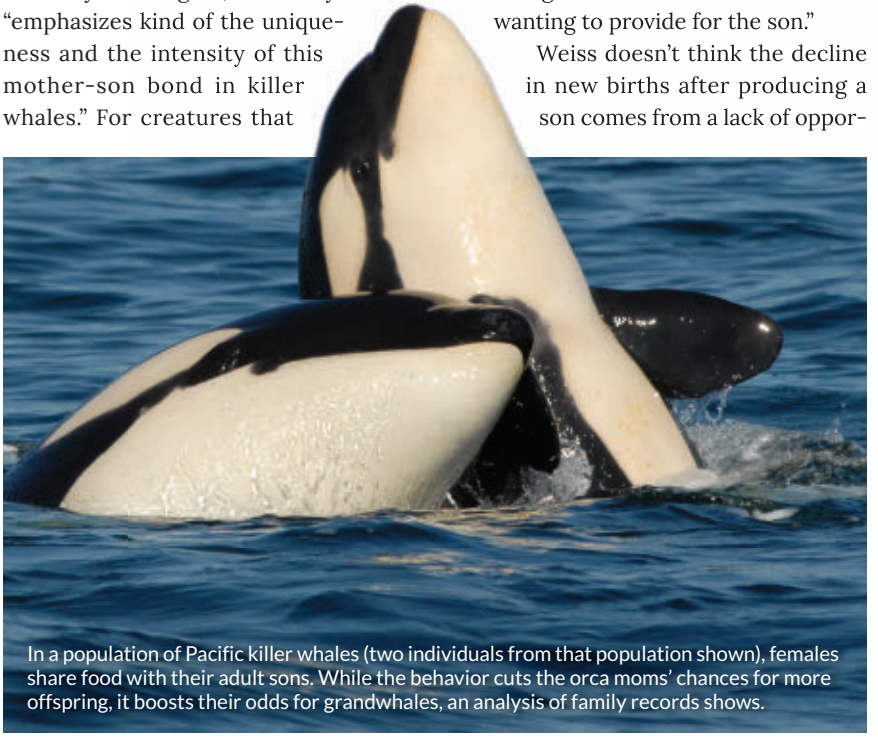
Female killer whales, however, face more constraints. Killer whale pregnancies last some 18 months. After a long time spent producing just one wrinkly not-so-little darling, the new moms then nurture their calves to independence.

Female killer whales have a chance to help later generations survive because the species is among the few nonhuman mammals that experience menopause (SN: 4/4/15, p. 8). Females can stop reproducing in their 30s or 40s, but can live into their 80s and 90s.

Whether moms in other killer whale populations also routinely and consequentially serve dinner for grown sons isn't an easy question to answer. Weiss wonders whether the same male whales in another place, perhaps with more abundant fish, would still reduce their mothers' success at later births.

No other killer whale population's records can match the depth of the ones Weiss used, says cetacean biologist Eve Jourdain of the University of Oslo. Her research focuses on killer whales around Norway, which follow the seasonal movements of herring and other food bonanzas.

Jourdain doesn't recall moms flinging fish, but she watches the whales herding local herring into big fish balls of swimming dinner. Which they share. So there may be other kinds of food-based bonding yet to be analyzed. ■



In a population of Pacific killer whales (two individuals from that population shown), females share food with their adult sons. While the behavior cuts the orca moms' chances for more offspring, it boosts their odds for grandwhales, an analysis of family records shows.

DAVID K. ELLIFRIT/© CENTER FOR WHALE RESEARCH (RESEARCH PERMIT NUMBER: NMFS 21238)

THE CLIMATE FIX

This article is part of a series of stories on climate change solutions and how people around the world are tackling the biggest challenge of our time.

Betting on dry farming

As water runs scarce in the American West, some growers are forgoing irrigation

By Katherine Kornei

In the parking lot behind a grocery store in Portland, Ore., last September, several hundred tomato aficionados gathered on a sunny, breezy day for Tomato Fest. While many attendees devoured slices of tomato quiche and admired garlands of tomatoes with curiously pointed ends, I beelined to a yellow-tented booth hosted by Oregon State University. Agricultural researcher Matt Davis was handing out samples of experimental tomatoes.

I took four small plastic bags, each labeled with a cryptic set of letters and numbers and containing a thick slice of a yellow tomato. Scanning a QR code with my phone led me to an online survey with questions about each tomato's balance of acidity and sweetness, texture and overall flavor. As I chewed on the slice from the bag marked "d86," I noted the firm, almost meaty texture. Lacking the wateriness of a typical supermarket tomato, it would hold up beautifully in a salad or on a burger, I thought. And most importantly, it was tasty.

I learned later that this tomato had been dry-farmed, a form of agriculture that doesn't require irrigation. Dry farming has roots stretching back millennia. But in the western United States, the practice largely fell out of widespread use in the 20th century.

Today, however, farmers in the West are once again experimenting with dry farming as they grapple with water shortages, which are being exacerbated by rising temperatures and more frequent and intense droughts linked to climate change.

Finding a more sustainable way to grow food in a thirsty state like California, for example, where agriculture accounts for roughly 80 percent of water usage and where a third of U.S. vegetables

These tomatoes for sale at a farmers market in Portland, Ore., were dry-farmed. The practice saves on water and produces more flavorful fruits and vegetables, advocates say.

K. KORNEI

are grown, is a top priority. Dry farming won't solve all of agriculture's woes, but it offers a way forward, particularly for smaller-scale producers, while drawing less on a scarce natural resource. And even though the practice isn't without limitations — dry-farmed produce tends to be physically smaller, and harvests are less bountiful overall — its benefits extend beyond water savings: Dry farming can also yield longer-lasting and better-tasting produce.

Tapping into the soil

It's a common misconception that dry farming means growing plants without water. "Nothing grows without water," says Amy Garrett, president of the nonprofit Dry Farming Institute in Corvallis, Ore. Instead, dry-farmed plants take up moisture stored in the ground rather than sprinkled from above.

Dry farming is possible in states throughout the West. What's needed is a wet rainy season, when rainwater infiltrates the soil, followed by a dry growing season, when plant roots pull in that moisture as needed. A wide variety of fruits and vegetables — including tomatoes, potatoes, squash, corn and even watermelons — can be dry-farmed. Dry farming is distinct from rain-fed agriculture, when crops grow during a wet season without the aid of irrigation.

For dry farming to work, a couple elements are essential. "You need to be in a place where there's sufficient rainfall to create moisture in the soil," says David Runsten, water policy director at the Community Alliance with Family Farmers in Davis, Calif. Sites must generally receive more than 50 centimeters of annual precipitation — in 2022, that was true in 26 of California's 58 counties, for example — and the soil must be composed of fine grains that help retain that water over time.

Beyond that, farmers employ a range of techniques to help crops get all the moisture they need. Those methods include planting earlier in the season than usual to take advantage of soil moisture stored up from winter rains and spacing plants more widely to give roots more room to search for water. Farmers can also plant young seedlings in furrows to minimize the drying effects of the wind and lay down an insulating layer of mulch — often leaves, wood chips or straw — on top of the soil.

Dry farming is standard practice in many places around the world, from olive groves in the Mediterranean to melon fields in Botswana to vineyards in Chile. In the American West, dry farming has a long history stretching back thousands of years among Indigenous peoples.

"Dry farming is just farming — it's our way of life," says Michael Kotutwa Johnson, an Indigenous resiliency specialist at the University of Arizona in Tucson. He's also a member of the Hopi Tribe and dry-farms corn, lima beans and other crops. He learned the practice from his grandfather.

The intimate knowledge of the natural world that dry farming requires aligns with the Hopi community's values and spiritual beliefs, he says. "You get to really learn what the environment gives you, and you learn to reciprocate." A relationship develops between the cropping system and the farmer, he says. "It's a beautiful thing, and it's something that needs to be cherished."

As non-Indigenous people started arriving in the West, they too began to dry-farm. But by the 20th century, many commercial farmers started relying on irrigation to capture growing markets. Having water on demand gave farmers more control and allowed them to boost production, says Jay Lund, vice director of the Center for Watershed Sciences at the University of California, Davis. "They could have a lot more reliable crop yields, and much higher crop yields."

But today, irrigation water in many parts of the West is in short supply. In places like California's San Joaquin Valley — the state's largest agricultural region — water is pumped up from deep aquifers and often transported through canals and pipes before being deposited on crops. Researchers estimate that more than a quarter of irrigation water can be lost during transport due to evaporation and leaks. An even bigger problem in this region is that water is being extracted from the ground at a

Children explore a field of dry-farmed corn on Hopi land in Arizona. Dry farming requires that crops be spaced farther apart than on an irrigated farm so that the plants have enough room to access all of the soil moisture they need.

M.K. JOHNSON

faster rate than it's being replenished. "There just isn't sufficient water for the amount of farmland that's been planted," Runsten says.

And access to irrigation is already being curtailed. Farmers in California and other states in the West are experiencing water shortages and have at times been entirely cut off from irrigation (SN: 9/25/21, p. 16).

That's not likely to change in the future, Runsten says. To meet the goals of California's 2014 Sustainable Groundwater Management Act, for instance, more than 200,000 hectares of irrigated farmland in the San Joaquin Valley — roughly 10 percent — will need to be taken out of irrigated production by 2040. Dry-farming speciality crops like agave or jujube, an Asian fruit similar to a date, could be an economically attractive alternative for the land, according to a 2022 report by the nonprofit Public Policy Institute of California.

~80
percent
The portion of California's water usage that goes to agriculture

Dry farming pros and cons

Catherine Nguyen, who farms on a little less than half a hectare of leased land outside of Portland, Ore., in the Willamette Valley, has been dry-farming for two years. Nguyen — whose customers include farmers market shoppers, members of her community supported agriculture, or CSA, program and small restaurants — was drawn to the practice in part out of curiosity. "I love experimentation and with the changing climate and cost of water, it seemed like something to learn more about," she says. A portion of her property also lacks access to irrigation, so dry farming made it possible to use land that would otherwise remain fallow.

Potatoes were the first crop Nguyen dry-farmed. Beyond saving roughly 7,500 liters of water, Nguyen and her small crew discovered other benefits. There was no need for sprinklers, drip tape, hosing or any other irrigation equipment. That meant Nguyen's farm could cut down on a lot of plastic equipment intended to last for just one or two growing seasons. "Not only is our water usage down, but so is our plastic usage," Nguyen says. That lighter environmental touch is important to Nguyen, who uses farming methods that promote healthy soil ecosystems, including minimal tillage and cover cropping, which involves growing plants specifically to improve the soil rather than for a harvest (SN *Online*: 4/12/22).

Last year, Nguyen dry-farmed delicata squash, corn, tomatoes, potatoes and beans. Nguyen noticed that her dry-farmed plots contained only about a fifth of the weeds that grow in her irrigated plots. That's another known advantage of dry farming, Garrett says. Irrigation creates conditions for weed growth: Dispensing water through aboveground sprinklers causes moisture to pool near the surface, precisely where weeds wait for water, she says. "There is a weed seed bank in the top few inches of soil."

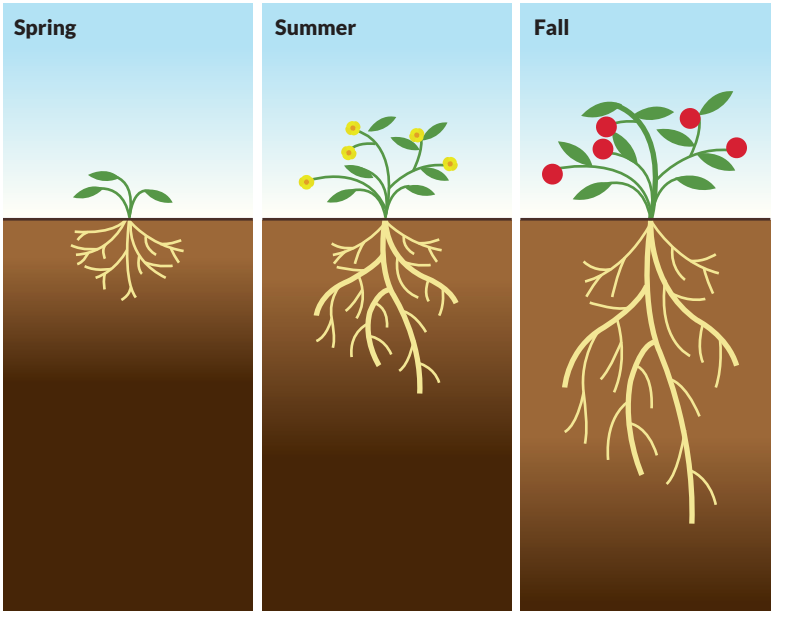
Not having to pull up as many weeds or apply herbicides can translate into labor savings. Coupled with not having to manage irrigation infrastructure, dry farming can streamline a growing operation, Garrett says. "There's a lot less to do." Labor accounts for more than a quarter of total production costs for U.S. fruit and vegetable farmers.

Another benefit is that the produce contains less water and therefore tends to store better. In 2016 and 2017, Alex Stone, a horticulturist at Oregon State University, and her student Jennifer Wetzel grew different varieties of winter squash at the university's research farm in Corvallis. The pair irrigated some vegetable plots and dry-farmed others. After harvesting the squash and leaving them in storage for four months, Stone and Wetzel found that about 1,000 of the roughly 1,250 dry-farmed winter squash, or about 80 percent, were still marketable. But only about 600 of the roughly 1,150 irrigated winter squash, or about 50 percent, were marketable.

Longer-lasting produce is a boon for small-scale fruit and vegetable growers, Garrett says. Winter is often a slow time sales-wise because there's not

All of these melons were grown in dry farming experiments at Oregon State University's Vegetable Research Farm. Melons are well-suited to dry farming because they originated in arid locations.

A. GARRETT



In search of water
Dry-farmed tomatoes grow longer roots (left in the photograph) than irrigated tomatoes (right). Dry-farmed tomatoes are planted early in spring so they can access water in the topsoil (darker brown in the diagram). A lack of irrigation in summer encourages the roots to go searching for water as the soil dries out. By fall, the roots can be more than a meter deep. SOURCE: DRY FARMING INSTITUTE

much ripening. Selling stored crops in winter is one way that these farmers can earn an income during that lull. "If winter squash is storing months longer, that makes a huge impact for our local growers," she says. Produce that lasts longer also means less food waste, both in farmers' storage bins and in shoppers' refrigerators and pantries.

Dry farming does have its downsides, however. The practice tends to produce smaller fruits and vegetables. That's a natural outcome of withholding irrigation, Lund says. "The plant has less water to feed the growth of the fruit." And growers, to say nothing of shoppers, can be wary of diminutively sized produce. That's true among farmers in Oregon, Stone says. "They want a big, red tomato."

Overall yields also tend to be lower. Not only does a dry-farmed plant produce fewer fruits or vegetables, but it also needs more space than its irrigated brethren so that its root system can spread out in search of water. Dry-farmed tomatoes, for instance, are typically planted almost two meters apart in rows separated by about two meters. Irrigated tomatoes can grow much closer together, about 60 centimeters apart, with rows separated by a meter or so.

Stone and Wetzel found that yields of irrigated winter squash at Oregon State's research farm averaged 35.7 metric tons per hectare in 2016 and 32.2 in 2017. Dry-farmed squash yields were only 37 to 76 percent as much.

Diminished harvests can be a challenge. "With land access already being one of the biggest obstacles to farming, sometimes it's hard for me to justify dry farming," Nguyen says. Last year, she dry-farmed on only about a tenth of her property. "I do have to consider yield per square foot when deciding how much land to dry-farm," she says.

Smaller harvests can translate to more expensive produce. "You don't have the economies of scale," Lund says. "Your costs are much higher per unit of production." Dry-farmed tomatoes, for instance, typically sell for $4–$6 per pound and are primarily found at farmers markets and specialty grocery stores. That's compared with $2–$3 per pound for traditional supermarket tomatoes grown with irrigation.

Dry-farmed produce may never become truly mainstream, Johnson says. "I don't see us moving in that direction as long as we still have a market system that's based on efficiency and quantity." But many dry farming experts argue that paying more for dry-farmed produce is an investment in the future. And, they point out, dry-farmed produce tastes better.

Going deep for flavor

In California's Napa Valley, there's nary an irrigation hose snaking through Dominus Estate's roughly 55-hectare Napanook Vineyard. Every last one of the more than 100,000 cabernet sauvignon, cabernet franc and petit verdot grapevines planted there is dry-farmed.

The water savings are tremendous, says Tod Mostero, Dominus Estate's director of viticulture and winemaking. A single irrigated grapevine is typically irrigated with nearly 40 liters of water several times or more over the growing season, he says. For a vineyard the size of Napanook, that translates to

FROM LEFT: A. GARRETT; C. CHANG

nearly 4 million liters, or about a million gallons, for just one watering, Mostero says. In drought-prone California, that's not sustainable, he says. "Pumping millions of gallons of water out of the soil is not something that we can continue to do."

Beyond the water savings, there's another reason Napanook Vineyard is dry-farmed, Mostero says. The practice produces the best wines, he contends. When grapevines are dry-farmed, the unique flavors of a wine associated with a place, and even a vintage, often shine through. Grapevines can send roots up to six meters deep in search of moisture. As those roots pass through layers of soil and rock, they absorb a complex set of minerals unique to that location, Mostero says. "You really find the terroir, the subtle differences between different areas." For that very reason, some wine-growing regions, in parts of Europe for example, forbid vineyards from irrigating wine grapes.

Oenophiles aren't the only ones swearing by the superior flavors of dry-farmed fruits and vegetables. Laurence Jossel, the chef-owner of Nopa, a restaurant in San Francisco that specializes in wood-fired cuisine, sources dry-farmed tomatoes from local farms. Tomatoes that are bloated with water taste "boring," Jossel maintains. "The acid is gone, and the sweetness is gone." He uses dry-farmed tomatoes in everything from soups to flatbreads. Sometimes they're the star ingredient: A salad of chopped tomatoes topped with a bit of feta or mozzarella is one of Nopa's summer offerings. "The tomato itself is just amazing," he says.

Dry farming's future

Despite the environmental benefits of dry farming, some farmers remain wary. Stone has found that growers in Oregon are often cautious about the practice, even when it comes to cultivating varieties that sell well elsewhere. A case in point is Early Girl tomatoes, which are extensively dry-farmed in California and available at both California supermarkets and farmers markets.

"They just see them as elite, expensive, small tomatoes," Stone says.

To explore the economic viability of dry farming, Stone is leading farming trials of dry-farmed crops to determine which varieties are most suited to commercial production. In recent years, she and colleagues have focused on tomatoes, which, after potatoes, are the most commonly consumed vegetable in the United States. (Technically a fruit, tomatoes are considered a vegetable for nutritional and culinary purposes by the U.S. Department of Agriculture.)

Stone's team at Oregon State has grown hundreds of types of tomatoes. By recording yields, susceptibility to common diseases like blossom-end rot, and the size, firmness and flavor of the tomatoes, the researchers have started to home in on varieties that thrive — and taste good — when the irrigation is turned off. The first yellow tomato I sampled at Tomato Fest is one of the researchers' leading contenders.

Dry farming offers one way forward as water resources become more unpredictable in the future. But it's not a one-size-fits-all panacea for climate change, researchers admit. In some cases, crops that once thrived without irrigation may no longer do well at some point in the future.

"As summers become hotter and drier, crops will require even more water as they will lose more water [through evapotranspiration], making dry farming riskier," Stone says.

Some farmers may have to swap one type of crop for another that's more suited to even drier conditions. Fruit trees with particularly long, deep roots are good bets, Garrett says, as are species like melons that originally evolved in arid locales.

Whatever the future holds, being adaptable will be key. Farmers must be prepared to respond to changing conditions, Johnson says, but must also allow nature to lead. After all, that's worked for his community for thousands of years.

"We raise corn to fit the environment," he says. "We do not manipulate the environment to fit the corn." ■

Explore more

- The Dry Farming Institute: dryfarming.org

Katherine Kornei is a freelance writer living in Portland, Ore.

Planting tomato seedlings in furrows, as shown on this dry-farmed plot in California, helps prevent the wind from wicking away precious moisture.

CAROLYN LAGATTUTA/UC SANTA CRUZ

Sacred Stone of the Southwest is on the Brink of Extinction

Centuries ago, Persians, Tibetans and Mayans considered turquoise a gemstone of the heavens, believing the striking blue stones were sacred pieces of sky. Today, the rarest and most valuable turquoise is found in the American Southwest— but the future of the blue beauty is unclear.

On a recent trip to Tucson, we spoke with fourth generation turquoise traders who explained that less than five percent of turquoise mined worldwide can be set into jewelry and only about twenty mines in the Southwest supply gem-quality turquoise. Once a thriving industry, many Southwest mines have run dry and are now closed.

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A Deadly Disease's LAST MILE

Physician Wilfried Mutombo Kalonji, shown here at the Bandundu Hospital sleeping sickness ward in the Democratic Republic of the Congo, is leading efforts to coordinate clinical trials for a new drug to treat the disease.

An experimental drug might draw the world nearer to eliminating sleeping sickness

By Meghan Rosen

The patient arrived at the hospital one hot night in Masi-Manimba, an agricultural town unfurled along the Democratic Republic of the Congo's Lukula River.

He couldn't speak, he couldn't walk, he was conscious but "barely could make … gestures," says Béatrice Kasita, a nurse who was there when he came in. She remembers his deformed posture, how his body curved into a fetal position.

He was also unusually drowsy — a telltale sign of his illness. The patient, a 27-year-old man, had been brought in by a medical team screening villagers for sleeping sickness, a deadly parasitic disease spread via the bite of a blood-feeding fly.

Since the first case report in the late 14th century, the illness has ebbed and flowed in sub-Saharan Africa. Across the continent, the predominant form of sleeping sickness shows up in about two dozen countries, most cases now occurring in the DRC. The disease is a nightmarish scourge that can maim the brain and ultimately kill. But today, cases hover near an all-time low. In 2021, the World Health Organization reported just 747 cases of the predominant form, down from more than 37,000 in 1998.

That precipitous plunge came out of decades of work, millions of screenings, spinal taps upon spinal taps, toxic treatments and the rapid rise of safer though often burdensome ones, countless IV infusions, long hospital days and nights, medicine lugged to remote villages, and communities on constant alert for sleeping sickness's insidious symptoms.

Now, a promising drug has fanned hope for halting transmission of the disease. Called acoziborole, the drug is taken by mouth in just a single dose. Kasita's patient, who arrived at the hospital in June 2017, was among the first to try it.

Her hospital is one of 10 clinical trial sites in the DRC and Guinea working to test the drug with the Drugs for Neglected Diseases initiative, or DNDi, a nonprofit organization based in Geneva. In a small trial reported last year, the drug appeared to be safe and effective. A larger trial is ongoing, with results expected by the end of this year.

If the findings hold up, the drug would be "a game changer," says Emmanuel Bottieau, an infectious disease specialist at the Institute of Tropical Medicine in Antwerp, Belgium, who is not involved with the clinical trial. A single-dose medication is "really a dream for us, coming from such a long history of very difficult or toxic or cumbersome treatments."

But he and others know that even a game-changing drug doesn't guarantee a win. The dominant form of sleeping sickness is on a short list of neglected tropical diseases the WHO is targeting for elimination by 2030. That means bringing cases in certain areas down to zero knowing that some control efforts may still be required. Vastly harder to achieve is disease eradication, where cases worldwide stay parked at zero permanently. (To date, just a single human infectious disease — smallpox — has been eradicated.)

Béatrice Kasita (center) is a nurse at a hospital in Masi-Manimba, one of 10 clinical trial sites in the DRC and Guinea for a new sleeping sickness drug. She has been caring for people with the disease for 10 years.

Even elimination is no easy task — and can get harder as you approach the finish line. "We are advancing very well," says José Ramón Franco, a WHO medical officer based in Geneva, "but we [haven't] reached the last mile."

Still, tiptoeing along the edges of optimism, some, like Kasita, are finding moments to cheer. For the severely ill patient, her team initially wondered if acoziborole would work. "Are we really going to help him with this single-dose treatment?"

Two weeks later, he could stand, with some support, and had started speaking again, a radical recovery. Kasita smiles widely as she remembers it. Watching him heal "was a great pleasure," she says.

Symptoms of the sickness

About 400 kilometers to the west of Masi-Manimba, physician Wilfried Mutombo Kalonji is preparing to visit Kasita's hospital. Afterward, he'll hit up hospitals in Idiofa, Bagata and then Bandundu, three other acoziborole clinical trial sites in the DRC. To reach the sites, Mutombo will travel by boat, plane, car and motorbike. He'll stay in both modern hotels and hotels without running water or electricity. Then, he'll return home to Kinshasa, the DRC's bustling capital. It's a great and noisy city, he grins, with people playing music in the streets and "many, many, many traffic jams."

In Kinshasa, Roi Baudouin hospital is one of the DNDi's acoziborole trial sites. Mutombo has been organizing logistics and ensuring that each site has what it needs to treat and monitor patients. That includes generators for electricity, an internet connection, medical equipment and trained clinical trial staff.

Mutombo has worked with sleeping sickness patients since 2004. Two weeks after finishing his medical training in Kasaï province, he shipped out to Kasansa, becoming the only medical

OPPOSITE PAGE: XAVIER VAHED/DNDI; THIS PAGE: PAUL SHEMISI/DNDI

doctor in a village of about 11,000 people. In Kasansa, which lies in western DRC, north of the Angola border, sleeping sickness was then, and still remains, endemic.

The disease, also called human African trypanosomiasis, is caused by a single-celled, ruffle-edged parasite that worms its way into the brain. One subspecies, *Trypanosoma brucei gambiense*, causes the vast majority of cases and tends to plague western and central Africa. Another, *T.b. rhodesiense* occurs in the eastern and southern parts of the continent and causes a more rapid, acute illness with far fewer cases in people.

Both subspecies can ride in the guts and glands of tsetse flies, which often buzz near bodies of water; many of Mutombo's patients in Kasansa were fishers or farmers. When the fly bites, the parasite enters the bloodstream. From there, it can get picked up again when other flies feed, shuttling from insects to humans in a disease-spreading cycle.

In the blood, *T.b. gambiense* sparks a slow-burning illness that can begin with a fever and, if left untreated, end with death. As the parasite multiplies, lymph nodes enlarge and the head, muscles and joints ache. Patients can also become intensely itchy, scratching hard enough to damage the skin, Kasita says.

When the parasite slips past the blood-brain barrier, patients enter the second stage of the disease. No one knows exactly where the parasite lodges in the brain, but neurological symptoms can vary. Doctors and nurses describe a range of distressing and bizarre behaviors. One common behavior gives the illness its name. Somehow, the parasite reverses people's sleep/wake cycle. "They will sleep a lot during the day, and at night, they will be up, watching," Kasita says.

Patients can also feel depressed and confused, neglect to care for themselves, hallucinate or experience logorrhea, words cascading from lips in nonsensical streams. In some infected people, personalities can swing like a wrecking ball. Jacques Pépin, an infectious disease specialist at the University of Sherbrooke in Canada, worked with sleeping sickness patients in the 1980s and remembers one who suddenly threw a large rock at his head.

Such outbursts can be scary for patients and families, says Antoine Tarral, a pharmacologist and infectious disease physician who works with Mutombo and led the DNDi's sleeping sickness program for 10 years. Fear of the disease can prompt villages to reject infected individuals, he says.

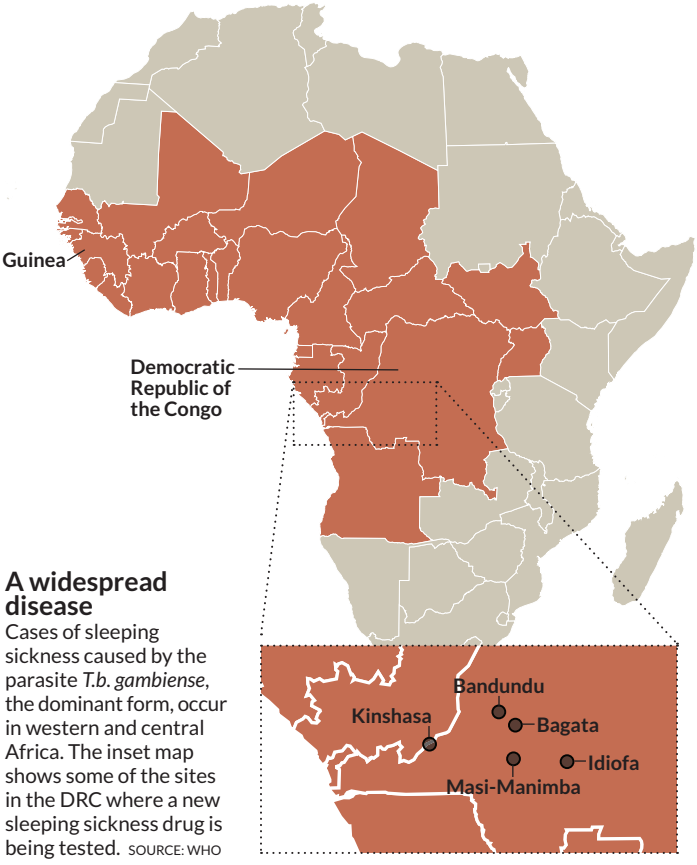
Sleeping sickness carries a social stigma that makes people feel like outcasts, Mutombo agrees. "This disease is terrible." When he first began treating patients, he says, "I was doing my best to make them feel like human beings."

But for decades, available treatments were terrible, too.

A history of terrible treatments

For most of treatment history, injected or intravenous drugs were the only option for sleeping sickness. They could cure patients, but only if doctors administered them in time. And when cases advanced to the second stage, medical staff had to switch tactics. For patients, that meant a spinal tap to confirm diagnosis followed by different drugs.

Countries where the dominant form of sleeping sickness is endemic



A widespread disease

Cases of sleeping sickness caused by the parasite *T.b. gambiense*, the dominant form, occur in western and central Africa. The inset map shows some of the sites in the DRC where a new sleeping sickness drug is being tested. SOURCE: WHO

Until the late 2000s, the most-used treatment for advanced gambiense sleeping sickness was the highly toxic melarsoprol. The drug is derived from arsenic (and it's still the leading treatment for advanced rhodesiense cases). Medical staff administered the drug for 10 days via daily intravenous infusions that burned entering patients' veins, Mutombo says. The treatment could also be lethal, killing some 5 percent of patients.

Mutombo grows somber remembering two of his patients who died, young men he tried to cure in Kasansa. "That was a very bad experience," he says. "When patients come to the hospital, they come to receive a treatment, not to die … [from] the drug we gave them."

But doctors didn't have a lot of options. Without melarsoprol, patients with serious cases faced near-certain death.

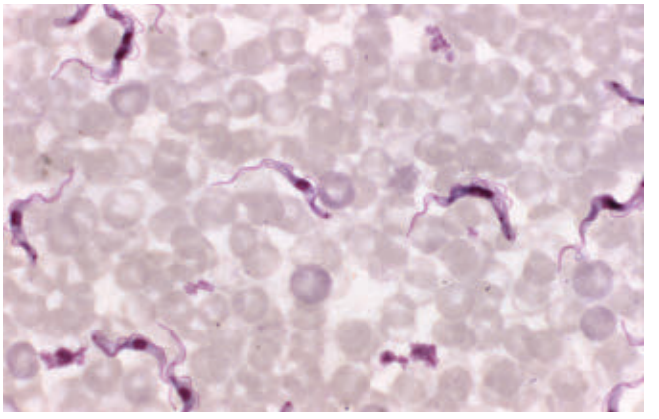
Not long after his patients died, Mutombo heard that the DNDi was launching a project on a new, less toxic treatment for advanced cases. He jumped at the chance, applied to be an investigator and joined the project in 2006. The new treatment, called NECT, combined eflornithine, an IV drug developed for cancer, with the oral drug nifurtimox. Eflornithine was already being used to treat sleeping sickness, but required dozens of infusions, and nifurtimox was a treatment for Chagas disease.

In 2009, after a clinical trial and the WHO's endorsement, NECT took off, rocketing past melarsoprol or eflornithine alone as the first-line treatment for advanced sleeping sickness. But

E. OTWELL

NECT had some logistical snafus, Mutombo says. It wasn't easy to transport, for one. Treatment for four patients came in 40-kilogram packages that had to be trucked over bad roads into rural areas that lacked medical workers. "That was a problem with NECT," Mutombo says. "It was effective, but it was heavy and needed trained staff."

Less than a decade later, Mutombo, Tarral and their DNDi colleagues debuted an easier alternative. Fexinidazole, at long last, was a drug doctors could deliver exclusively via pills rather than an IV. It's not perfect—it's administered by a nurse, patients need to take it for 10 days and it's not best for the most severe cases (for these, the WHO still recommends NECT). But easy-to-use oral drugs lower the burden on health systems, Mutombo says. Medical staff could more easily bring treatments to remote patients. And that brought scientists one step closer to sleeping sickness's elimination.



Sleeping sickness is caused by *Trypanosoma brucei* parasites, which appear in dark purple in this 1,000-fold magnification of a blood sample.

Aiming for zero

Acoziborole, the drug now being tested in clinical trials, may be another big step in the right direction. Just one dose cured some 95 percent of patients with late-stage infections, Mutombo, Tarral and colleagues reported November 29 in the *Lancet Infectious Diseases*. That's comparable to treatment with NECT. "Acoziborole is one solution to manage this disease," Tarral says.

Not only does the drug seem to be effective, but "it's given orally … and it needs to be given only once," says the University of Sherbrooke's Pépin, who was not involved with the trial but wrote an opinion piece that appeared alongside the new report.

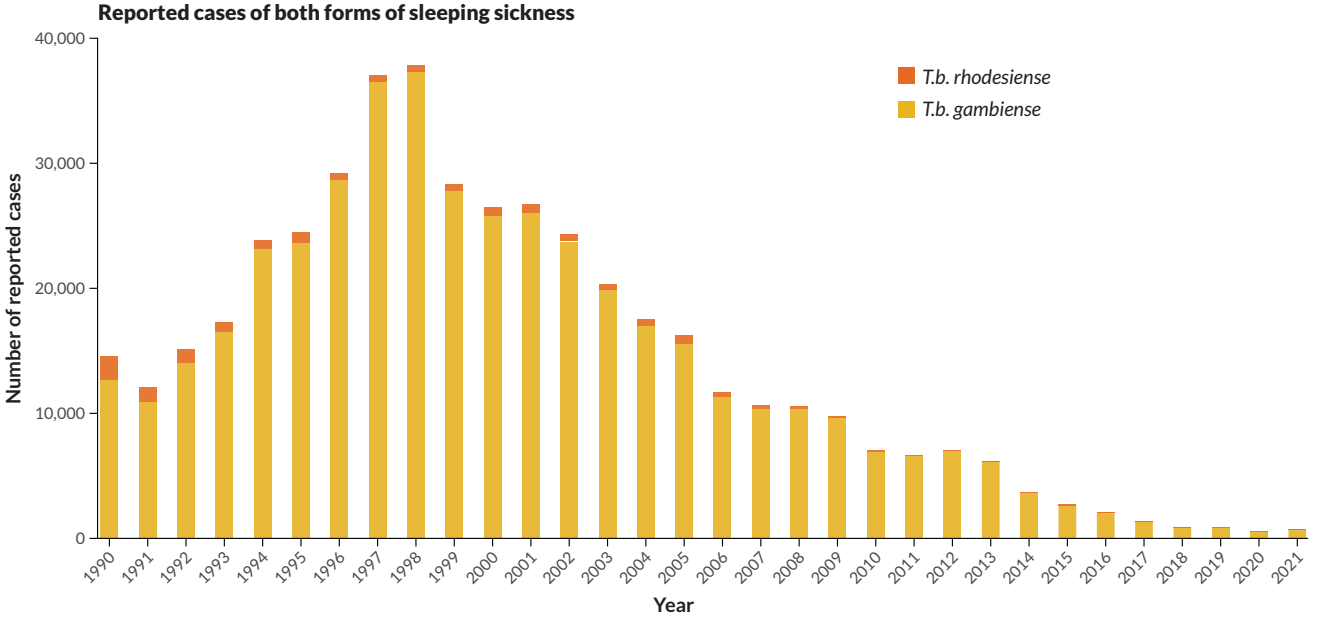
Yet, as Pépin points out, the acoziborole study has some limitations. The scientists tested the drug in just 208 patients, so no one knows if serious adverse effects might occur in larger populations. And the study wasn't performed like the classic gold-standard clinical trial, with patients randomly assigned into different groups receiving different interventions.

Tarral acknowledges these drawbacks, which he says were due to low participant numbers. The researchers included only people with video-confirmed parasitic infections, which required years of searching for patients across 10 hospitals in two different countries.

"It's not the standard approach, but that was the only possible approach," Pépin says. "They did what could be done with the number of cases that are occurring now."

The study's promising results spurred a new, larger trial that will include 1,200 participants. This time, the team is enrolling people with positive antibody blood tests even if the parasite's presence hasn't been confirmed. Many of these participants

Efforts pay off The number of reported sleeping sickness cases caused by *T.b. gambiense* (yellow) and *T.b. rhodesiense* (orange) has dropped steadily since the late 1990s. The World Health Organization hopes to eliminate transmission of gambiense sleeping sickness by 2030. SOURCE: WHO



FROM TOP: DR. MAE MELVIN/CDC; E. OTWELL

Physician Felix Akwaso Massa (far left), an investigator with the DNDi's sleeping sickness clinical trials, speaks with Charnelle Mafuta (pictured with her family), a woman who was treated for sleeping sickness with the oral drug fexinidazole.

XAVIER VAHED/DNDI

may not actually be sick, says Veerle Lejon, a scientist at the French National Research Institute for Sustainable Development in Montpellier who was not involved in developing the drug but is collaborating with the DNDi on evaluating sleeping sickness diagnostics.

What this trial will offer, she says, is a raft of new data that will help determine the drug's safety.

The perils of success

Even if acoziborole gets the green light, stamping out sleeping sickness isn't a sure bet.

Eliminating an infectious disease is a slippery task. Success can, paradoxically, churn out new challenges. When case numbers dip low enough, for instance, interest in the disease can wane. Donors move money to other public health priorities, and once-robust control programs wither.

That happened for sleeping sickness in the 1960s, the last time cases dropped. Over the next few decades, cases ratcheted up, and epidemics broke out in Angola, the DRC and South Sudan. "Control of the disease was neglected, and then slowly, the disease came back," says WHO medical officer Franco.

A doubled-down effort to find cases and treat them with ever-improving drugs got sleeping sickness under control again, with case numbers cratering to their low point today. But that level of surveillance is not sustainable, Franco says.

Health care workers can also lose knowledge of how to recognize the disease as they encounter fewer and fewer infected individuals, says Jennifer Palmer, a medical anthropologist at the London School of Hygiene and Tropical Medicine. "The challenge is really in making sure that people are aware that sleeping sickness is still a problem," she says. In a small study in South Sudan, reported in 2020, Palmer and colleagues found that lay people encouraging people in the community to get tested accounted for more than half of detected cases.

Still, getting patients tested and treated can depend on whether they're able to safely travel to health facilities. With the threat of violence in South Sudan and armed conflict in eastern DRC, the fate of sleeping sickness may also be shaped by the whims of war.

Even if every infected person was promptly found and treated, the disease-causing parasite would likely linger in wild and domestic animals. Scientists have found *T.b. gambiense*, for instance, in dogs, pigs, goats and sheep. No one knows the role infected animals play in reigniting outbreaks in humans.

Though the road to elimination may still be rocky, the patients Kasita and others are treating in Masi-Manimba and beyond offer a lesson for those working on disease elimination: Don't give up too soon. Maybe the world won't reach zero sleeping sickness cases by 2030, Lejon says, "but I think we should really give it a try," she says. "We have momentum at this moment to do it."

Mutombo echoes her enthusiasm. In less than 20 years, new drugs have completely overhauled patient care, he says. "We've made a great change in less than one generation.... Now, we expect that elimination is within reach." ■

Explore more

- The Drugs for Neglected Diseases initiative: dndi.org
- Jose R. Franco *et al.* "The elimination of human African trypanosomiasis: Achievements in relation to WHO road map targets for 2020." *PLOS Neglected Tropical Diseases*. January 18, 2022.

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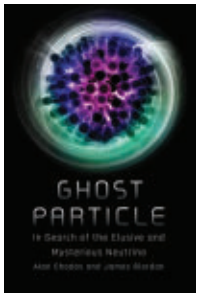


Ghost Particle
Alan Chodos and James Riordon
MIT PRESS, $32.95

BOOKSHELF

Get to know physics' most puzzling particle

We live in a sea of neutrinos. Every second, trillions of them pass through our bodies. They come from the sun, nuclear reactors, collisions of cosmic rays hitting Earth's atmosphere, even the Big Bang. Among fundamental particles, only photons are more numerous. Yet because neutrinos barely interact with matter, they are notoriously difficult to detect.

The existence of the neutrino was first proposed in the 1930s and then verified in the 1950s. Decades later, much about the neutrino — named in part because it has no electric charge — remains a mystery, including how many varieties of neutrinos exist, how much mass they have, where that mass comes from and whether they have any magnetic properties.

These mysteries are at the heart of *Ghost Particle* by physicist Alan Chodos and science journalist James Riordon. The book is an informative, easy-to-follow introduction to the perplexing particle. Chodos and Riordon guide readers through how the neutrino was discovered, what we know — and don't know — about it, and the ongoing and future experiments that (fingers crossed) will provide the answers.

It's not just neutrino physicists who await those answers. Neutrinos, Riordon says, "are incredibly important both for understanding the universe and our existence in it." Unmasking the neutrino could be key to unlocking the nature of dark matter, for instance. Or it could clear up the universe's matter conundrum: The Big Bang should have produced equal amounts of matter and antimatter, the oppositely charged counterparts of electrons, protons and so on. When matter and antimatter come into contact, they annihilate each other. So in theory, the universe today should be empty — yet it's not. It's filled with matter and, for some reason, very little antimatter.

Science News spoke with Riordon, a frequent contributor to the magazine, about these puzzles and how neutrinos could act as a tool to observe the cosmos or even see into our own planet. The following conversation has been edited for length and clarity. — *Erin Wayman*

In the first chapter, you list eight unanswered questions about neutrinos. Which is the most pressing to answer?
Whether they're their own antiparticles is probably one of the grandest. The proposal that neutrinos are their own antiparticles is an elegant solution to all sorts of problems, including the existence of this residue of matter we live in. Another one is figuring out how neutrinos fit in the standard model [of particle physics]. It's one of the most successful theories there is, but it can't explain the fact that neutrinos have mass.

Why is now a good time to write a book about neutrinos?
All of these questions about neutrinos are sort of coming to a head right now — the hints that neutrinos may be their own antiparticles, the issues of neutrinos not quite fitting the standard model, whether there are sterile neutrinos [a hypothetical neutrino that is a candidate for dark matter]. In the next few years, a decade or so, there will be a lot of experiments that will [help answer these questions,] and the resolution either way will be exciting.

Neutrinos could also be used to help scientists observe a range of phenomena. What are some of the most interesting questions neutrinos could help with?
There are some observations that simply have to be done with neutrinos, that there are no other technological alternatives for. There's a problem with using light-based telescopes to look back in history. We have this really amazing James Webb Space Telescope that can see really far back in history. But at some point, when you go far enough back, the universe is basically opaque to light; you can't see into it. Once we narrow down how to detect and how to measure the cosmic neutrino background [neutrinos that formed less than a second after the Big Bang], it will be a way to look back at the very beginning. Other than with gravitational waves, you can't see back that far with anything else. So it'll give us sort of a telescope back to the beginning of the universe.

The other thing is, when a supernova happens, all kinds of really cool stuff happens inside, and you can see it with neutrinos because neutrinos come out immediately in a burst. We call it the "cosmic neutrino bomb," but you can track the supernova as it's going along. With light, it takes a while for it to get out [of the stellar explosion]. We're due for a [nearby] supernova. We haven't had one since 1987. It was the last visible supernova in the sky and was a boon for research. Now that we have neutrino detectors around the world, this next one is going to be even better [for research], even more exciting.

And if we develop better instrumentation, we could use neutrinos to understand what's going on in the center of the Earth. There's no other way that you could probe the center of the Earth. We use seismic waves, but the resolution is really low. So we could resolve a lot of questions about what the planet is made of with neutrinos.

Do you have a favorite "character" in the story of neutrinos?
I'm certainly very fond of my grandfather Clyde Cowan [he and Frederick Reines were the first physicists to detect neutrinos]. But Reines is a riveting character. He was poetic. He was a singer. He really was this creative force. I mentioned [in the book] that they put this "SNEWS" sign on their detector for "supernova early warning system," which sort of echoed the ballistic missile early warning systems at the time [during the Cold War]. That's so ripe. ■

During a Society for Science event in 2022 in Boston, Dr. Shantanu Gaur (far left), an ISEF alumnus, moderated a conversation on nutrition and obesity science between fellow ISEF alumna, Dr. Fatima Cody Stanford (middle) and Dr. Jeffrey Flier (right).

ENGAGING WITH COMPETITION ALUMNI

Are you or someone you know a past participant of the Science Talent Search, International Science and Engineering Fair (ISEF) or one of Society for Science's middle school competitions?

The Society offers competition alumni opportunities to connect with one another and members of the community who share a curiosity and love of science. We want to fuel your passion for STEM education and science literacy, and connecting is the first step.

During the last two years, the Society has increased opportunities for alumni to connect both in person and virtually. Alumni can participate in panel discussions, attend networking events and volunteer at ISEF. Past events have included an in-person discussion in Boston about obesity science (pictured above) and a conversation with renowned economist Raj Chetty, held virtually.

Scan here to take a brief survey and get involved today

‘Parachute paleontology’ visualized for 3 countries

In the Cretaceous Period, roughly 100 million years ago, *Ubirajara jubatus* probably turned heads with its feathers and shoulder rods. In 2020, the petite theropod made headlines as the first feathered dinosaur fossil discovered in the Southern Hemisphere (*SN: 1/16/21, p. 11*).

Today, the dinosaur is notorious because the fossil’s backstory quickly raised red flags. It was unearthed in Brazil, yet no Brazilian researchers were involved in its study. The researchers initially said they found the fossil in a Brazilian museum and then brought it to a German museum in 1995 for further study, yet that museum later revealed it bought the fossil in 2009 from a private company. That company imported the fossil to Germany in 2006. It’s not clear if that import was legal.

U. jubatus is an example what some call “parachute paleontology.” This is where researchers from high-income countries travel to lower-income countries to study fossils without the involvement of local experts or by skirting local laws around fossil collection and export. In other instances, foreign researchers buy fossils from dealers, smugglers or collectors in their own countries.

“I’ve heard it described as a conquest culture, where the Earth is there to be explored and exploited,” says paleobiologist Emma Dunne of Friedrich-Alexander-Universität Erlangen-Nürnberg in Germany. This culture can encourage corruption in local communities, discourage local scientists and produce unethical research.

To understand the extent of parachute paleontology, Dunne and colleagues searched the scientific literature to see just how common these practices were around the world. The graphs to the right offer snapshots of the situation in Brazil, Mexico and Myanmar — all former European colonies. Each country acts as a case study showing a spectrum of the different ways parachute science hurts communities where fossils are found. “As soon as you give people cold, hard numbers, they suddenly just turn around and listen,” Dunne says.

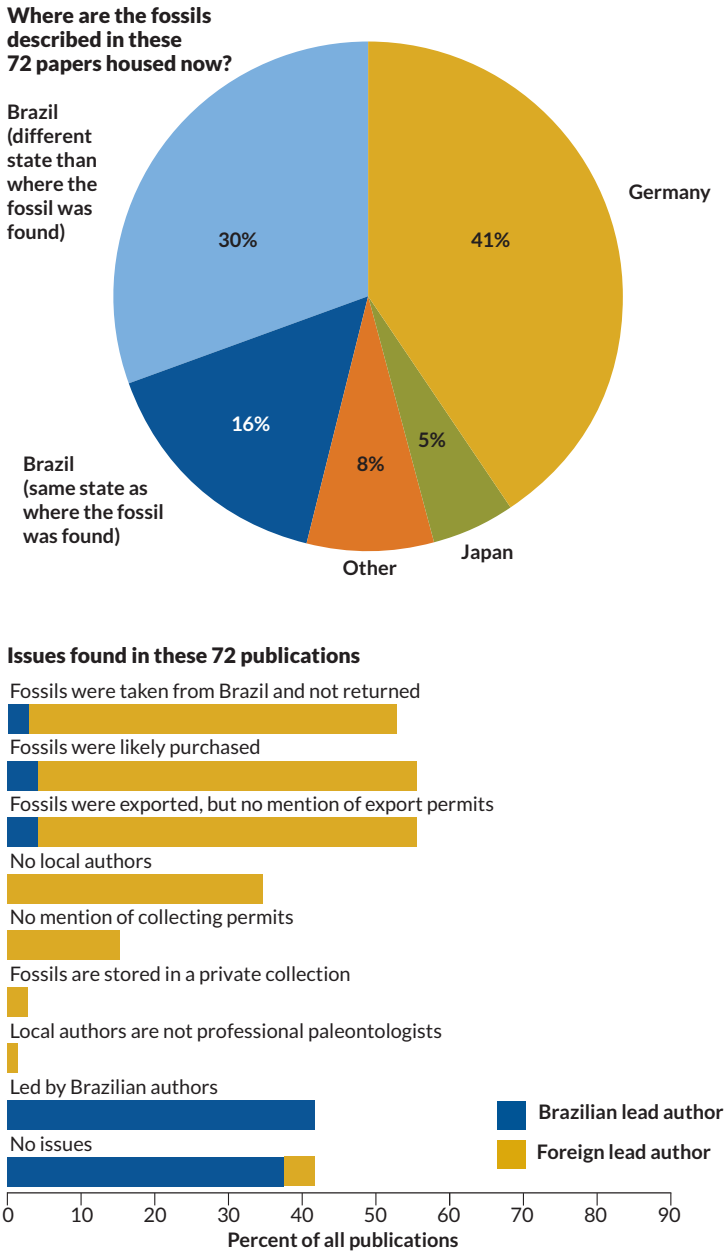
Combating the issue requires work on all fronts, she says. Journals must require more information on a fossil’s origin and chain of custody; funders need to insist that grant recipients work with local experts and follow local laws; governments have to enforce those laws; and foreign researchers should collaborate with and credit their local counterparts.

U. jubatus got a somewhat happy ending. The journal *Cretaceous Research* withdrew the discovery paper, and in July, Germany agreed to return the fossil to Brazil. But paleontology still has work to do. The pressure to publish papers that make splashy headlines, which drives some of this bad behavior, as Dunne notes, isn’t going away.

— Helen Thompson

Brazil

Publications on Cretaceous fossils from Araripe Basin, 1990–2020

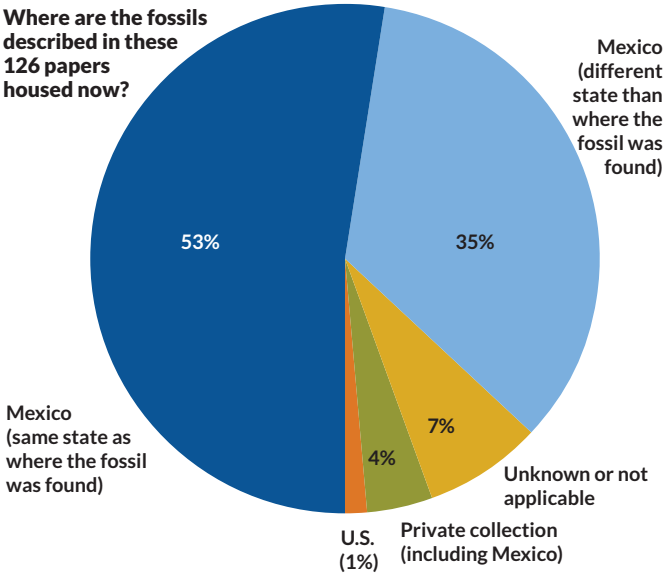


Exported heritage For Brazil, Dunne and colleagues looked at 72 papers from 1990 to 2020. Each paper described the fossil of a new Cretaceous vertebrate or plant species found in Araripe Basin. By law, all fossils unearthed in Brazil are owned by the federal government. And yet over half the fossils described in these papers are now in a different country (top graph), the team found. Of the nearly 60 percent of papers on exported fossils, none mentioned export permits (bottom). Over half of all studies described fossils that were likely bought, though the sale of fossils is illegal in Brazil. Papers led by Brazilian authors had far fewer of these issues. These problems make local students lose interest in paleontology, says study coauthor Juan Carlos Cisneros, a paleontologist at Universidade Federal do Piauí in Teresina, Brazil. “They see that foreigners are basically doing their research.” In Brazil, fossils are considered part of the national heritage. When fossils are housed in other countries, Cisneros says, it becomes hard for local researchers to study their own heritage. SOURCE: J.C. CISNEROS *ET AL*/*ROYAL SOCIETY OPEN SCIENCE* 2022

BOTH: H. THOMPSON, T. TIBBITTS

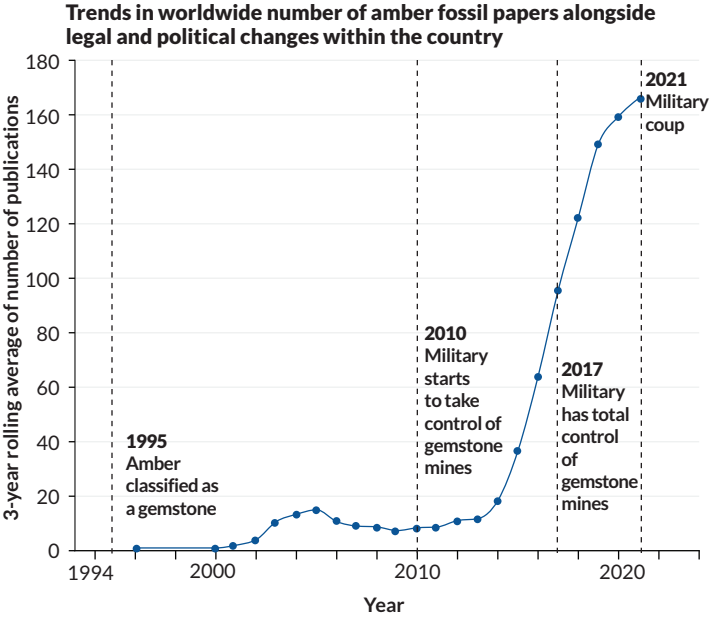
Mexico

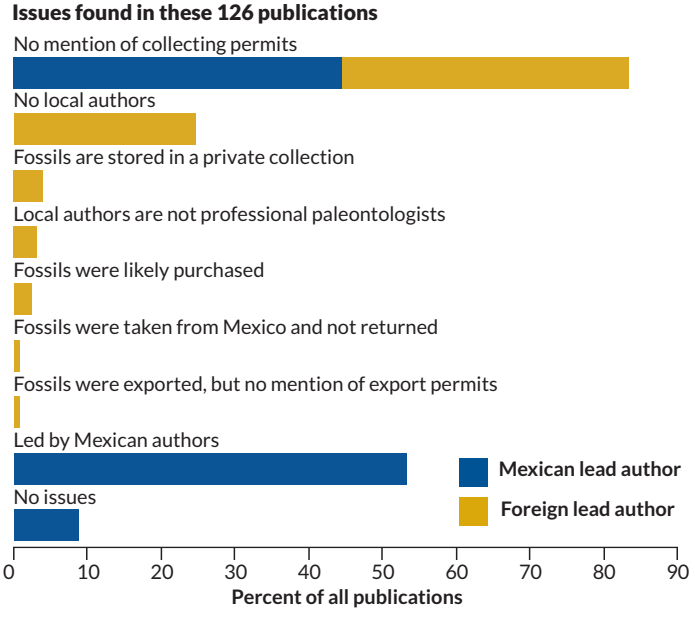
Publications on Jurassic and Cretaceous fossils from sites in the states of Coahuila and Nuevo León, 1990–2021

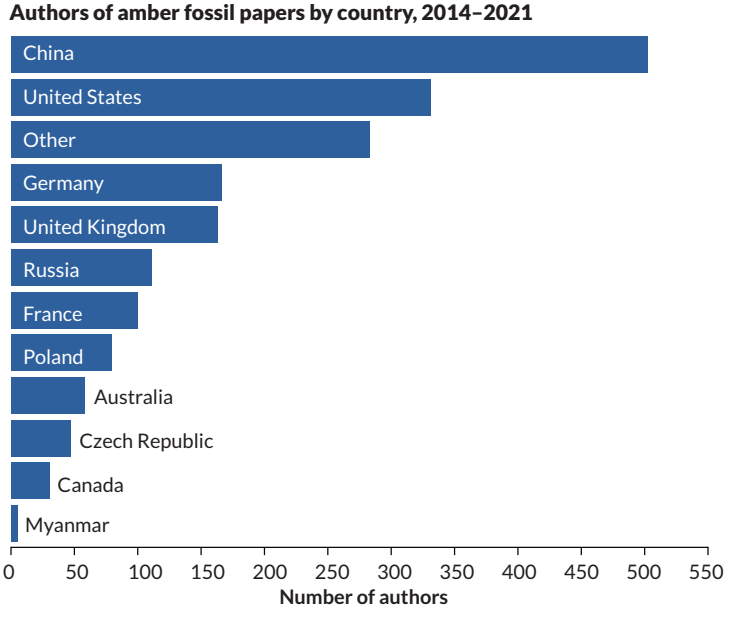


Myanmar

Publications on fossils in amber from Myanmar, 1996–2021







Questionable collections For Mexico, Dunne and colleagues analyzed 126 papers from 1990 to 2021. Each paper described one or more Jurassic or Cretaceous fossils of a vertebrate, invertebrate or other organism from one of three basins. As in Brazil, fossils belong to the government and cannot be exported permanently without permission or commercially traded. Unlike Brazil, most of the fossils in these papers stayed in Mexico (top graph) — possibly due to stricter enforcement, Cisneros says. But many of the same issues with the papers cropped up, the team found (bottom). Of the 59 papers led by foreign researchers, most did not include local authors. Few papers had info on collection permits — an issue just as present when locals led the work. Ideally, fossils would be stored in museums near where they are found, Cisneros says. "If they go to the local museums, they will improve the local economy, the social conditions of the community." But in Mexico, many fossils are housed in museums far from the rock formations where they were discovered. SOURCE: J.C. CISNEROS *ET AL/ROYAL SOCIETY OPEN SCIENCE* 2022

Conflict amber Myanmar is renowned as a source of fossils preserved in amber. The country prohibits fossil exports, but it classifies amber as a gemstone, which can be exported legally. Press reports suggest scientists who study Myanmar amber might buy it from dealers or across the border in Chinese markets, and there are concerns about where that money ends up. In 2010, the Myanmar military began taking over the gemstone mines. Around 2014, the number of Myanmar amber papers started to surge (top graph), Dunne's team found. Reports of human rights violations and military conflict with ethnic militias increased around the same time. In 2021, military leaders overthrew the government. During the publication spike, little research on Myanmar amber fossils involved anyone from Myanmar (bottom). There's no paper trail to connect the military or militias to amber fossils described in journals. But given that both groups have used mining to fund their operations, scientists who buy amber might inadvertently help fund human rights violations, Dunne says. SOURCE: E.M. DUNNE *ET AL/COMMUNICATIONS BIOLOGY* 2022

ALL: H. THOMPSON, T. TIBBITTS

JANUARY 28, 2023

For good measure

*Cutting carbon dioxide emissions to curb climate change and reach net-zero is possible but not easy, **Alexandra Witze** reported in "The road to net-zero"* (SN: 1/28/23, p. 22).

A report by Princeton University's Net-Zero America project, released in 2021, estimates that wind and solar power production needs to roughly quadruple by 2030 to achieve the United States' goal of net-zero carbon emissions by 2050, **Witze** reported. In the most ambitious scenario, "wind turbines would cover an area the size of Arkansas, Iowa, Kansas, Missouri, Nebraska and Oklahoma combined," she wrote.

Reader **Mary Sweeney** noted that, while technically correct, the statement quoted above could be misleading. "What the Princeton report actually states is that the visual footprint of the turbines would be equivalent to the combined areas of the states listed above. In other words, that figure for land use was reached by considering the very large area from which the very tall turbines would be visible," **Sweeney** wrote. The actual land use would be only a tiny fraction of the visual footprint.

Disappearing act

*A glass frog hides nearly all of its red blood cells in the liver while it sleeps, upping the animal's transparency, **Susan Milius** reported in "Glass frogs make their blood vanish"* (SN: 1/28/23, p. 6).

Reader **Len Yaeger** wondered what criteria the researchers used to determine transparency in the frogs.

Biologists think about transparency a bit differently from physicists, says **Jesse Delia** of the American Museum of Natural History in New York City. "If the individual tissues are transmitting over 90 percent of light, they're — as far as biology goes — relatively perfectly transparent," he says. Glass frogs' green dorsal skin "gives them sort of a diffuse transmittance, like the filtered light if you were to look up at the tree canopy on a sunny day."

What's more, the translucence of glass frog skin appears across a continuum. The clearest see-through skin is on the belly, which helps explain why it took **Delia** some years to notice the cell-hiding phenomenon in sleeping frogs. **Delia** had often seen the frogs sleep in the wild, their less-translucent backs facing outward as the frogs clung to leaves. "It wasn't until I saw them sleeping in captivity on glass that I could actually see their bellies," he says. From there, "you can see straight in to their organs."

Since the frogs can pack their red blood cells together without forming clots, reader **Mara Chen-Goldberg** wondered, could the discovery aid research into blood clot treatments for humans?

Many people are asking the same question, **Delia** says. The frogs seem to somehow inhibit the typical vertebrate blood-clotting process. "But at this point, we don't know whether that mechanism would be directly translatable to human medicine," he says.

Correction

"A cunning fox catches fish, stunning researchers" (*SN: 11/5/22, p. 4*) incorrectly stated that fishing in foxes had not been observed before. While the study featured in the story describes the first record of a red fox fishing, a 1991 study published in *Polar Research* had previously reported fishing in arctic foxes in Greenland. This incorrect fact also appeared in a year-end roundup in *Science News*' December 17, 2022 & December 31, 2022 issue.

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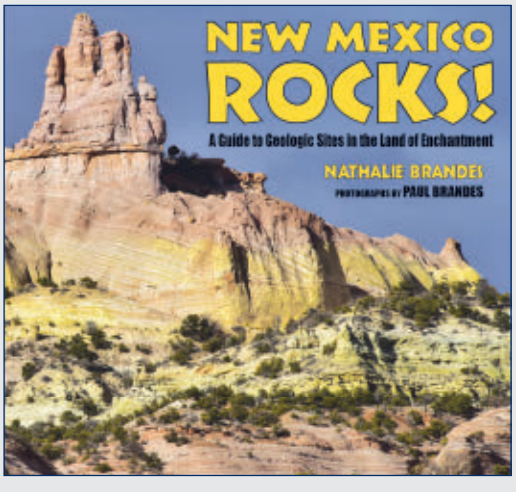

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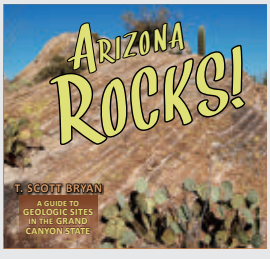

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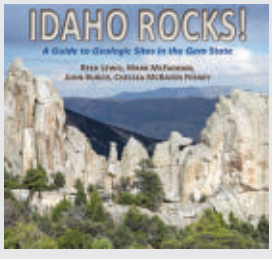

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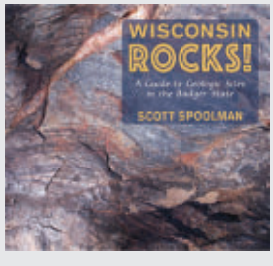

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