Bennu Asteroid Sample Arrives | Why Hippos Are Bad Chewers

ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ NOVEMBER 4, 2023

Inside View

Neutron imaging reveals secrets hidden within fossils and antiquities

Thermo Fisher Scientific
Junior Innovators Challenge
A program of Society for Science

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2023 Finalists!

Thermo Fisher Scientific and Society for Science salute the amazing young scientists and engineers selected from nearly 2,000 entrants as finalists in the Thermo Fisher Scientific Junior Innovators Challenge.

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The Thermo Fisher Scientific Junior Innovators Challenge (JIC), a program of Society for Science, is the nation's premier middle school STEM research competition in the United States, created to inspire sixth, seventh, and eighth grade students to pursue their personal passion for STEM subjects into high school and beyond.

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COVER In this artist's rendering of a crocodile fossil embedded in rock, neutron imaging uncovers a hidden bone. *Natasha Mutch/SayoStudio*

FROM TOP: NGĀTI WHĀTUA ŌRĀKEI; P. KRAFT *ET AL*/*NATURE* 2023; © JAIME CULEBRAS/PHOTO WILDLIFE TOURS

The early women who shaped science journalism

When *Science News* was founded in 1921, journalism was still a men's domain, with women relegated largely to writing for the society pages. But women in the United States had just gained the right to vote, and more women in journalism were saying "no thank you" to the society beat, choosing instead to report on big issues of national importance.

Ruth Finney came to Washington, D.C., from California in 1923 as a correspondent for the Scripps-Howard newspaper chain. She covered national politics throughout her career. Bess Furman came to Washington from Nebraska in 1929 to cover the wives of elected officials for the Associated Press, notably Eleanor Roosevelt, who held regular press conferences. Furman continued to cover the White House after the Roosevelt administration, including for the *New York Times*.

In the late 1920s, another writer, Jane Stafford, joined Science Service (now known as Society for Science, publisher of *Science News*) to cover medicine.

Jane Stafford was a founding member of the National Association of Science Writers.

That may not seem as glamorous as presidential events and nominating conventions. But I expect that for Stafford, who had always wanted to write and wanted to be a chemist, helping people understand advances in cancer treatment and public health was as vital to the public welfare as political machinations. And a lot more interesting.

Other women also joined Science Service in the early days — Emma Reh (archaeology), Emily Davis (anthropology and nutrition), Marjorie Van de Water (social sciences). Their work helped establish Science Service's reputation for accurate science reporting. But the job wasn't easy. Stafford, who would become a founding member of the National Association of Science Writers, was repeatedly barred from press events of the American Society for Control of Cancer because they were held at men's-only clubs. "The University Club having been selected as the most convenient meeting place for the doctors, our hands are tied," Stafford was told, according to a new book by historian Marcel Chotkowski LaFollette, *Writing for Their Lives: America's Pioneering Female Science Journalists*, published by MIT Press. LaFollette will be taking part in an online conversation about the book with *Science News* Executive Editor Elizabeth Quill on November 15 at 2 p.m. ET. Sign up with this link to take part: bit.ly/WritingForTheirLives

Since the 1920s, the number of women in journalism — and in science — has expanded, but in neither case have women reached parity with men. Today in the United States, women make up 46 percent of reporting journalists, and just about one-third of the workforce in STEM fields. Other groups and communities are likewise underrepresented in these spheres. There's a lot of work yet to do to make journalism and science more inclusive. Jane Stafford and other pioneering female journalists are one source of inspiration. — *Nancy Shute, Editor in Chief*

Science News
1719 N Street NW, Washington, DC 20036
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Subscriber services:
Email subscriptions@sciencenews.org
Phone (800) 552-4412 in the U.S. or
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Mail Science News, PO Box 292255, Kettering, OH 45429-0255
Editorial/Letters: feedback@sciencenews.org
Science News Learning: snlearning@societyforscience.org
Advertising/Sponsor content: ads@societyforscience.org
Science News (ISSN 0036-8423) is published 22 times per year, bi-weekly except the first week only in May and October and the first and last weeks only in July by the Society for Science & the Public, 1719 N Street, NW, Washington, DC 20036.
Subscribe to Science News: Subscriptions include 22 issues of *Science News* and full access to www.sciencenews.org and cost $59 for one year (international rate of $77 includes extra shipping charges).
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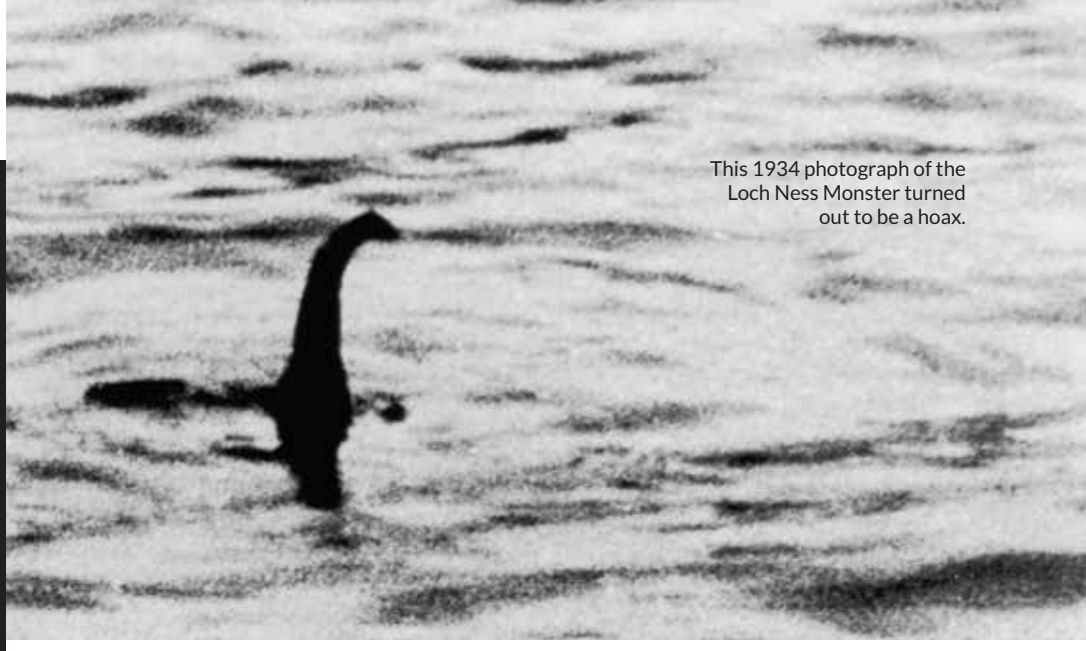
Excerpt from the November 10, 1973 issue of *Science News*

50 YEARS AGO

Off to Mercury

Mercury ho! Mariner 10 is on its way. Venus ho, too. Launched at 12:45 a.m. on November 3, Mariner should pass within 3,330 miles of Venus on February 5. It will then become the first spacecraft to … let the gravitational field of one planet bend its course around toward a second objective. That's Mercury, of course, where it will arrive less than two months later.

UPDATE: Mariner 10 arrived on schedule, becoming the first probe to visit Mercury and map a portion of its moon-like terrain. Since then, NASA's MESSENGER spacecraft used gravity assists from Mercury, Venus and Earth to reach an orbit around Mercury in 2011, where the probe mapped the rest of the planet's surface, uncovered evidence of past volcanism and spotted signs of water ice and organic compounds (*SN: 1/12/13, p. 17*). Today, the international BepiColombo mission is using gravitational assists from Mercury — following one from Earth and two from Venus — to steer itself into eventual orbit around the planet. Beginning in 2025, BepiColombo will investigate Mercury's innards and magnetic field.



This 1934 photograph of the Loch Ness Monster turned out to be a hoax.

THE SCIENCE LIFE

Statistics aid searches for Nessie, other monsters

There were drones, there were boats. There were spotters on land and a hydrophone listening for suspicious sounds underwater. In what may have been the biggest search of its kind in 50 years, crowds of people gathered this summer in Scotland to hunt for any sign of the Loch Ness Monster.

Some 6,000 kilometers away, data scientist Floe Foxon emailed the event's organizers and wished them good luck. Foxon wasn't joining them, but from his home in Pittsburgh, he has examined

THE –EST

The highest-energy pulsar pushes theoretical limits

The sweeping beams of cosmic lighthouses called pulsars can be much more energetic than previously thought. A new analysis described October 5 in *Nature Astronomy* reveals a pulsar that radiates at 20 trillion electron volts — making it the most energetic pulsar ever seen. Previously, pulsars were seen to top out at about a trillion electron volts.

The most energetic pulsar radiation ever seen comes from the Vela constellation (pulsar's wind nebula, shown).

Pulsars are dense remnants of exploded stars that emit beams of light as they twirl up to hundreds of times per second. As a pulsar rotates, its magnetic field rips charged particles from the surface, ejecting them along magnetic field lines and spitting radiation out the pulsar's poles. Using the High Energy Stereoscopic System array in Namibia, astrophysicist Arache Djannati-Ataï of CNRS in Paris and colleagues traced 78 super-energetic particles of light to a pulsar in the constellation Vela.

The finding supports the idea that, thousands of kilometer's from a pulsar's surface, its magnetic field lines can collide and snap, launching particles to extreme speeds, Djannati-Ataï says. But the pulsar's radiation pushes the limit of how much energy the process can release. If higher-energy radiation keeps turning up, scientists will have to find new explanations. — *Zack Savitsky*

TOP: KEYSTONE/STRINGER/HULTON ARCHIVE/GETTY IMAGES; BOTTOM: X-RAY: (IXPE) FEI XIE, MSFC/NASA AND (CHANDRA) SAO/CXC/NASA; OPTICAL: CHANDRA, STSCI HUBBLE/NASA, PROCESSING BY JUDY SCHMIDT; HUBBLE/CHANDRA/IXPE PROCESSING AND COMPOSITING BY KIMBERLY ARCAND AND NANCY WOLK, SAO/CXC/NASA

Nessie's lore with statistics.

In July, Foxon reported the probability of finding a giant eel in the loch, one of many hypotheses for sightings of the storied sea monster. The answer: essentially zero. Even the chances of finding a merely 1-meter-long eel are low, about 1 in 50,000, Foxon reported in *JMIRx Bio*. Once you get much longer than that — into monster-sized eel territory — the probability plummets.

Foxon's background is in physics, and by day, he's a data analyst for a health consulting firm. In his free time, he flits through far-flung fields of science, including astronomy, paleontology and cryptology, the study of ciphers. "When you learn data science," Foxon says, "you find that it can be applied to more or less anything." Even monsters.

Foxon analyzed the mass distribution of eels caught in Loch Ness and other freshwater bodies in Europe. He converted mass data to eel length and then calculated the odds of finding eels of different sizes. In a separate monster study posted July 20 at bioRxiv.org, Foxon looked at data on Bigfoot sightings and black bear populations across the United States and Canada. As black bears in a region increase, Bigfoot sightings tend to go up as well, he found.

Data scientist Floe Foxon has analyzed supposed Bigfoot sightings. This image, from 1967 footage, depicts the purported creature.

That doesn't tell you whether Bigfoot is real. "You can't answer that sort of question without a specimen," Foxon says. Instead, he thinks about it from a probability standpoint. If you think you've seen a sasquatch, he says, it's probably a bear.

People claiming glimpses of mythical beasts probably aren't hoaxers, Foxon says. "Most people are very earnest and honest about having an experience that they personally cannot explain." He thinks scientists should take them seriously.

Foxon considers his work to be folk zoology, a field at the intersection between zoology and Indigenous knowledge of animals in folklore. His work has roots in cryptozoology, but that field has been "overrun by a lot of pseudoscience," Foxon says. His quest takes a strictly scientific tack that relies on established mathematical methods.

"It's not what you study, it's how you study it," says Charles Paxton, a statistician at the University of St. Andrews in Scotland who has published papers on the Loch Ness Monster. "The methods of science can be more widely used than people might think." — *Meghan Rosen*

SCIENCE STATS

Here's how much coronavirus people with COVID-19 exhale

The coronavirus that causes COVID-19 spreads through the air. Now researchers know how much virus people breathe out over the course of an infection.

Olfactory researcher Gregory Lane and colleagues analyzed breath samples from 43 people with COVID-19 who were followed for nearly three weeks. Some people shed a lot, releasing over 800 copies of viral RNA per minute at times, but on average, participants breathed out 80 copies per minute for eight days after symptoms began, the team reports in an upcoming paper in *eLife*. Only then did levels become nearly undetectable.

Lane, of Northwestern University Feinberg School of Medicine in Chicago, and colleagues still need to confirm what percentage of that exhaled viral RNA represents viruses that can still replicate in another person's body.

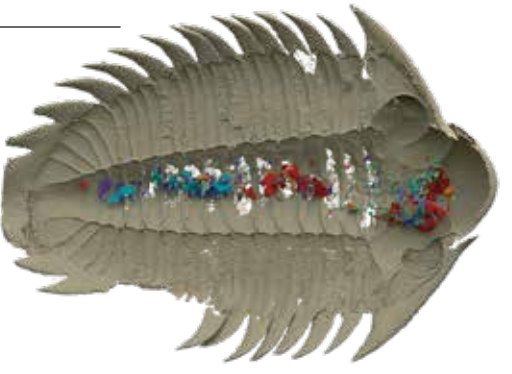
But the team estimates that a high shedder might be able to infect someone in a closed space in about 20 seconds. With an average shedder, infection could take a little under four minutes. — *Saima S. Iqbal*

80

Average amount of viral RNA copies exhaled per minute after the onset of COVID-19 symptoms

FIRST

A trilobite's last suppers



A 3-D reconstruction of a trilobite shows its final few meals (colored).

A mysterious, prehistoric marine creature has spilled its guts. For the first time, scientists have unearthed a fossilized trilobite whose final meals were preserved within its digestive system.

Researchers discovered the partially digested meals when they looked at a digital 3-D reconstruction of *Bohemolichas incola*, a trilobite species that lived 465 million years ago. The contents include shell fragments, bits of echinoderms (a group that includes modern sea urchins and starfish), and bottom-dwellers that were swallowed whole, the team reports September 27 in *Nature*.

The finding also hints at how the trilobite foraged. Shells throughout the gut suggest the creature fed almost continuously, perhaps by scavenging the seafloor for broken remains, says paleontologist Valéria Vaškaninová of Charles University in Prague. Since the shells show no signs of being dissolved, the trilobite's gut may have had an alkaline or neutral pH. That biochemistry would have reduced the amount of hard-to-process dissolved calcium entering the bloodstream, the team proposes. — *Sid Perkins*

FROM TOP: ROGER PATTERSON AND ROBERT GIMLIN/WIKIMEDIA COMMONS; P. KRAFT *ET AL*/*NATURE* 2023

PLANETARY SCIENCE

OSIRIS-REx delivers asteroid cache

Bonus material from Bennu contains water and carbon

In September, the OSIRIS-REx spacecraft delivered to Earth a capsule of rock and dust from the asteroid Bennu. Scientists have started studying debris that adhered to the outside of the collection container (shown).

BY JAMES R. RIORDON

NASA scientists are just beginning to reveal details of about 250 grams of dust and rock brought to Earth from the asteroid Bennu. The sample is the result of the first U.S. mission to return a sample from an asteroid and the largest cache of material ever collected beyond the orbit of the moon.

This mission is the beginning of "a new era of exploration, and this is the era of sample science," Makenzie Lystrup, director of NASA's Goddard Space Flight Center in Greenbelt, Md., said October 11 during a live streaming event. "This is when sample science really begins."

The mission began seven years ago when the OSIRIS-REx spacecraft left Earth to rendezvous with Bennu, a near-Earth asteroid that may hold clues to the formation of the solar system and the origin of life on Earth. OSIRIS-REx lightly touched down on Bennu in 2020, scooped up a coffee cup–sized sample and sealed it away for the long trip back home (SN: 11/21/20, p. 5).

OSIRIS-REx jettisoned its sample-return capsule back to Earth on September 24. The spacecraft continued on its way to its next mission. Under the new name OSIRIS-APEX, it will orbit around the near-Earth asteroid Apophis.

The capsule containing the Bennu sample parachuted down to a desert landing site in Utah, where it was picked up and flown to NASA's Johnson Space Center in Houston. NASA scientists carefully opened the capsule in a dedicated clean room designed to ensure that the pristine asteroid material wouldn't be contaminated by any terrestrial material.

The material in the capsule was collected by blowing dust and rock into a container with a blast of nitrogen gas. The sample consists primarily of asteroid material from as deep as 50 centimeters below the surface. Additional dust and grit that adhered to the collection container's surface contact pads when OSIRIS-REx touched down on Bennu will offer a look at the composition of the asteroid's surface.

The mission returned some bonus material as well, in the form of loose debris that was inadvertently kicked up into the capsule in the area around the collection container, before the capsule was sealed for the trip home. The science team has delayed opening the collection container, instead taking time to collect and analyze the bonus sample.

Much of that material is made of water-bearing clay minerals. "The reason that Earth is a habitable world, that we have oceans and lakes and rivers and rain," said planetary scientist Dante Lauretta of the University of Arizona in Tucson, who leads the OSIRIS-REx mission, "is because these clay minerals, like the ones we're seeing from Bennu, landed on Earth 4 billion years ago to 4.5 billion years ago, making our world habitable."

Other grains contain chemical elements common on Earth, including carbon and iron, as well as platelike sulfur structures that, Lauretta said, may have been crucial for jump-starting life.

A quarter of the Bennu sample will go to scientists on the OSIRIS-REx mission for analysis. The rest will be divvied up among scientists around the globe, with a portion set aside for future study.

"This stuff is an astrobiologist's dream," said Daniel Glavin, a senior scientist for sample return at Goddard. "I just can't wait to get at it. And this material will be around for generations and generations." ■

ERIKA BLUMENFELD AND JOSEPH AEBERSOLD/NASA

PHYSICS

Antimatter upholds theory of gravity

Antihydrogen atoms fall toward Earth just like matter does

BY EMILY CONOVER

It's official: Antimatter falls down, not up.

In a first-of-its-kind experiment, scientists dropped antihydrogen atoms and watched them fall, showing that gravity attracts antimatter toward Earth, rather than repelling it.

The study confirms a pillar of Einstein's general theory of relativity known as the weak equivalence principle. According to that principle, gravity pulls on every object in the same way, no matter what it's made of. "This concept is at the heart of our comprehension of gravitation," says Ruggero Caravita, a physicist at the National Institute for Nuclear Physics in Trento, Italy.

Antimatter is the mirror image of matter, carrying the opposite electric charge but the same mass. An electron's antiparticle, for example, is a positively charged particle called a positron. A proton's alter ego is a negatively charged antiproton, and so on.

Most physicists didn't seriously entertain the idea that antimatter could fall up instead of down, says Jeffrey Hangst of Aarhus University in Denmark. But scientists had never been able to directly test it before. "Antimatter is kind of mysterious … so we want to actually confirm that behavior," says Hangst, who is the spokesperson for the Antihydrogen Laser Physics Apparatus, or ALPHA, collaboration, which reported the new result.

Not only did the antimatter fall as expected, but it also dropped with roughly the same acceleration as normal matter, the team found.

The results, described in the Sept. 28 *Nature*, showcase scientists' growing control over antimatter, and antihydrogen in particular. Antimatter is a wily substance that can be difficult to work with. If it touches anything made of matter — the walls of a storage container or molecules of air — it quickly annihilates. It has taken decades of work to measure any effect of gravity on antimatter at all, Hangst says.

In the experiment, performed at the European laboratory CERN near Geneva, scientists mixed antiprotons with positrons and trapped the resulting antihydrogen atoms with strong magnetic fields.

The team then released the antihydrogen, counting how many atoms went up versus down. If gravity treats antimatter and matter equally, most atoms should fall down, with a few flying upward due to the initial jostling motions of the atoms. That's just what the researchers found.

"It's a very nice, very neat and very simple concept," says theoretical physicist Yunhua Ding of Ohio Wesleyan University in Delaware, Ohio.

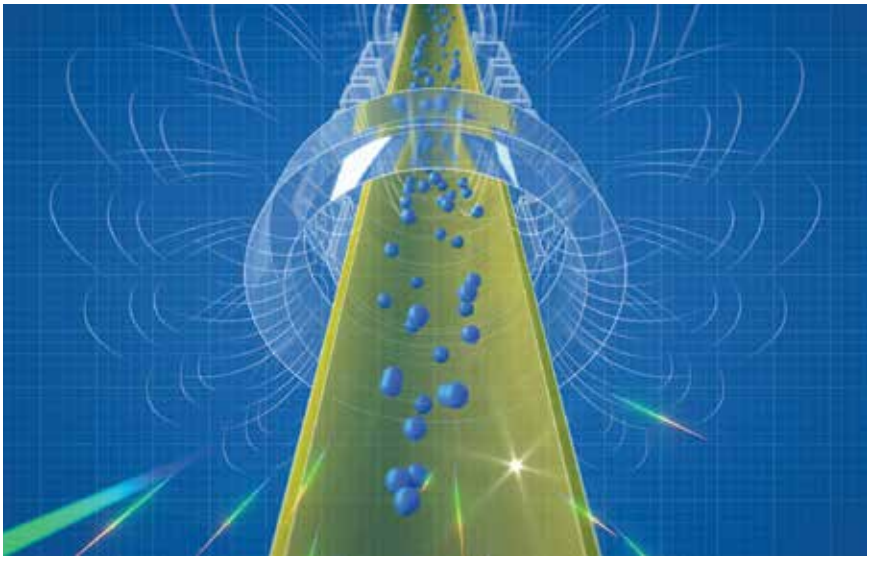
To confirm that the antihydrogen behaved as expected, the team altered the magnetic fields to push atoms upward, canceling out gravity's effect. Roughly equal numbers of atoms went up and down. Further varying the magnetic fields likewise matched expectations.

Previous experiments already hinted that gravity treats matter and antimatter the same. In 2022, the BASE experiment, also at CERN, reported that oscillations of confined antiprotons suggested that matter and antimatter feel the same tug of gravity (*SN Online*: 1/5/22). But ALPHA's experiment is the first to directly observe antimatter particles falling.

The idea that different types of objects fall with the same acceleration predates Einstein. In the 16th century, Galileo supposedly dropped different objects off the Leaning Tower of Pisa to demonstrate this effect. Scientists have since tested it in a variety of situations, even with objects in orbit around Earth.

Although physicists didn't expect the antimatter to fall up, some researchers have proposed that antimatter may fall with a slightly different acceleration than normal matter. "If we find even the tiniest difference, this would be an indication that something new is happening," says Caravita, who is the spokesperson of the AEgIS collaboration at CERN. AEgIS is one of a cadre of experiments there also working to measure gravity's effect on antimatter.

The current experiment isn't precise enough to suss out such subtle differences. But new techniques, such as cooling antihydrogen atoms with lasers, could make future tests more precise. That could help scientists see, when it comes to matter and antimatter, whether gravity truly is agnostic. ■



KEYI "ONYX" LI/U.S. NATIONAL SCIENCE FOUNDATION

Using strong magnetic fields (wispy curved lines in this illustration), scientists trapped antihydrogen atoms (blue spheres) before releasing them and watching them fall under the influence of gravity.

Watch an animation of antimatter falling at **bit.ly/SN_Antimatter**

These pink diamonds come from Australia's Argyle mine, a cache that may have formed about 1.3 billion years ago when Nuna, the first supercontinent, broke up.

MURRAY RAYNER/RIO TINTO

EARTH

Diamond jackpot linked to breakup

Pink gems may have risen up when a supercontinent split

BY NIKK OGASA

The world's largest deposit of natural diamonds — and of more than 90 percent of all pink diamonds found so far — may have formed due to the breakup of Earth's first supercontinent, researchers report September 19 in *Nature Communications*.

The diamond-bearing rocks of the Argyle mine in Western Australia probably formed about 1.3 billion years ago, along a rift zone that sundered the supercontinent Nuna, analyses of ancient mineral grains shows. The finding suggests that exploring ancient rift zones for diamond troves may be more worthwhile than previously thought.

Within Earth's crust, carbon atoms that are sufficiently squeezed and heated may form soft, gray graphite. But down in the forge that is the upper mantle, extreme conditions mold the element into hard, dense gemstones (*SN*: 10/10/20 & 10/24/20, *p.* 18). These diamonds can escape their chthonic womb by hitching a ride in rapidly ascending magmas (*SN*: 2/25/12, *p.* 11). Near the surface, the molten material solidifies as vertical tubes of volcanic rock known as kimberlite pipes. Most diamonds are found in these formations.

But this story does not explain the Argyle formation, nor its pink diamonds. To make a diamond blush, something more powerful than mere mantle conditions must contort the gem's sturdy crystal structure, altering how it absorbs and transmits light.

Another wrinkle lies in Argyle's diamondiferous pipe. It is a lamproite pipe, which is generally thought to form at shallower depths than kimberlites, says geologist Maya Kopylova of the University of British Columbia in Vancouver. A shallow origin may explain why lamproites usually lack rich diamond loads. The exception is Argyle — somehow, its lamproite raised treasures from the deep.

The oddities of the Argyle formation have long puzzled geologists. Chemical analyses conducted in the 1980s suggested it formed roughly 1.2 billion years ago. But that dating was questionable; the mineral that was analyzed may have been chemically altered by fluids in the Earth, potentially yielding a too-young age.

Those results did little to clear up Argyle's mysterious origins, says Hugo Olierook of Curtin University in Perth, Australia. Geologically, "nothing was really happening in Australia at the time."

So Olierook and colleagues dated resilient grains of the minerals apatite and zircon that fell into the lamproite when it was still molten. The researchers also analyzed titanite, a mineral that appears to have crystallized slightly later than the rest of the lamproite.

By measuring the quantities of radioactive elements and their decay products within each mineral, the team found that the lamproite formed about 1.3 billion years ago, roughly 100 million years earlier than previously suggested.

"When I first got the age, I thought, 'this doesn't make any sense at all,'" Olierook says. But while he was bicycling home a couple of hours later, it clicked. "That's when the first supercontinent was breaking up," he says.

Argyle sits within an ancient continental suture, where two plates collided roughly 1.8 billion years ago to form part of the supercontinent Nuna (*SN*: 1/21/17, *p.* 18). "It's the smashing of those continents together; that's what made those diamonds pink," Olierook speculates.

About 500 million years later, when Nuna rifted apart, that suture split like a reopened wound. The event may have opened conduits for lamproite magmas laden with rosy gems to rise through, Olierook says.

For decades, geologists have thought that tectonic processes like rifting destroyed diamonds, Kopylova says. But Olierook and colleagues' finding supports a recent paradigm shift, she says. Rifting "might be a trigger to get diamonds from deep in the mantle to the surface."

Nonetheless, she says, it remains a mystery why Argyle's lamproite pipes are the only ones known that contained minable quantities of diamonds. In late 2020, the diamond mine there stopped production after exhausting the diamonds that were economically feasible to extract.

More gem-studded lamproites may be awaiting discovery, Olierook says. Perhaps somewhere, another Argyle lies hidden in the ruins of an ancient rift. ■

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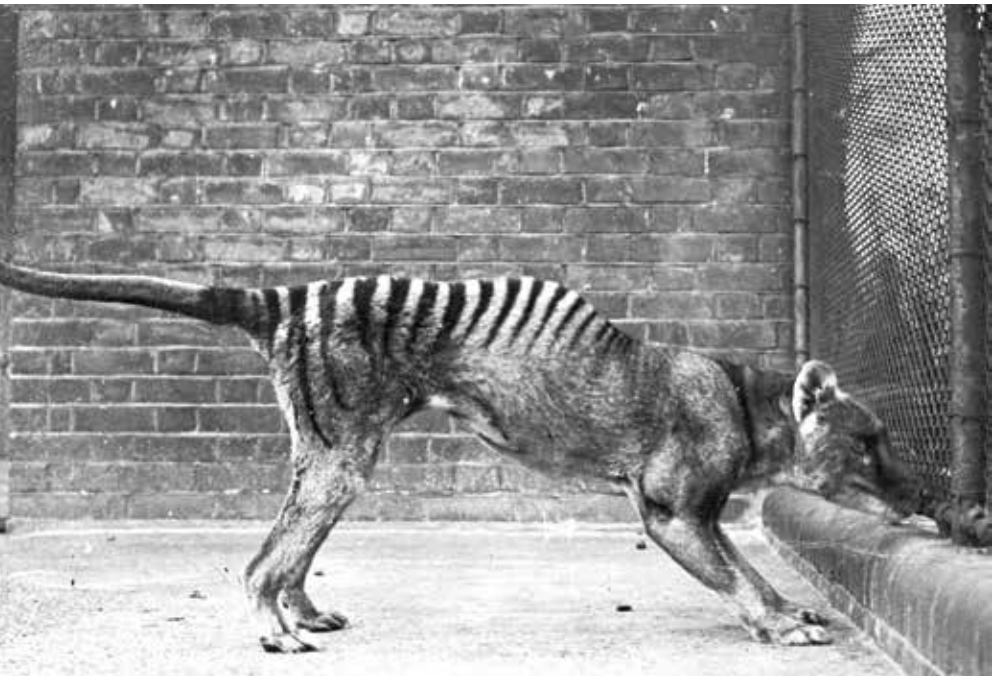

Scientists achieved a new scientific feat when they extracted RNA from a Tasmanian tiger (one shown in captivity in 1930), an animal that went extinct after the last one died in 1936.

GENETICS

Tasmanian tiger's RNA gets decoded

Study reveals how the extinct animal's cells functioned

BY KATHERINE KORNEI

For the first time, researchers have successfully extracted and decoded RNA from an extinct animal.

The thylacine, also known as the Tasmanian tiger, was a wolflike marsupial that went extinct after the last one died in a zoo in Hobart, Tasmania, in 1936. Now a roughly 130-year-old museum specimen has yielded bits of RNA, the fragile molecules responsible for turning DNA's genetic instructions into cellular functions, researchers report in the August *Genome Research*.

The results shed new light on thylacine biology and may inform efforts to bring the marsupial back from extinction.

With dark stripes running over its tawny coat from the shoulders to tail, and jaws capable of opening more than 80 degrees, the thylacine (*Thylacinus cynocephalus*) was a striking animal. But the carnivore was no match for humans: As sheep farming proliferated in the 1800s in Tasmania — the home of the last wild thylacines — the animals were frequently implicated in killing livestock. In the late 19th century, a bounty was established for every thylacine killed, and the animals were hunted nearly to extinction.

In recent years, researchers have mapped out the thylacine genetic blueprint, in addition to the genomes of other extinct animals like the woolly mammoth (*SN: 3/13/21, p. 6*). But such investigations were all focused on DNA. Only RNA can reveal how an organism's cells actually functioned, says Emilio Mármol-Sánchez, a geneticist at the Karolinska Institute in Stockholm. "You see the real biology of the cell."

In 2020, Mármol-Sánchez and colleagues came across a thylacine specimen in storage at the Natural History Museum in Stockholm. "It was just there in a cupboard," says Mármol-Sánchez, then at Stockholm University and the Center for Palaeogenetics.

The team collected six small samples of skin and muscle from the desiccated animal. Back in the laboratory, the researchers ground each sample into a powder and added chemicals that isolated nucleotides, the building blocks of RNA. Next, the team used a computer algorithm to compare those strings of nucleotides, or sequences, with a database containing the genomes of thousands of animals (including the thylacine), plants, fungi, bacteria and viruses.

The team concluded that roughly 70 percent of the RNA sequences they found were reliably thylacine, with some contamination from human RNA since the thylacine specimen was repeatedly handled.

The analysis revealed different protein-coding RNA molecules in the skin and muscle samples. That makes sense, Mármol-Sánchez says. "Muscle cells and skin cells serve quite different functions in the body." For instance, the researchers pinpointed RNA molecules for making slow-twitch muscle fiber, which helps with endurance.

The team also found over 250 thylacine-specific short RNA molecules known as microRNAs. These RNA sequences regulate cell functioning, Mármol-Sánchez says. "They're the policemen of the cell."

The results are impressive, says Andrew Pask, a developmental biologist at the University of Melbourne in Australia who was not involved in the study. Many researchers never even look for RNA, he says. "It's much less stable than DNA." The findings are doubly impressive given that the specimen was stored at room temperature, Pask says, rather than in sterile or frozen conditions. (RNA has been previously extracted from samples of existing species preserved in alcohol or ice.) "It's transformed the way that we look at museum and archive specimens," he says.

In the not-too-distant-future, Pask and other researchers hope to bring the thylacine back to Tasmania. The plan to de-extinct the animal involves modifying the genes of one of the thylacine's closest living relatives, a marsupial known as the fat-tailed dunnart (*Sminthopsis crassicaudata*). These new findings could inform that effort, Pask says, by revealing genes that controlled the Tasmanian tiger's attributes. "It's a whole other layer of information," he says. ■

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ARCHAEOLOGY

Disputed tracks really may be very old

Footprints suggest an early arrival of humans in North America

BY MCKENZIE PRILLAMAN

Human footprints in New Mexico's White Sands National Park sparked controversy two years ago when scientists found the prints to be surprisingly old, dating to about 22,000 years ago. Now two other ways of dating the fossilized tracks converge at similar ages as the first estimate, researchers report in the Oct. 6 *Science*.

The finding adds to mounting evidence that pushes back on a long-held theory that the first humans in North America came from Siberia via a land bridge sometime around 16,000 to 14,000 years ago.

"The answer to how old the footprints really are is critical," says archaeologist Loren Davis of Oregon State University in Corvallis. "We need to … understand how early we should be looking for archaeological evidence in the Americas."

In 2021, geologist Jeff Pigati of the U.S. Geological Survey and colleagues described over 60 footprints embedded in what was once mud by an ancient lake. Radiocarbon dating of an aquatic plant's seeds in and around the footprints—which span several rock layers—suggested people roamed there between roughly 23,000 and 21,000 years ago (*SN: 11/6/21, p. 12*).

But some scientists noted that the aquatic plant could have absorbed ancient carbon from groundwater, a well-known phenomenon. "There's a potential then for the plant to give exaggerated perspectives on its age," says Davis, who cowrote a critique of the 2021 paper.

To add to their past work, Pigati and colleagues radiocarbon-dated pollen stuck in the same layers as some of the footprints. The pollen came from land plants, primarily evergreen trees, avoiding the groundwater carbon issue. The researchers also collected quartz grains from above the lowest footprint tracks and used a dating method that estimates how long the quartz had been buried.

In line with the dating of the aquatic plant's seeds, the pollen yielded an age range of roughly 23,400 to 22,600 years old, and the quartz gave a minimum age of about 21,500 years old.

"This triumvirate is really, really robust and difficult to argue against because they're just fundamentally different approaches for dating," Pigati says.

Still, Davis says quartz ages from more rock layers with footprints are needed to resolve the debate. But many of the other layers are too thin, so sampling could mix them together, Pigati and colleagues say.

Despite possible errors in the individual dating methods, "the data overall from the study strongly indicate human presence in the Americas" around 22,000 years ago, Bente Philippsen, a physicist at the Norwegian University of Science and Technology in Trondheim, wrote in a commentary in the same issue of *Science*. ■

COSMOLOGY

Universe expands faster than expected

Yet more data hint that our view of the cosmos is flawed

BY JAMES R. RIORDON

The greatest puzzle in cosmology just got even more puzzling.

Images from the James Webb Space Telescope have confirmed that the universe appears to be expanding faster than expected, researchers report in a study that has been accepted in the *Astrophysical Journal*. The observation is in conflict with the standard model of cosmology, an esteemed theory that describes how the universe has evolved since the first moments after the Big Bang.

The conflict comes down to calculations of the Hubble constant, a number that describes how fast everything in the universe is flying apart. One calculation, based in part on Planck satellite observations of the oldest light in the universe in conjunction with the standard model of cosmology, suggests the Hubble constant is 67.4 kilometers per second per megaparsec (a megaparsec is about 3 million light-years). Another calculation, based on Hubble Space Telescope observations of stars at various distances from Earth, gives an incompatible value: 73 km/s/Mpc.

The discrepancy is known as the Hubble tension, and new JWST data hasn't done anything to ease it (SN: 9/14/19, *p.* 22). JWST took images of the same stars as the Hubble telescope, and the data suggest a very similar Hubble constant.

Telescope studies of galaxies, including this spiral one 75 million light-years away, hints the leading theory of cosmology needs revising.

A.G. RIESS/JHU, STSCI, NASA, ESA, CSA

The discrepancy between those numbers and the Planck number, while small, implies that there's something wrong with our understanding of the universe. Unless an error turns up in any of the three measurements, it will take strange new physics to explain the tension.

Over the last 10 years, proposed explanations for the Hubble tension have included weird dark matter, weird dark energy, some unknown exotic particle and a magnetic field in the early universe, says cosmologist Adam Riess of Johns Hopkins University. Resolving the tension "is still very much in the skunkworks stage of trying to understand what it could mean."

One way that astronomers calculate the Hubble constant is by observing flashing stars known as Cepheid variables. The stars flare up periodically at rates that indicate how much light they're putting out. Comparing a star's brightness in telescope images with its expected brightness based on the flare-up rates gives a measure of the distance to the star. Shifts in the color of the light coming from the star reveals how fast it's moving. Combining distance and speed observations of Cepheid stars leads to a measure of the expansion of the universe.

But Cepheid variable stars tend to sit deep inside galaxies, surrounded by crowds of other stars. That can make it difficult to get precise measurements of the Cepheids' speeds and locations. One resolution for the Hubble tension could have been that the Hubble telescope measurements were simply off.

Enter JWST, which can peer through the stellar crowds to clearly make out the color and brightness of Cepheid variables. The high-resolution JWST images provide more precise data than the Hubble telescope could manage. The result: The Hubble telescope measurements have been right all along, Riess and colleagues report.

Astronomer Wendy Freedman of the University of Chicago isn't convinced by the supposed confirmation. The two galaxies that JWST studied are comparatively close to the Milky Way, on cosmic scales, with the farthest one about 75 million light-years away. The proximity makes it easier to pick out the Cepheids from the stellar crowds. As JWST observes much more distant galaxies, it will become harder for the telescope to decipher Cepheids from neighboring stars, Freedman suspects. The resolution, she says, "gets worse as you go to a higher distance," even for JWST. As a result, she says, the team's confirmation of the higher Hubble constant may crumble with analysis of more distant Cepheids.

However, hints that the measurements might hold up at larger distances were reported September 12 at a conference in Baltimore dedicated to the first year of JWST science. Riess presented preliminary Cepheid data from four more galaxies — including one that, at 140 million light-years, is among the most distant galaxies in the Hubble telescope observations. JWST data from those stars also line up with the Hubble telescope measurements. Although that study awaits peer review, the images strongly suggest that JWST has indeed overcome the uncertainties surrounding the Hubble telescope images, Riess says.

Astrophysicist George Efstathiou of the University of Cambridge, a member of the Planck satellite collaboration, is convinced that Riess and colleagues' measurements are correct but confounded by the implications. "My reaction was, 'Well, you know, I'm stumped,'" Efstathiou says.

That the various measurements all seem to hold up suggests the problem is the standard model of cosmology. But it too appears unimpeachable; the model has withstood numerous other challenges.

Discovering the accelerating expansion of the universe, which earned Riess and others a Nobel Prize in physics, helped shape the standard model into the simplest theory that can accurately describe the universe we see around us. Though the new finding is "a crack, or a surprise that doesn't fit," Riess says, it could lead researchers to discover new physics. ■

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HEALTH & MEDICINE

Gene editing takes on bird flu

Modified chickens could limit the spread of avian influenza

BY ERIN GARCIA DE JESÚS

In a new experiment, gene-edited chickens (one shown, right) could resist an infection of avian flu and were just as healthy as regular chickens (left).

A. IDOKO-AKOH *ET AL/NATURE COMMUNICATIONS* 2023

Genetically modified chickens may one day prevent the spread of bird flu on farms. Just small tweaks to a single gene made chickens resistant to an avian influenza infection, researchers report October 10 in *Nature Communications*.

In chickens, the gene ANP32A encodes instructions for making a protein that flu viruses rely on to hijack chicken cells. Disrupting the avian virus's ability to commandeer the protein stopped most genetically edited birds from getting infected.

Testing the gene editing in such a ubiquitous farm animal that's susceptible to bird flu makes the study "especially impactful and important," says Jacob Yount, a viral immunologist at Ohio State University in Columbus.

The virus can rapidly spread among birds on poultry farms. Beginning in 2022, an outbreak hit the global poultry industry hard, pushing farmers to cull millions of birds in the United States alone. After a lull this summer, on October 4, a turkey farm in South Dakota confirmed the first case on a U.S. poultry farm since April. About 47,300 birds on that farm were culled.

Many avian flu strains cause only mild illness in birds, but strains like the one behind the global outbreak can kill birds (SN: 4/8/23, *p.* 6). Chickens also occasionally transmit flu to other animals like pigs or even people.

Vaccines to defend poultry from flu are expensive, and the virus swiftly adapts to evade that protection, developmental biologist Mike McGrew of the University of Edinburgh said in an October 5 news conference. Gene editing, on the other hand, could offer a way to make resistance permanent.

McGrew and colleagues made two changes to ANP32A in chicken embryos using the molecular scissors CRISPR/Cas9, so that the gene's protein could no longer interact with avian flu viruses. After monitoring the birds for two years, the edited chickens were healthy, and hens laid eggs, genetic engineer Alewo Idoko-Akoh of the University of Bristol in England said at the news conference.

The team then placed 10 normal and 10 gene-edited chicks in separate incubators and exposed them via the nasal passage to a dose of avian influenza roughly equivalent to what a bird might be exposed to on a farm. A day later, the two groups of chicks were each joined by 10 unexposed peers, called sentinels. The unedited birds were paired with unedited sentinels, and gene-edited birds were paired with gene-edited sentinels.

All 10 unedited chickens got infected and had high levels of virus, and so did seven of their sentinels. Only one of the gene-edited birds contracted the virus.

That infected modified bird had low viral levels and didn't transmit the virus to any of the edited sentinels. Still, to verify the resistance of edited chickens, the team repeated the experiment, exposing chickens to 1,000 times as much virus as in the first experiment. The team also mixed in both unedited and edited sentinels with exposed chickens.

In one incubator, all the normal chickens got infected and transmitted the virus to every unedited sentinel. No edited sentinel birds in that incubator caught the flu. In the other incubator, five of 10 modified chickens became infected after exposure, transmitting the virus to one unedited sentinel but no edited ones. That suggests that even though the virus could infect modified chickens at high doses, the animals weren't very contagious.

Viruses that infected gene-edited chickens had adapted so that they didn't need to rely on ANP32A protein to get into cells, instead co-opting proteins coded by two other genes in the ANP32 family. So editing more than one gene may be necessary to make chickens fully resistant to flu.

"If this was a disease that only infected chickens, then the resistance that we created would be better than what we would get with a vaccine," McGrew said. "But because this is a zoonotic disease and can be spread potentially to humans, we really need to aim for complete resistance."

Eliminating the three ANP32 genes from chicken cells grown in a lab dish stopped the virus from replicating at all. But because having at least some ANP32 proteins may be important for the development of chick brains, bones and hearts, that strategy might cause problems. More work is needed to figure out if that's the case, Yount says, and whether other genes outside of the ANP32 family might be good candidates for editing.

Genetic modification in agriculture is not without controversy. But it's important to continue such work, Idoko-Akoh said, "so that then when maybe it becomes widely or more culturally accepted, we can take advantage of the technology." ■

And the Nobel Prize goes to…

Winners studied mRNA, ultrafast light pulses and quantum dots

Research at the smallest scales snagged this year's Nobel Prizes, announced in October. Honorees paved the way for COVID-19 vaccines, offered a window into the world of electrons and developed nanoparticles that light up everything from TVs to medical images.

mRNA saves the day

Biochemist Katalin Karikó of the University of Szeged in Hungary and immunologist Drew Weissman of the University of Pennsylvania won the prize in medicine or physiology for their work on modifying RNA, which made the first COVID-19 vaccines possible.

Cells make RNA copies of instructions encoded in DNA. Some copies—known as the messenger RNA, or mRNA—are used to build proteins.

The mRNA vaccines against COVID-19 contain mRNA that carries instructions for making one of the coronavirus's proteins. That mRNA triggers human cells to produce the viral protein for a short period. After seeing that protein, the immune system builds defenses to prevent serious illness if the person later gets infected with the coronavirus.

Traditional vaccines use a weakened or killed pathogen, or a pathogen's protein to jump-start the immune system. In the latter case, the mRNA vaccine has an advantage because scientists can "skip the step of making large amounts of proteins in the laboratory," says Kizzmekia Corbett-Helaire, a viral immunologist at Harvard University.

Karikó and Weissman laid the groundwork for mRNA vaccines by solving a fundamental problem: Pumping mRNA into the body causes the immune system to unleash a flood of inflammatory chemicals.

Swapping the RNA building block uridine for modified versions dampens the bad reaction, Karikó and Weissman reported in 2005, and the modified mRNA produces enough protein to make effective vaccines. In the wake of the COVID-19 vaccines' success, mRNA may soon combat other diseases too.

Spying on electrons

Within atoms and molecules, electrons zip around at extreme speeds. Capturing their to-and-fro is possible only with extremely short pulses of light. The physics prize honored work to create these light pulses by physicists Anne L'Huillier, Pierre Agostini and Ferenc Krausz. Each pulse is akin to a camera flash that lasts mere attoseconds, or billionths of a billionth of a second.

In the 1980s, L'Huillier, now at Lund University in Sweden, noticed that infrared laser light sent through a gas would create light of a variety of wavelengths, what's known as high-harmonic generation. The effect is a result of how that light interacts with the electrons in the gas, by a process which L'Huillier's research helped clarify.

These other wavelengths, known as overtones or harmonics, are similar to the overtones that help give musical instruments their distinctive sounds. Adding together the right combinations of overtones results in very short light pulses. With this method, in 2001, Agostini, now at Ohio State University, and colleagues produced a series of light pulses, each of which lasted just 250 attoseconds. The same year, Krausz, now at the Max Planck Institute of Quantum Optics in Garching, Germany, and colleagues created single pulses lasting 650 attoseconds.

Scientists have used this technique to explore the behavior of electrons and molecules. "You can watch the motions of molecules themselves, essentially to make movies of molecular motion," says Peter Armitage, a physicist at Johns Hopkins University. "This is of vast interest for all kinds of things, for understanding why some materials are superconductors at high temperatures to photovoltaic applications, harvesting energy from light.... I think it's really just right at the beginning."

Liquids in these vials glow different colors thanks to quantum dots.

TAYFUN RUZGAR/ISTOCK/GETTY IMAGES PLUS

The power of tiny, tunable dots

The discovery and synthesis of dots that light up TV screens and help doctors see the blood vessels that feed tumors earned three scientists the chemistry prize.

Just adjusting the size of nanoparticles known as quantum dots can change their properties—optical, electric, even melting points—thanks to quantum mechanics.

When quantum dots are irradiated by light, electrons within get energized, releasing that energy as fluorescent light. The smaller the dots are, the more they compress what's known as the wave function of an electron, increasing its energy so that the dot appears blue. Larger dots appear red.

Making these dots requires a perfectly crystalline material and the ability to control the size of the material, sculpting it atom layer by atom layer.

In the 1980s, physicist Alexei Ekimov and chemist Louis Brus showed it could be done. Ekimov, now at Nanocrystals Technology in New York, demonstrated this in glass, adding copper chloride to make crystals and revealing that the glass color was linked to the size of those crystals. Brus, of Columbia University, made a similar discovery using crystals floating in a solution and in gaseous compounds.

Later, chemist Moungi Bawendi of MIT developed a method to precisely control the rate of crystal growth. The method opened a world of potential applications. In addition to use in TVs and medical imaging, quantum dots might someday help build quantum computers or customized solar cells that are highly efficient in different light conditions. —*Emily Conover, Erin Garcia de Jesús, Carolyn Gramling, James R. Riordon, Meghan Rosen and Tina Hesman Saey*

In a new survey of amphibians, Ecuador's Morona-Santiago stubfoot toad (two shown) was found to be critically endangered.

ANIMALS

Amphibians face dire extinction risks

A global assessment delivers bad news but also signs of hope

BY ANNA GIBBS

Nearly 20 years ago, the first global assessment of amphibians found they faced widespread declines. Now an updated report shows that many amphibians are still in trouble, but with some silver linings, researchers report in the Oct. 12 *Nature*.

"We are realistic and hopeful at the same time," says conservationist Jennifer Luedtke, a global amphibian coordinator for the International Union for Conservation of Nature, which tracks extinction risk trends for species globally.

The report's wealth of data, which includes about 8,000 amphibian species, could help focus conservation efforts for years to come, says Luedtke, who also works from Washington, D.C., for the conservation organization Re:wild.

Having two assessments that can be compared is a big deal, experts say. "It's important not just to have a picture but actually to have a sequence of pictures…where you can see what's happening over time," says conservation ecologist Ana Rodrigues of CNRS in Montpellier, France, who worked on the first report.

One of the new report's big takeaways is that amphibians remain more threatened with extinction than any other vertebrate group. About 41 percent of amphibian species, which include frogs, toads and salamanders, face extinction, Luedtke and colleagues found. That's more than sharks and rays (37 percent), mammals (27 percent), reptiles (21 percent) and birds (13 percent).

As part of the new report, the researchers used recently collected data to revise estimates of species at risk in 2004 and 1980. In 2004, 39 amphibian species were threatened. Even in 1980, 38 percent faced extinction threats.

Habitat loss and degradation is the most common threat, with agriculture affecting 77 percent of the studied species. Other threats include climate change and disease, each affecting 29 percent of species. "These things are never completely isolated," Rodrigues says, and each threat may increase the likelihood of other threats.

Threats also vary regionally. An outbreak of deadly chytrid fungus, for example, has affected much of the world, but it hit Central and South America especially hard from the 1970s to the 2000s. That probably explains why that region has the largest proportion of species in the IUCN Red List categories of highest concern, the researchers say. New Guinea and Africa were spared much of the devastation, though the pathogen has recently started to emerge in sub-Saharan Africa.

In Europe and East Asia, habitat loss is the leading cause of decline, followed by a newly emerging fungal pathogen in Europe, *Batrachochytrium salamandrivorans*, which affects salamanders (SN: 10/5/13, *p.* 18). It hasn't yet reached North America, which is home to over a quarter of the world's salamander species. That would be disastrous, Rodrigues says.

For now, North America's amphibian declines are most associated with climate change. South and Southeast Asia are seeing an improving trend among their species' extinction risk, probably due to better management of protected areas.

Another silver lining in the report: The IUCN conservation status of 120 species improved since 2004. About half of those species recovered unaided. Many had suffered declines due to chytrid and are now bouncing back, possibly as frogs become resistant to the fungus. It's a source of hope that "we have these little frogs evolving, in front of our eyes, resistance to chytridiomycosis," Luedtke says.

The other half improved thanks to conservation efforts. One of those species is India's indigo bush frog (*Raorchestes indigo*), which was classified as critically endangered in 2004. A couple years later, a legal battle ended mining in the Kudremukha mountain range, and the species's status has improved to vulnerable.

Such stories are evidence that effective habitat protection can make a noticeable difference, the researchers say. Yet, with most amphibians still facing declines, current efforts are not enough. A companion report to the new assessment identifies 50 target conservation areas around the world — including Jamaica, Brazil's Atlantic Forest and the Central Annamite Highlands in Vietnam — that feature a high density of threatened species.

"Yes, the number of threatened amphibians continues to increase, but our understanding is improving," Luedtke says. "And because we understand them better, we can act in a more accurate and effective way." ■

ANIMALS

Hippos' scary teeth hinder chewing

Problems chomping may limit where the herbivores can live

BY JAKE BUEHLER

Hippos are horrible at chewing, and their giant tusks and front teeth are to blame.

These intimidating dental features help hippos protect themselves and their territory. But some of the gnarly teeth interlock or hinder jaw movements, preventing the efficient side-to-side grinding seen in other herbivores, researchers report October 4 in *PLOS ONE*.

Plant-eating mammals typically use the broad teeth near the sides of the mouth to grind and shred fibrous vegetation before swallowing. Since the digestion process barely reduces food particle size, particles in feces are a gauge of chewing efficiency.

In 2009, veterinarian Marcus Clauss of the University of Zurich and colleagues compared fecal particle size across nearly 200 mammal species. The evidence suggested hippos are the least effective chewers among herbivorous mammals. Years later, Clauss and his Zurich colleague Annika Avedik wondered whether hippos' enormous front teeth explained the meager munching.

Some herbivores, such as deer and cattle, have lost some of their front incisors during evolution, possibly because they impeded chewing. African rhinos have lost theirs entirely. "Hippos are a case example of a taxon that did not lose them," Clauss says.

He and Avedik analyzed videos of common (*Hippopotamus amphibius*) and pygmy hippos (*Choeropsis liberiensis*) eating, tracking how the teeth interacted as the jaws moved. The team also measured physical features of more than 100 hippo skulls in museum collections, including the spacing and arrangement of the teeth. The researchers tested the side-to-side jaw range of the skulls and measured places where the teeth wore on each other.

Clauss had thought that common hippos' huge tusks, which are modified canine teeth, would be what stopped the animals from proper side-to-side chewing. "Boy, was I wrong," he says.

Instead, common hippos' upper and lower sets of long, spearlike incisors cross and interlock as the lower jaw closes, restricting the back teeth to up-and-down mashing. The herbivores still try some side-to-side movement of the jaw, Clauss says, evidenced by wear marks on the sides of the incisors.

Pygmy hippos' incisors don't interlock, but their tusks bump up against the snout, allowing only a limited amount of side sliding. Wear patterns show that the incisors glide past each other when chewing.

Because pygmy hippos show some side-to-side jaw movement when chewing, it hints that "lateral grinding chewing is something [hippos] once did, and that it got lost along the way," Clauss argues.

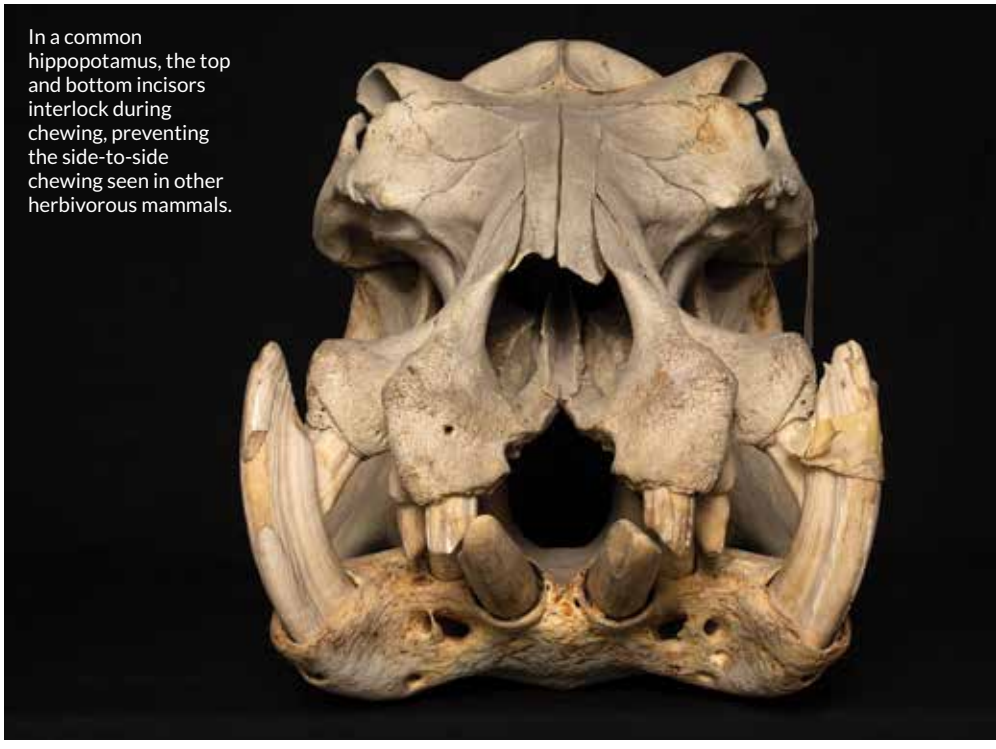
Hippos now use their rigid jaws, wide gapes and sharp, sturdy tusks and incisors to combat other hippos over territory and access to mates, and to defend against predators. But the potential shift to less efficient chewing could have come with consequences. Because hippos can't mulch food into very small pieces, it takes longer for it to be digested, Clauss says.

"If food has to stay longer in the gut, it means one cannot eat more, quickly," he explains. "Hence hippos are, among mammalian herbivores, characterized by relatively low food intakes."

The comparatively low food intake may put hippos at a competitive disadvantage against other, more efficient chewers, such as antelope. An inability to compete with fully land-dwelling species for sufficient food may keep hippos wedded to the African waterways the semiaquatic animals call home.

The study is "a really good reminder of the complexity of organisms, and that when anatomical parts, such as teeth, are viewed in isolation, they may not explain the whole picture," says comparative biomechanist Susan Williams of Ohio University in Athens.

Studying fossil hippo ancestors could reveal if, and when, hippos' side-to-side chewing was lost. Juvenile hippos also don't yet have incisors large enough to interlock, so Clauss is curious to see if these youngsters temporarily use side-to-side chewing. ■



In a common hippopotamus, the top and bottom incisors interlock during chewing, preventing the side-to-side chewing seen in other herbivorous mammals.

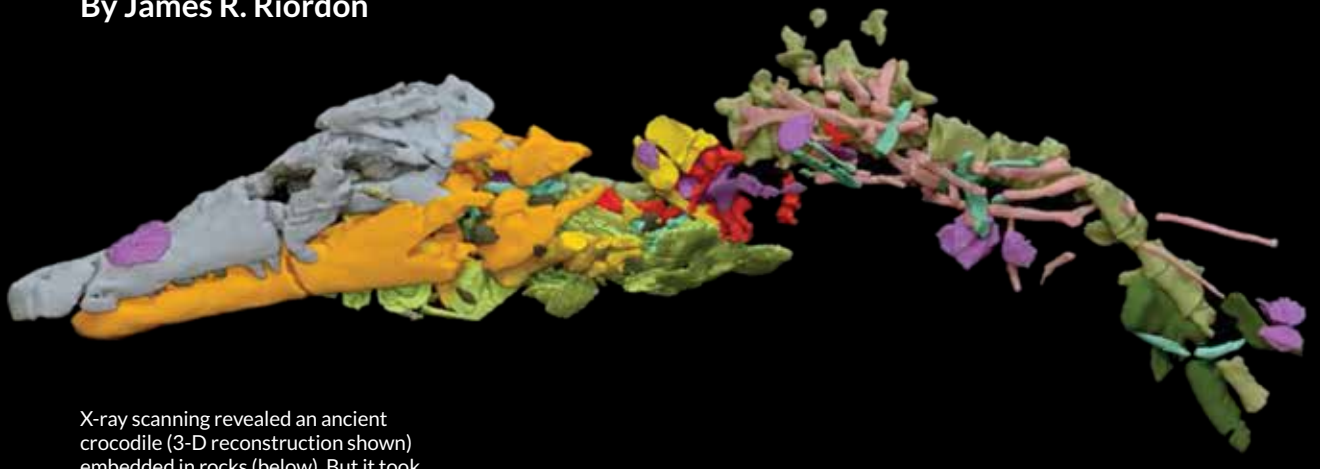
MICHELLE AIMÉE OESCH (CC BY 4.0)

FEATURE

Seeing into the Past

Researchers are embracing neutron imaging to uncover hidden details of fossils and artifacts

By James R. Riordon



X-ray scanning revealed an ancient crocodile (3-D reconstruction shown) embedded in rocks (below). But it took neutron scanning to discover dinosaur bones (red in the reconstruction) in the crocodile's belly.

Shattered crocodile. Formally, *Confractosuchus*. It was discovered in Australia when a bulldozer clearing a boulder broke a stone into pieces. Exposed portions of the broken-up rock made clear that fossils were inside, but there was no immediate sign that this discovery would later reveal an unprecedented snapshot of life from the Cretaceous Period.

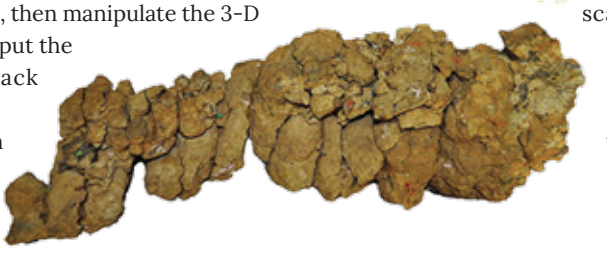
Paleontologist Matt White of the University of New England in Armidale, Australia, and colleagues arranged to have the fossil-laden rock scanned with X-ray computed tomography. Like a medical CT scan, the method takes multiple images of an object that can be assembled into a 3-D map of the interior. The team hoped to use the scans as guides to isolate individual bones in the fossil without removing them, then manipulate the 3-D images to virtually put the shattered croc back together.

But one section of the fossil puzzle gave them trouble. Iron-rich stone surrounding the bones made it difficult to get good X-ray images. So the researchers decided to try another approach.

They sent the mystery chunk to chemist Joseph Bevitt of the Australian Centre for Neutron Scattering in Sydney, who specializes in using subatomic neutron particles to image ancient objects. Along with the expected croc bones, Bevitt discovered one that looked like a dinosaur leg bone. It was in the portion of rock where the crocodile's stomach cavity would have been.

"When I saw the neutron result and the little dino femur, I was shaking with shock," Bevitt says, "both in awe and doubt with what we had seen."

Years of analysis plus more X-ray and neutron scanning eventually confirmed that the remains of a previously unknown species of dinosaur, bitten into chunks and



BOTH: M.A. WHITE *ET AL/GONDWANA RESEARCH* 2022

scored with tooth marks, were in the croc's belly. The finding earned the shattered crocodile the second half of its name: *sauroktonos*, for lizard killer. White, Bevitt and colleagues published their discovery of both the newly identified species of crocodile and the never-before-seen dinosaur inside last year in *Gondwana Research* (SN: 3/26/22, p. 5).

It's a stunning discovery: *Confractosuchus sauroktonos*, the shattered crocodile lizard killer, and the remains of its last meal, its dinosaur victim, frozen in stone 100 million years ago. It's a vignette that may never have come to light if not for neutron tomography. Although neutrons have been used for imaging in industrial and military applications since shortly after the neutron was discovered in 1932, it's only in the last few decades that these subatomic particles have begun to provide scientists with unprecedented views inside fossils and antiquities.

Look, don't touch

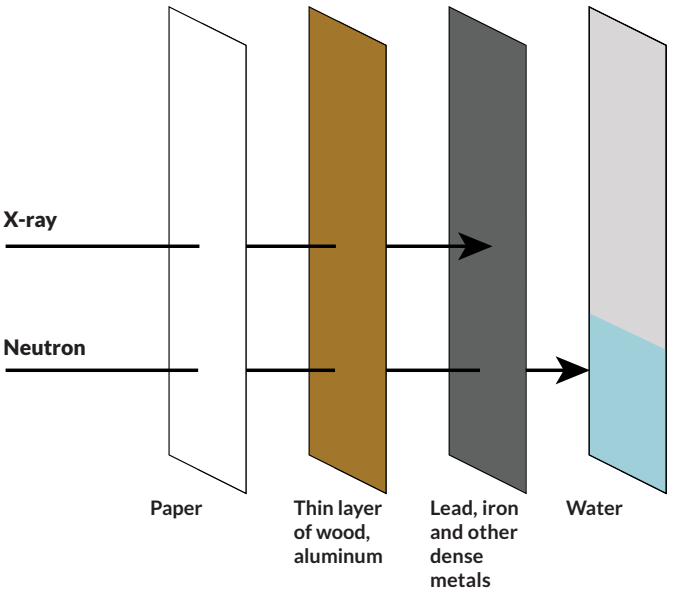
There was a time when studying fossils and artifacts often meant damaging or destroying them. Mummified remains were dissected. Sealed containers were cracked open. Fossils were pried loose from rock. In some cases, fossil-containing samples were ground down, layer by layer, to create images of sequential portions in slices that revealed the fossilized structures inside.

Fortunately, X-rays offer nondestructive insights. As a high-energy form of electromagnetic radiation, or light, X-rays interact with the electric and magnetic fields associated with electrically charged particles. In a doctor's office, when a technician shines a beam of X-rays at a broken leg, the light gets scattered or absorbed by the fields of the electrons around atoms in the leg. The denser a material is, the more electrons are packed in it, and the less effectively X-rays can pass through. That's why higher-density portions of the body — like bones — stand out in X-ray images more than lower-density portions. Skin, muscle and other soft tissues are essentially invisible because X-rays pass straight through.

X-rays have provided views into the hidden interiors of artifacts since the radiation was discovered in 1895. But after computationally intensive X-ray CT was developed in the 1970s, it became the standard approach to studying objects in paleontology and archaeology (SN: 12/18/21 & 1/1/22, p. 44). X-ray CT scanning is now the modern-day alternative to the grinding that 19th century scientists often relied on. Recent examples include scans of mummified animals from ancient Egypt (SN: 9/12/20, p. 17); newly uncovered inscriptions on the 2,000-year-old Antikythera mechanism, an ancient Greek astronomical calculator used to predict eclipses and other celestial events (SN: 12/2/06, p. 357); and a study of the brain cavity in a 20-million-year-old monkey skull (SN: 9/14/19, p. 11). Many large museums and research institutions have their own X-ray CT scanners on hand that are essentially the same systems that doctors use.

For all that X-ray imaging has revealed about the past, though, it still has some drawbacks. X-rays can't penetrate a particularly dense material, like lead or thick layers of other metals, to see an object hidden inside. On the flip side, an object made of low-density material, such as soft tissue, will be invisible to X-rays.

Neutrons can fill in the picture.



See through Scientists rely on X-ray and neutron scanning to penetrate materials that hide objects of interest. Differences in how X-rays and neutrons interact with atoms explain why neutrons, unlike X-rays, can pass through lead but get blocked by water.

The difference is in the scattering

Neutrons, as their name implies, are neutral. These subatomic particles have no electric charge, so neutron beams don't notice the electrons in orbit around atoms. Instead, neutrons pass right by electrons and hit nuclei packed with protons and neutrons at the centers of atoms. Incoming neutrons can bounce off an atom's nucleus or be absorbed into the atom. The interactions are more complicated than with X-rays and depend on how fast the neutrons are moving and on complex quantum mechanical interactions.

T. TIBBITTS

Lilies in a lead cask demonstrate the abilities of neutron imaging. Neutrons can sail through the lead, which would stop X-rays, to reveal the flowers within, including water in the vascular structure (right).

Neutrons suitable for tomography are produced with comparatively massive particle accelerators or as by-products from nuclear reactors. The neutrons are relatively slow moving, with energies one-hundred-millionth those of X-rays in CT scanners. These slow neutrons interact strongly with some low-density materials that X-rays pass through blithely, including lithium, boron and hydrogen.

"Water to neutrons is like lead for X-rays," because of the hydrogen atoms, Bevitt says. Too much hydrogen-rich material can hide details from neutron beams. But in the same way that a metal hip joint stands out in a medical X-ray, hydrogen can also make some features visible in neutron images. Lead, iron and copper, on the other hand, are essentially transparent to low-energy neutrons.

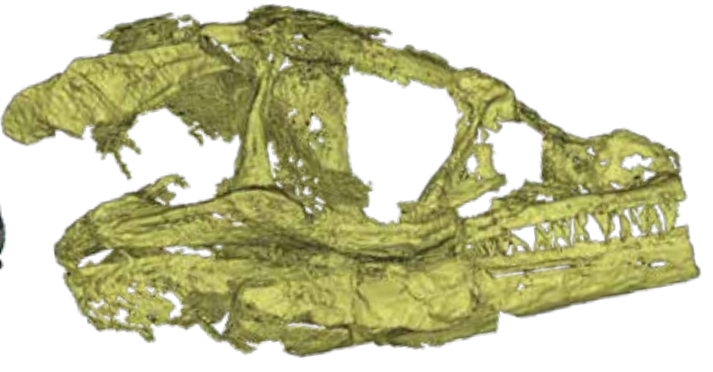
Physicist Jacob LaManna of the National Institute of Standards and Technology in Gaithersburg, Md., likes to demonstrate the comparative capabilities of neutron and X-ray imaging with a CT "still life" of Asiatic lilies tucked inside a hollow cask with thick lead walls. "The neutrons can go right through the lead, and then you can see basically all the water [in the] vascular structure of the flowers," LaManna says. An X-ray scan would show nothing but the opaque outer surface of the cask.

The ability to glide through dense materials that block X-rays has made neutron imaging an important technology for industrial testing of automobiles and planes. The particles can reveal the flow of hydrogen-rich oil inside engine blocks or expose flaws in metal castings. Since the 1970s, U.S. national laboratories have relied on neutron imaging to develop and maintain the nation's nuclear weapons stockpiles; the neutrons are powerful quality-control tools for mapping out the insides of dense bomb parts and for studying hydrogen-rich fusion explosives inside warhead components.

At NIST, LaManna leads the Neutron and X-ray Tomography, or NeXT, facility, which can simultaneously run X-ray and neutron imaging. The dual views provide distinct yet complementary information about things that contain combinations of materials — like hydrogen fuel cells, building materials and soil samples — that would be difficult to study with only one or the other imaging approach.

Over the last couple decades, as word has spread about the capabilities, a growing number of paleontologists, archaeologists and anthropologists have added neutron imaging to their analytical toolboxes. Despite neutron imaging being around for a while, "we are really the new kids on the block," Bevitt says.

In addition to revealing multiple dinosaur bones in the belly of a shattered crocodile, along with the femur that initially caught Bevitt's eye, neutron computed tomography has allowed researchers to study the fabric swaddling cat mummies without unwrapping them, find signs of recently applied glues holding together fraudulently assembled



To see the bones of an ancient crocodile skull embedded in iron-rich mudstone (left), researchers turned to neutron scanning. The images allowed for a 3-D view of the skull (right) without damaging the specimen.

FROM TOP: DANIEL HUSSEY/NIST; J. STIEGLER

artifacts, and uncover the most ancient vertebrate heart ever found, in a 380-million-year-old fish.

Rewards and risks

Paleontologist James Clark places a pair of fossilized crocodile skulls on the table in his basement lab at George Washington University in Washington, D.C. The 165-million-year-old fossils are dwarfed by a nearby modern alligator skull. While the alligator skull is about as long as my forearm, the fossilized croc skulls are only slightly bigger than my thumb tip.

The fragile skulls, which Clark collected in Mexico four decades ago, are embedded in hardened blobs of sediment with just a few bones and teeth peeking through. At first glance, the specimens resemble wads of chewed gum, but made of gritty, iron-rich mudstone. "If you try to X-ray that, you basically end up with … these bright sparkles from all the iron," Clark says. The result is blurring and streaking that hide the skeletal structures.

Clark could have hired preparers to clean away the sediment surrounding the delicate bones. But it's a slow and expensive process that can end up damaging the specimen, he says.

It wasn't until 2019 that he finally got a good look at the hidden bones. After a seminar where he met Bevitt, Clark realized that neutron scanning could be the answer. The event led to an introduction to LaManna and the NIST facility 25 kilometers up the road in Maryland.

Because iron is essentially transparent to neutrons, LaManna says, "it's much easier to basically isolate just the fossil portion of the object." Images from the NIST neutron CT scans revealed the intricate details of the tiny bones. "You can then start playing digital jigsaw puzzles with the bone fragments to try to reconstruct the particular creature."

While the material around a fossil or object may present a problem for X-rays, sometimes it's the object itself that's the issue. Tissues, fibers, wood and other low-density materials can be difficult to resolve with X-rays, and metals within an object can block other features from view. Both challenges plague researchers studying antiquities like the 3,000-year-old dagger-axes that I saw on display in the Smithsonian's Freer Gallery of Art in Washington, D.C.

These ceremonial weapons from China's Shang dynasty are suspended in a vertical glass case, where I could get my nose just a few centimeters from the jade blades and turquoise-encrusted bronze handles. I found it was best to lean up close so that I could appreciate the intricate blue-green patterns of gemstones sunk into the metal.

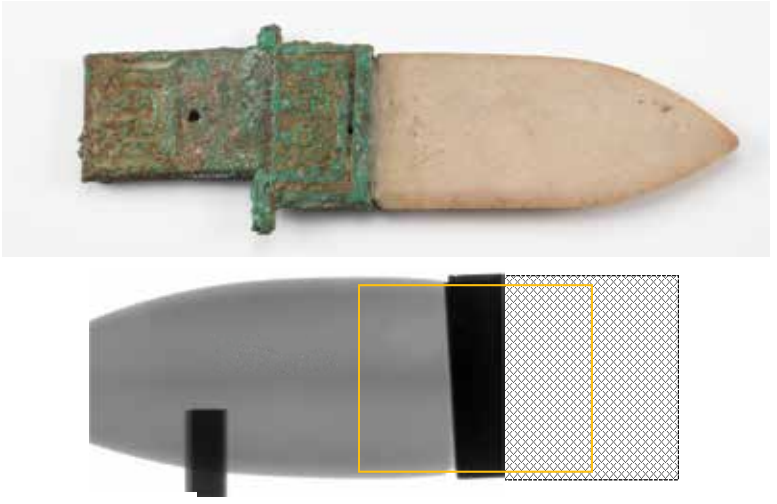
Together, X-ray and neutron scanning provided an inside view of this mummified cat from ancient Egypt, with no unwrapping required. X-rays (center) revealed the cat's skeleton while neutrons (right) showed details of the cloth wrappings, including layers of varying tightness and coarseness (inset).

Smithsonian art conservator Ariel O'Connor would love to know how the dagger-axes were put together. X-ray CT doesn't work on the combination of stone, metal, fibers and other materials that may be within. Neutron imaging could help, but it comes with a risk. Neutron beams make things radioactive. It's not always clear in advance how radioactive a sample will become, but materials often exceed the level of radioactivity that's safe for humans to handle, or even view in a museum, for days to weeks after exposure to neutron beams.

"We could actually do calculations and determine what's going to be the problematic element and how long would it be radioactive and how much," LaManna says. "[But,] in the case of the jade, where it's material basically just completely dug up from the ground, it can have all sorts of stuff in it that you might not necessarily expect." That makes residual radioactivity difficult to predict.

So, O'Connor decided to do a test. She and colleagues made a crude replica of an ancient dagger-ax. They used jade from Wyoming in lieu of the ancient Chinese jade, stacks of brass from a repurposed door kickplate to simulate the bronze handle, and some silk thread similar to the type that holds some Shang dynasty dagger-axes together. Then LaManna scanned the dagger with X-rays and neutrons at NIST.

As expected, the brass was entirely opaque to the X-rays, hiding features of the replica's construction. But the neutron beam revealed key details, including a view of the jade inserted inside the brass handle and even individual silk threads.



In a test of how neutron imaging might work on a 3,000-year-old jade dagger-axe from China (top), researchers at the Freer Gallery of Art made a replica using jade, stacks of brass plates and silk thread. In an X-ray of the replica (middle, shown facing the opposite direction as the real artifact), the haft is completely obscured by brass. Imaging a portion of the replica (area outlined in yellow) with neutrons revealed hidden details (bottom).

As for residual radioactivity, the replica showed none of any significance nine days later. In general, Bevitt says, residual radiation dies down quickly. One fossil he studied remained radioactive for three months, due to the presence of radium, but most samples are safe to send back to labs and museums within a few weeks or less.

Still, with that uncertainty and questions about how chemically similar the replica is to the real dagger-axes, O'Connor is not yet ready to risk scanning the artifacts.

"As a conservator, I am entrusted with the preservation and safety of these remarkable 3,000-year-old objects to ensure they remain for future generations. If an analytical technique such as neutron imaging might answer our research questions but would alter the objects and prevent them from being accessible" due to induced radioactivity, O'Connor says, "we will look for other options."

Opening a new window to the past

Despite the increasing popularity of neutron tomography for studying fossils and antiquities, X-ray CT remains the go-to imaging choice for most researchers. In the 1990s, a few dozen scholarly papers on using neutrons to study the past were published annually; recently, it's been hundreds per year. Publications related to imaging fossils and artifacts with X-ray CT, though, number in the thousands every year.

Most of the time, X-rays suffice, and the advantages are clear. They offer high resolution to uncover small details with no lingering radioactivity. X-ray CT machines are also widely available because they've been used in medical settings for over 50 years, and they're small enough to fit in most labs and museum research spaces.

At the moment, there are only a few dozen neutron tomography facilities on the planet. The particle accelerators and nuclear reactors that produce suitable neutrons are large, expensive and heavily regulated. Only a handful of the facilities worldwide are available to analyze fossils and antiquities, according to Burkhard Schillinger, a physicist at the Technical University Munich who runs the neutron imaging beamline there. He ticks off a few facilities in the United States, a half dozen in Europe and one in Australia.

Still, LaManna says the lack of access doesn't seem to be the bottleneck in widespread adoption of the technique. Along with the concerns over lingering radioactivity, the novelty of the technology and general lack of awareness may stand in the way.

"I try to recruit as broad a range of users as I can" to submit fossils and antiquities for imaging at NIST, LaManna says. "It's not like they're getting pushed out of the way" to make space for more conventional neutron studies. "It's just more of getting the correct people interested to then write proposals, come to us [and] work with us to get beam time."

In the last decade, Australia-based Bevitt has spread the word on neutron tomography through lectures and outreach around the world. Most of the experts contacted for this story trace their initial interest in neutron imaging to Bevitt's influence. Many researchers in his home country have already embraced the technology.

"Basically, in Australia, when a new dinosaur is discovered," Bevitt says, "the first thing that happens is it comes to our lab." ■

Explore more

■ Matt A. White *et al.* "Abdominal contents reveal Cretaceous crocodyliforms at dinosaurs." *Gondwana Research*. June 2022.

DAGGER-AXE: FREER GALLERY OF ART; SCANS: R. LIVINGSTON *ET AL*/*JOURNAL OF ARCHAEOLOGICAL SCIENCE: REPORTS* 2018

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WHAT IS LONELINESS?

The feeling stems from more than social isolation, scientists say. A more holistic view could offer new ways to manage it **By Sujata Gupta**

For centuries, the Turkana pastoralists of northern Kenya have followed the water. Families once moved about 15 times a year in search of watering holes for their cows, donkeys, camels, goats and sheep.

But the Turkana people's seasonal way of life has become precarious in recent decades. With drought and ongoing fighting across the region, many women and children stay put while men roam the landscape — often at their own peril. Violence has forced many families to flee for their lives at a moment's notice. Separated from their livestock, these families eke out a living along the edges of cities or bide their time in displacement camps ringed by tightly woven fencing.

Friendships built on the exchange of livestock also disintegrate. "When no one has any animals, how can we help one another?" a Turkana woman asked anthropologist Ivy Pike, who has worked in the region for 25 years, during an interview.

The suffering within these communities is profound, says Pike, of the University of Arizona in Tucson. Unable to safely comb the landscape for medicinal plants, such as herbs to stem postpartum bleeding or curb fevers in children, women find it hard to fulfill their role as nurturers. Men's identities, meanwhile, are often so bound up in owning livestock that the Turkana language has a word to describe a man without animals — *ekebotonit*.

"The loneliness of having no animals holds a particular place of distress that transcends the food and livelihood that livestock offer," Pike and a colleague wrote in 2020 in *Transcultural Psychiatry*. "An *ekebotonit* ... not only loses his sense of purpose and the companionship herds offer, but according to the Turkana, becomes erased — a man with no say in society."

These experiences of loneliness among many Turkana people demonstrate how the feeling defies simple characterization — it's more than social disconnection. That complexity is seen in cultures worldwide. In a study done in the United States during the COVID-19 pandemic lockdowns, for instance, many respondents attributed their loneliness to several factors that left them feeling disconnected. One woman missed going to the grocery store, anthropologist Michelle Parsons of Northern Arizona University in Flagstaff reported in 2022 in *SSM-Mental Health*. Another woman longed to browse the stacks at the library, a typically solitary activity.

Efforts to broaden the definition of loneliness to include a feeling of disconnect from animals, places, habits, rituals and even the weather have been gaining momentum across the social sciences.

A young Turkana man in northern Kenya takes his cattle to a dam for water. Recent drought and violence have made it difficult for Turkana pastoralists to maintain their herds, leading to widespread loneliness.

In October 2020, for instance, Parsons coauthored the introduction to a special issue on the anthropology of loneliness in *Transcultural Psychiatry*.

Getting a handle on the constituents of loneliness — and its flip side, belonging — is not just an academic pursuit; it's a matter of public health, research suggests. In a May advisory, U.S. Surgeon General Vivek Murthy declared loneliness a public health epidemic, citing findings from numerous studies: Loneliness appears to increase a person's risk of heart disease by 29 percent and risk of stroke by 32 percent. In older adults, chronic loneliness is associated with a 50 percent increase in the risk of developing dementia. Social isolation can increase the risk for premature death by 29 percent.

Broadening concepts of loneliness can help expand the toolkit of possible interventions, Parsons says.

Tethering people to the wider world could even help people recognize and address climate change, suggests geographer Sarah Wright of the University of Newcastle in Callaghan, Australia. This process begins, she says, by "building intentional relationships with more than human beings."

Ancient forms of belonging

To understand belonging and by extension loneliness, Wright has looked to Indigenous communities. Though these communities span the globe and are comprised of myriad practices and languages, broadly speaking, they share a belief that well-being stems from harmony between people and the planet (SN: 9/23/23, *p.* 14).

OPPOSITE PAGE: UNDREY/ISTOCK/GETTY IMAGES PLUS; THIS PAGE: FRANCIS NKAYO

The lyrics of ancient songs called songspirals sung by members of the Yolŋu describe people's connection to their land and community. This snippet of a songspiral sung by a matriarch on her deathbed translates as, "I can see the saltwater carrying me, moving together with the current."

Wright and colleagues recently studied the stories the Aboriginal Yolŋu people tell through ritualized songs known as songspirals. This ancient practice explores the connections among place, culture, people and the stories they tell. Wright's team, including members of the Yolŋu community and drawing on the work of the Gay'wu Group of Women, published an analysis of one matriarch's songspiral in 2022 in *Qualitative Inquiry*. In keeping with the Yolŋu world view, Bawaka Country, the tribe's homeland in northern Australia, is listed as the lead author.

While lying on her deathbed, the matriarch began singing about her place, her sense of belonging, within a wide web of human and nonhuman relationships. In accordance with her people's tradition, the matriarch saw this last journey as taking her to the sea; she envisioned herself as a whale. "I can see the saltwater carrying me, moving together with the current; carrying me further into the depths of the ocean, where the foundation of my bloodline lies."

The matriarch built from an ancient script, one that spirals outward from a voiceless land, explain the authors. That song always starts something like: "At the beginning of time someone had to talk for the land, it was quiet, nothingness. And then it began with the sound from deep within the water, 'Hmmm hmmm.' That was the starting point...."

From there, the matriarch's song moves forward and backward across generations to anchor people in the broader arc of time, Wright says. The matriarch sings of swimming alongside her deceased grandmother; she sings of her daughters, her granddaughters and her great-granddaughters.

The song also anchors the Yolŋu people to their homeland by giving voice to whale migratory patterns, key fishing grounds and physical connections across the land and sea. The songspiral "maps the land from the sea point of view," Wright says.

The matriarch's songspiral shows how for the Yolŋu people, nonhuman relationships are as real as relationships with humans, Wright says. With such relationships, people feel a sense of belonging in the world. Without them, people feel lost.

As the matriarch's daughter Merrkiyawuy explains in the paper, if the laws of balance between people and land, or country, are broken, "the spiral can come tumbling down and burst. That's what we say, it will burst open and just float and you will be like a leaf floating in the air, nothing controlling you ... if that spiral is burst open, then the songs disappear."

Losing place — through migration, development, climate change or some other cause — can manifest as loneliness in Indigenous communities, other research suggests. For instance, in 1987, anthropologist Theresa O'Nell of the University of Oregon in Eugene began an 18-month study of depression among the Salish and Pend d'Oreille peoples living on the Flathead Reservation in Montana. But whenever O'Nell asked people if they had ever been depressed, they would invariably talk about loneliness.

"Time after time, I asked about 'depression,' and time after time, I was told about 'loneliness,'" O'Nell recounted in the 2004 issue of *Culture, Medicine and Psychiatry*. As an example, O'Nell cited "the loneliness of an elder lamenting the loss of a song that is no longer sung."

O'Nell attributed this loneliness to several causes, including a feeling of exclusion from society, an existential feeling of separation between the self and a higher power, and bereavement over losing rituals and language. The Salish and Pend d'Oreille peoples, she observed, did not see their loneliness as pathological, but instead saw it as a natural response to the erosion of their way of life.

"Traditionally oriented Indian people are less susceptible to sadness and more susceptible to loneliness," says Joseph P. Gone, a psychologist at Harvard University and a member of the *Aaniiih*-Gros Ventre tribal nation located in Montana.

If land loss is connected to loneliness, especially in Indigenous communities, then the feeling would be expected to grow as climate change wreaks havoc on people's ancestral lands. (SN: 3/28/20, p. 6). For instance, the 2019–20 bushfires that scorched millions of hectares in Australia caused tremendous suffering for Aboriginal communities, researchers in Australia who worked with these communities wrote in 2020 for the Conversation, a nonprofit news organization: "For Aboriginal people ... who live with the trauma of dispossession and neglect and now, the trauma of catastrophic fire, our grief is immeasurably different to that of non-Indigenous people."

BAWAKA COUNTRY *ET AL/QUALITATIVE INQUIRY* 2022

Longing for daily rituals

An emphasis on harmony between people and the planet appears less frequently in industrialized cultures, Wright says. "The fact that you can have a nourishing relationship with place has been invalidated."

But as the pandemic illuminated, even in industrialized cultures, many people's sense of belonging still hinges on connections to the more-than-human world. Rather than a connection between person and the landscape, though, these relationships frequently show up between people and aspects of the built environment.

This need for relationships with the built environment comes through in journal entries submitted to the Pandemic Journaling Project, Parsons says. This global initiative to gather people's experiences of the historic health crisis amassed some 22,000 entries from 1,750 people from May 2020 to January 2022.

"The loneliness creeps up on me. It appears out of left field. The desire to just go and hang out with friends, go out to eat, even browse stacks at the library," wrote Denise, described as a divorced Midwestern Black woman in her 60s.

The typical tools psychologists use to measure loneliness probably miss these feelings, Parsons reported in her 2022 article in *SSM-Mental Health*. She reached that conclusion after homing in on 35 U.S. journal writers, many with multiple entries, who used words containing the fragments "lone" or "isolat" in at least one entry. The journal writers also filled out a five-statement loneliness survey alongside their first entry and then every six weeks thereafter. Journal writers responded "yes," "more or less" or "no" to statements such as: "I miss having people around me." "There are plenty of people I can rely on when I have problems." "There are enough people I feel close to."

Even though many respondents reported feeling lonely in their entries, they still scored low on the loneliness survey, Parsons found. For instance, on the same date that Taylor, described as twenty-something, nonbinary single white person, wrote that they had "never been more lonely," they scored a 0 on the loneliness survey.

Parsons attributes the discordance to limitations in the survey. The psychological survey used in the journaling project, called the De Jong Gierveld Loneliness Scale, and another widely used survey, the UCLA Loneliness Scale, both define loneliness as a form of social pain brought on by the felt absence of a social network or meaningful relationships.

By design, then, most loneliness surveys miss people's connections to places, activities or even casual acquaintances. In the journaling project, people wrote about missing rituals and other practices, such as birthday celebrations, holidays, religious services and funerals, or missing places, such as the gym, grocery store, library and friends' houses, Parsons notes. People also wrote about missing everyday encounters with others, the seemingly mundane interactions that can arise when people wander their communities.

Those feelings of loneliness show up in one of Taylor's entries. They write: "Not only do I miss my friends, but I also miss strangers. I miss the random encounters I used to have with people on the street, in stores, at bars. I miss making a connection with someone and then going our own ways."

FROM LEFT: C.V. OLIN *ET AL*/*WELLBEING, SPACE AND SOCIETY* 2022; NGĀTI WHĀTUA ŌRĀKEI

To foster community connections, a Māori group in Auckland developed a cohousing community known as a *papakāinga* (colorized area in this aerial view, left). This *papakāinga* includes 30 homes connected by communal gardens and play areas for children (a child bikes through the neighborhood, right).

The De Jong Gierveld Loneliness Scale is great at capturing a longing for the sort of deep, meaningful relationships that people typically associate with loneliness, but it misses other sorts of loneliness, Parsons says. "It's not picking up place at all. It's not picking up practices."

Expanding the toolkit

Including the built environment in assessments of loneliness is not yet common. But architects, whose trade rests on understanding how people move about their communities, often intuitively think about how the design of the physical environment can worsen feelings of isolation or foster belonging.

"We usually think of loneliness as a singular situational, social or mental experience of being detached from place, domicile, or other human beings," reads the opening line of the Finnish architect Juhani Pallasmaa's chapter in the 2021 book of essays and lectures *Loneliness and the Built Environment*.

"People can be socially isolated but still not feel lonely."
EMILY RUGEL

Many architects, including Pallasmaa, have found inspiration in the writings of German philosopher Martin Heidegger, who believed that dwellings provide a means of both shelter and self-expression. Architects thus design environments that imbue life with meaning, he argued.

Social scientists are starting to join architects in thinking about how the built environment can affect loneliness. In his recent public health advisory, Surgeon General Murthy outlined six pillars to advance social connection. In the first pillar, he recommended facilitating connection among people through better urban planning, such as providing people with easy access to green spaces and bolstering the reach of public transit.

Similarly, in January, a cross-disciplinary team of researchers in Australia and England, whose areas of expertise include urban planning, public health and sociology, identified several urban design features that have the potential to reduce loneliness. Those features include common spaces, walkability, public transit, housing design, sense of safety and access to natural spaces.

While the focus of such urban design projects often aim to get people together, there is growing awareness that connecting people with the natural world may also alleviate loneliness. "People can be socially isolated but still not feel lonely," says Emily Rugel, an environmental epidemiologist at the University of Sydney. "They may find that ability to tap a biophilic connection and go out and view wildlife and walk among the trees. [That may be] enough to make them feel connected to the broader world. They don't necessarily need interaction with friends or family members to do that."

Consider, for instance, a small project in New Zealand that aims to alleviate loneliness, in part, by helping people reconnect to their extended families and ancestral lands. Members of one Māori subtribe, the Ngāti Whātua Ōrākei, developed a 30-home *papakāinga*, a type of communal Māori cohousing setup, on ancestral land. Completed in 2016, that project brought people together by connecting homes via shared lanes, community gardens and play spaces for children.

Developers wanted people to feel as if they were walking the same paths as their ancestors, researchers wrote in the 2022 issue of *Wellbeing, Space and Society*. They hoped that feeling would help residents feel rooted in their culture and the long arc of time. Even when building on ancestral lands is not possible, bringing often far-flung community members back together has the potential to revive languages and cultural practices, the authors note. But more research is needed to know if a return to the *papakāinga* reduces loneliness.

The bottom line is that expanding how we think about loneliness has the potential to expand the toolkit of possible interventions, Parsons says. "We can regulate our loneliness by not necessarily calling up a friend but by going out, going for a walk, or going to the library, or going and sitting in a coffee shop."

Loneliness and climate change

Many years ago, I moved to a small city in New England while several months pregnant. I knew no one except my husband and spent my lonely days wandering the woods behind my house. Once, after my baby was born, I strapped him into a carrier and scrambled down a steep embankment. There, at the edge of a lake, a log had lodged into the rocky shore. We would spend hours watching waves pummel the log's rough bark. As I observed loons dive for fish in summer and heard waves shatter ice like glass in winter, my loneliness would briefly ebb.

I was reminded of this log after speaking with Sarah Wright about songspirals and why we should all cultivate intentional relationships with the natural world. I had never considered my relationship with the log particularly important, or even as a relationship at all. But Wright made me realize that in this new and unfamiliar place, the log had provided a haven. Her words also explained the sadness I felt over the years as the waves chipped away the log's bark—a process accelerated no doubt by a lake that froze over less and less come winter.

There's a word to describe what I was feeling. In

Many cultures recognize that people disconnected from places, animals and ways of life can feel lonely. Writer Sujata Gupta experienced that sort of loneliness when a log she frequently visited (her son is shown with the log) floated away.

S. GUPTA

the early 2000s, environmental philosopher Glenn Albrecht of the University of Sydney coined the term "solastalgia" to describe the pain or sickness a person experiences when natural or human-made disasters destroy their home. Etymologically, the word originates from both solace and desolation. Desolation, Albrecht wrote in 2007, has "meanings connected to abandonment and loneliness." Solastalgia is also a play on nostalgia.

Albrecht felt compelled to create such a term after observing and interviewing over 50 people living in the Hunter Valley region north of Sydney, where there has been intensive mining. Residents expressed concerns over how mining was affecting their health and well-being. "The fact that you can see those huge mine heaps et cetera makes you think that sometime in the future there may be dreadful consequences for the water table movement in the valley," a man named Leo said. A woman named Eve said, "When the coal is gone, the people of Singleton will be left with nothing but 'the final void.'"

The residents' experience is ironic, Albrecht noted. These people are descended from the colonizers who dispossessed Indigenous communities of their land. Now, this "second wave of colonization," Albrecht wrote, "is leading to complete dispossession for some and solastalgia for those left behind." In other words: desolation, abandonment and loneliness.

In recent years, related terms have emerged: ecoanxiety and climate grief (SN: 2/29/20, *p.* 22). Unlike solastalgia, though, researchers rarely connect these ideas to loneliness. That's changing. In 2022, an online survey of over 3,000 German adults, for instance, showed that those who scored high in loneliness on the De Jong Gierveld Loneliness Scale also tended to score high in climate anxiety on a different scale.

These terms make clear that building a relationship with the nonhuman elements of our world is bittersweet in this time of rapid climate change. We come to love what we may well lose. Yet, absent these deep relationships, how can we care for the world we live in?

Last winter in my New England town, it didn't snow until mid-February and the water around the log never froze. Those months of battering waves were hard on the log. When I trekked down to that rocky shore one muddy spring day, my two school-aged children in tow, the log was smooth to the touch and white as bone.

On a solo walk a few weeks later, I discovered that the log was gone. It had, after so many years of holding on, floated away. ■

Explore more

- Michelle Anne Parsons. " 'I miss my friends, but I also miss strangers': Pandemic loneliness and the importance of place and practice." *SSM-Mental Health*. December 2022.

POLAR BEAR PELTS INSPIRE NEW FABRIC

Polar bears have black skin covered by fur that looks white. That fur "has a very unique structure," notes Trisha Andrew, a materials engineer at the University of Massachusetts Amherst. Hollow hairs channel the sun's infrared light toward the skin, helping the animals keep warm. This inspired Andrew's team to develop a new heat-trapping fabric that mimics polar bears' pelts.

Under light, the new fabric kept a surface beneath it 10 degrees Celsius (18 degrees Fahrenheit) warmer than a cotton T-shirt fabric did. The new material also outperformed a material used to make warm outdoor gear.

This story appears online and in the October print issue of Science News Explores, our award-winning magazine for young people. In this installment of Analyze This—our data literacy series—we invite readers to read about this research, interpret data and engage in critical thinking to answer questions about the findings.

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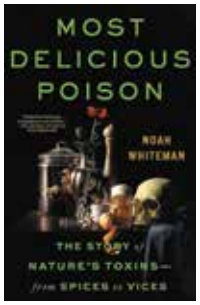

Most Delicious Poison
Noah Whiteman
LITTLE, BROWN SPARK, $30

BOOKSHELF

How nature's toxins shape the human world

After his father's unexpected death from alcohol use disorder in 2017, evolutionary biologist Noah Whiteman undertook a journey to understand how nature's toxins affect the world. The result is his debut book, *Most Delicious Poison: The Story of Nature's Toxins—From Spices to Vices*.

The book weeds through chemistry, evolution and world history to explore the origins of toxins and how humans have co-opted them for everything from medicines to spices to pesticides. "The chemicals in these products of nature are not a sideshow—they are the main event," Whiteman writes, "and we've unwittingly stolen them from a war raging all around us."

That tussle, part of what Charles Darwin called the "war of nature," is the innovative ways plants and animals continuously evolve traits that one-up their predators or competitors. Many of the chemicals that we stock in our cabinets and pharmacies, for instance, originated in plants as deterrents against insects snacking on them, Whiteman points out. These chemicals act on our brains and bodies thanks to the surprising neurological similarities between insects and humans.

Whiteman, who studies how insects adapt to plant toxins, is a knowledgeable tour guide through this greenhouse of poisons and cures. And it is a greenhouse. Though people put some animal-made toxins to use, the plant derivatives steal the show.

Chrysanthemums with their insecticidal compound, pyrethrin, make an appearance in the book, as do terpenoid-wafting pines, calming chamomile and morphine-like water lilies. To tame the tangle of chemicals and their interactions, Whiteman dedicates each chapter to a couple of toxin classes and lays out their source in the natural world, their chemical mechanisms and historical context for their use by people.

Quinine, commonly used to treat malaria, is a toxin derived from the bark of the cinchona tree (shown), native to South America.

CELSO ROLDAN/AFP VIA GETTY IMAGES

Take tannins. They show up in a wide array of plants, including oaks, tea plants and grapes. Whiteman muses that these chemical compounds may protect plants by inhibiting the ability of microbes and herbivores to absorb nutrients. Tannins also bind to salivary proteins, resulting in the "rough, dry puckering sensation" that many people enjoy while sipping a glass of Cabernet Sauvignon. Humans have also long put the protein-binding properties of tannins to use in tanning animal hides for leather. For nearly 1,500 years, Europe and then its colonies relied on ink manufactured from tannin-rich oak galls for drafting important documents, including the Magna Carta and the Declaration of Independence.

Perhaps the most important role of toxins in the human world can be found in our pantries and medicine cabinets. Whiteman focuses on pharmacological heavyweights such as the antimalarial drug quinine, derived from the bark of the cinchona tree, and salicylates, such as aspirin and oil of wintergreen. Curare, cocaine and scopolamine demonstrate how we've wrangled these alkaloids into anesthetics. It's one of many instances where Whiteman nods to Indigenous communities around the world that have been repeatedly exploited or gone uncompensated for their medicinal discoveries. "It is no wonder that many countries in Latin America and elsewhere in the global tropics now have biopiracy laws that strictly regulate the export of natural products," Whiteman notes.

Whiteman closes by examining how medieval Europe's lust for spices catapulted the world into five centuries of geopolitical upheaval. The Columbian exchange, the Opium Wars and the founding of the East India Company are all pit stops along Whiteman's exploration of how the pursuit of all things psychoactive and medicinal fueled European colonialism. The lasting consequences, Whiteman argues, include infringement on Indigenous rights, global biodiversity loss and the climate crisis.

The opioid epidemic and alcohol use disorder also loom large in the book. Here, Whiteman's assertion that our use of toxins "walk[s] a knife's edge between healing and harm" is loudest. His father haunts many of the personal anecdotes sprinkled throughout the 304-page read. Whether he's recalling the toxicology report from his father's autopsy or noting his family's fondness for black pepper, Whiteman explores grief as much as he does science: "My attempt to grasp why [my father] died allowed me to identify and then draw together the many ways that nature's toxins affect the world."

Personal and well-researched, *Most Delicious Poison* has wide appeal, in part, as Whiteman points out, because indulging in nature's toxins "is an essential part of what it means to be human." So go ahead. Pour a cup of herbal tea, add some drops of lavender oil to the diffuser and enjoy this mind-bending read. —*Aaron Tremper*

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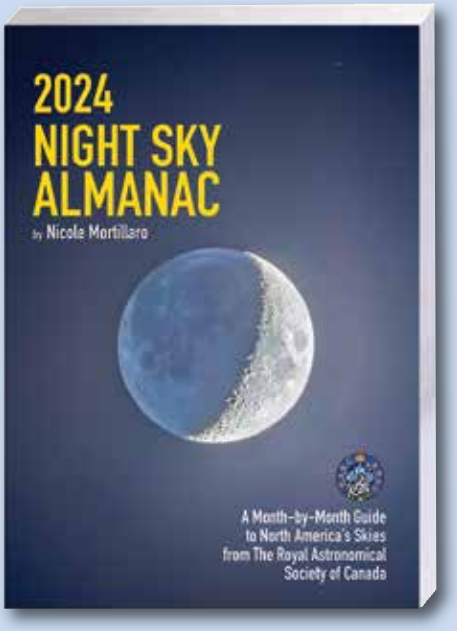

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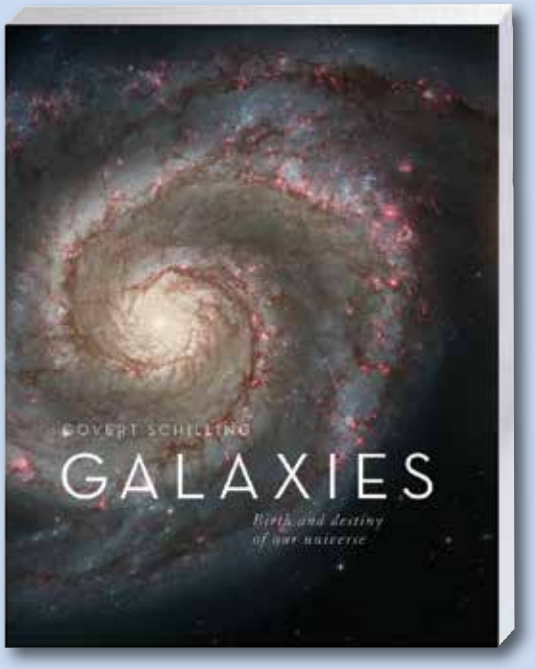

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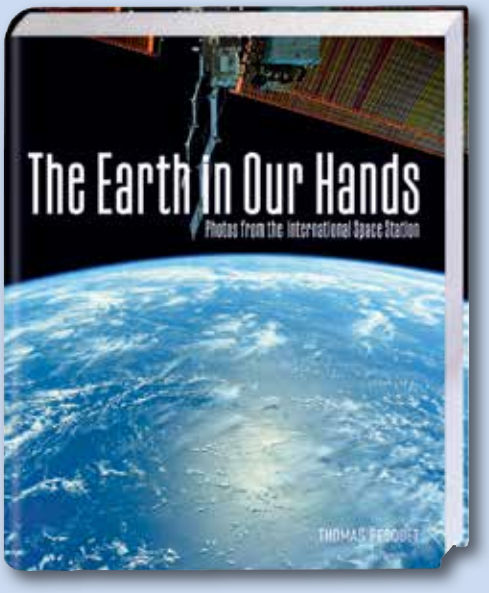

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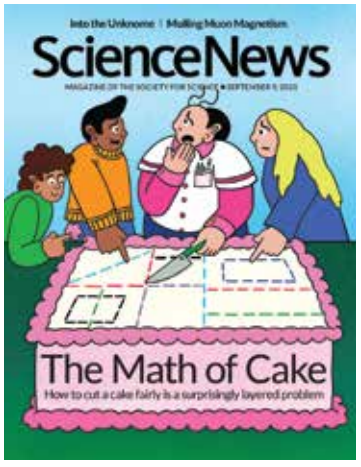


SEPTEMBER 9, 2023

Piece of cake

*For decades, researchers have studied the cake-cutting problem, which explores how to fairly divide resources, **Stephen Ornes** reported in "A fair slice?" (*SN: 9/9/23, p. 14*).*

The last-diminisher method is one way to divide a cake among a group, **Ornes** wrote. One person cuts a slice they deem is a fair share. Each remaining person then gets a turn to either trim the slice or pass. The last person to trim gets the piece and exits the game. The trimmings are then recombined with the remaining cake, and the process restarts.

Reader **Robert Lavelle** tried this method to split a sandwich among 13 students. It worked smoothly until one student wanted a smaller piece than her fair share. Those who left the game before her got pieces equal to each other, as did those who left after. But the first group ended up with smaller pieces.

As the story covers, this method is not envy-free: Those who exit early may covet pieces cut later. But there is a solution, says **Steven Brams**, a game theorist and political scientist at New York University. "Let all the players not make full cuts but notches where they would make cuts. If a person indicates she wants only a smaller piece, cut this piece off for her. Then run the procedure again, without her piece, for the other players," he says.

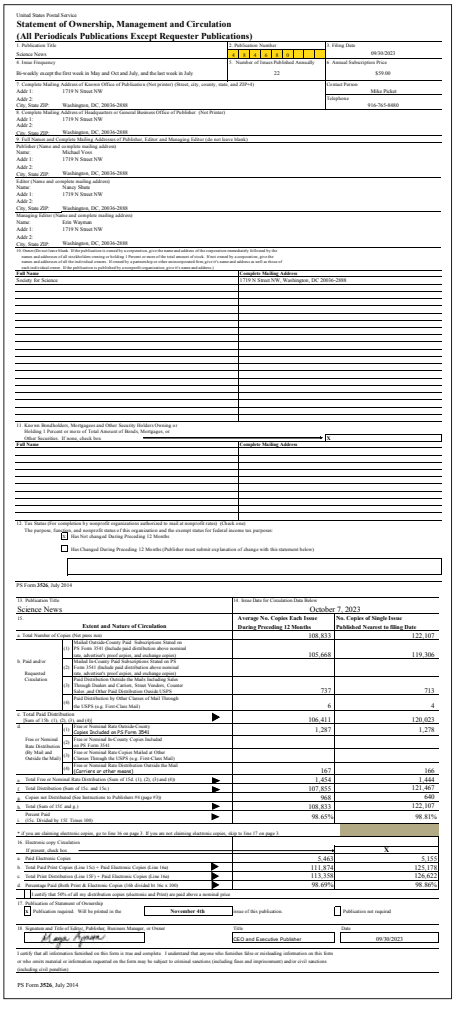
Clarification

"Extravagance of early galaxies" stated that about 372,000 years after the Big Bang, during the "cosmic dark ages," hydrogen formed and filled the cosmos with an opaque gas (SN: 8/12/23, *p.* 18). It would have been clearer to write that hydrogen made the cosmos transparent to certain wavelengths of light while opaque to others. Eventually, after the first stars and galaxies formed, hydrogen atoms lost their electrons, lifting the veil that blocked certain wavelengths.

Corrections

"Extravagance of early galaxies" incorrectly defined the cosmic dark ages. That period is so named because no stars, hence no starlight, existed then, not because hydrogen gas clouded the cosmos. The story also mistakenly noted that protons, electrons and neutrons combined to form that hydrogen. Only protons and electrons did.

Due to an editing error, "Semaglutide may benefit the heart" stated that 15 kilograms is about 11 pounds (SN: 9/23/23, *p.* 8). It is about 33 pounds.



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1. Publication Title	2. Publication Number	3. Filing Date
Science News	0 0 3 6 – 8 0 7 8	09/30/2023
4. Issue Frequency	5. Number of Issues Published Annually	6. Annual Subscription Price
Bi-weekly except the first week in May and Oct and July, and the last week in July	22	$59.00

7. Complete Mailing Address of Known Office of Publication (Not printer) (Street, city, county, state, and ZIP+4): 1719 N Street NW; Washington, DC, 20036-2888 — Contact Person: Mike Picket; Telephone: 916-765-8400

8. Complete Mailing Address of Headquarters or General Business Office of Publisher (Not Printer): 1719 N Street NW; Washington, DC, 20036-2888

9. Full Names and Complete Mailing Addresses of Publisher, Editor and Managing Editor (do not leave blank)

Publisher (Name and complete mailing address): Name: Michael Veve; Add 1: 1719 N Street NW; Add 2: ; City, State ZIP: Washington, DC, 20036-2888

Editor (Name and complete mailing address): Name: Nancy Shute; Add 1: 1719 N Street NW; Add 2: ; City, State ZIP: Washington, DC, 20036-2888

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It's the galaxy NGC4632, and radio telescope images suggest that it sports a rare polar ring: a halo of mostly hydrogen gas tilted about 90 degrees from the plane of the galaxy's disk (shown here in a composite false-color image).

Such spectacular structures, which can also contain dust and stars, were thought to encircle about 1 in 1,000 galaxies. But now it seems that many more — possibly 30 times as many — could be hiding in plain sight, researchers report in the November *Monthly Notices of the Royal Astronomical Society*.

Astronomers are still puzzling out how galaxies get polar rings. But they're thought to form as galaxies gobble up gas or collide with other galaxies. "The rings give us clues about how [galaxies] can grow and evolve," says astronomer Nathan Deg of Queen's University in Kingston, Canada.

Deg and colleagues spotted the ring-like structure encircling NGC4632 — and one wrapped around another galaxy, NGC6156 — in data from the WALLABY survey, a project to scan the southern sky with Australia's ASKAP radio telescope. And these two may have plenty of company, the team says. The fact that the researchers have spotted two polar rings in the nearly 600 galaxies included in the first bits of WALLABY data suggests that previous estimates of polar ring frequency were too low.

Computer simulations testing how polar ring galaxies look when viewed at different angles support that conclusion. All together, the observations and simulations suggest that as many as 3 percent of nearby galaxies could have overlooked rings. Thanks to large surveys like WALLABY, Deg says, "we're in an era where we can discover these and figure out the rings in a way that we never could before." — *Elise Cutts*

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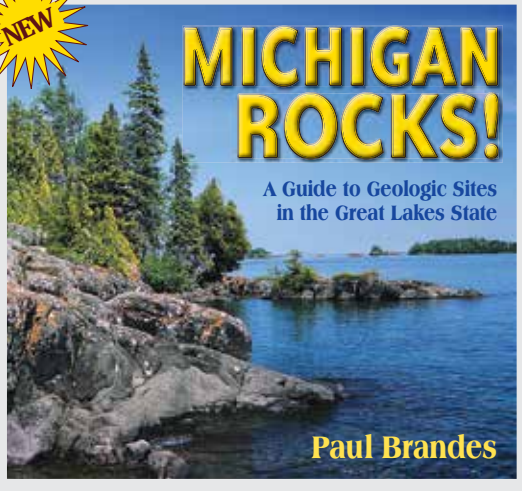

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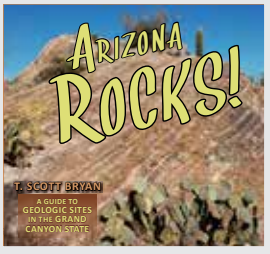

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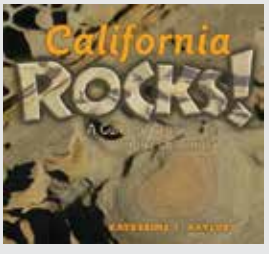

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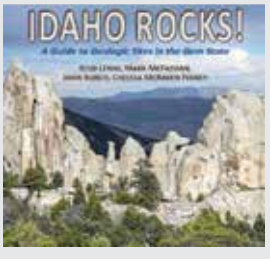

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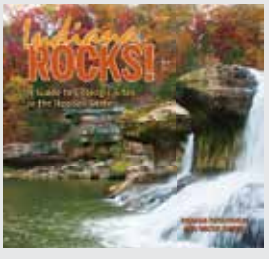

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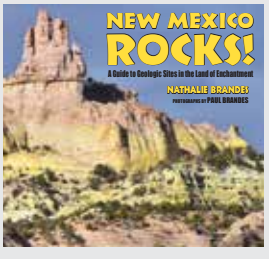

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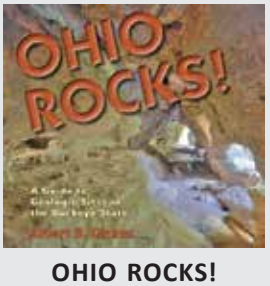

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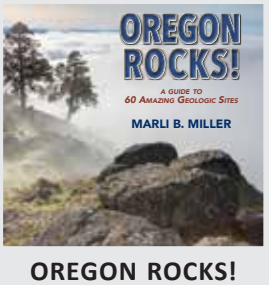

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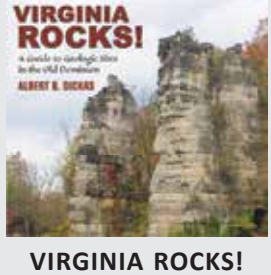

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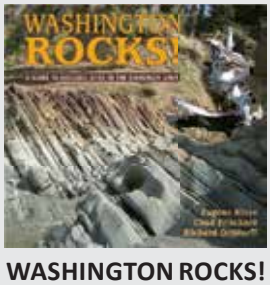

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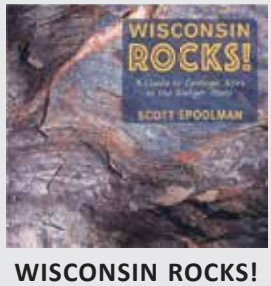

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