Your Brain on Psilocybin | The Woolly Mammoth's Last Gasp

ScienceNews

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The new science of UFOs

They're almost certainly not aliens. But the truth is out there.

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ScienceNews

Features

News

Departments

COVER A new era of science aims to identify the objects (human-made, natural or otherwise) behind UAP sightings. *Matt Chinworth*

FROM TOP: R. KNAPP; FABRIZIO LAVEZZI; CHAKARIN WATTANAMONGKOL/MOMENT/GETTY IMAGES

Of frogs and the people who love them

The notion of a human falling in love with a bug-eyed amphibian is so preposterous that the Brothers Grimm used it to test the character of a princess. That fairy tale continues to inspire jokes, memes and endless metaphors (even though in the original version the princess threw the frog against a wall, which triggered his transformation into a prince).

Cranky princesses aside, there is a long, rich history of human-frog love. The amphibians generally mean us no harm, they come in an array of gorgeous hues and that bug-eyed baby face can be ugly cute. They even sing. After a long day at work, I like to seek out a frog pond near my house, stand in the dusk and listen to their burbling symphony.

So it's no surprise that humankind responded with collective dismay when news broke in the 1990s that frogs around the world were dying from a fungal epidemic. Many people didn't just mourn; they leaped into action to help make the world safe for hopping, ribbiting amphibians. And they've made progress.

In this issue, we take you to the Sierra Nevada of Northern California, where biologist Roland Knapp of the University of California, Santa Barbara has worked for the last three decades to protect frogs in the wild. That includes figuring out how some individuals infected with the chytrid fungus sidestep death. For years, Knapp has been transporting those survivors to mountain lakes, where he hopes the transplants will form new, fungus-proof colonies (Page 22).

It's been a battle fought on many fronts. An early system for transporting frogs in damp cloth bags resulted in some tragic deaths, so the frogs now travel safely in sturdy plastic containers. The teams also seek out lakes that don't freeze all the way to the bottom; the frogs need a pocket of water below the ice to survive the winter.

Other efforts in the fight for frogs include seeking the genetic variations that help some of them resist the fungus, and testing to see if providing frogs in Australia with toasty-warm hideouts will keep the disease at bay in winter (Page 25). The work is far from done, but the narrative is shifting from a murder mystery to — hopefully — a modern fairy tale. It shows how dogged fieldwork and basic research have combined to combat a seemingly impervious foe.

If you're in the mood for more true tales of legendary critters, check out the exquisite trilobite fossils preserved by a volcanic eruption in Morocco (Page 8) and a *Jurassic Park*–style method that stores DNA in an amberlike material (Page 9). And let us introduce you to a newfound dinosaur dubbed *Lokiceratops rangiformis*, so named because its impressive horns evoke the Norse god Loki (Page 5). Finally, we have a poignant report on the mysterious end of the world's last woolly mammoths, which died marooned on Wrangel Island in the Arctic Ocean (Page 9). Even though those creatures perished some 4,000 years ago, the remains of structures that Indigenous residents built with scavenged mammoth tusks serve as a haunting reminder of the time when these great beasts roamed the Earth. — *Nancy Shute, Editor in Chief*

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Excerpt from the August 10, 1974 issue of *Science News*

50 YEARS AGO

Food and migraines

A new study of migraine and food ingestion … is reported in the July 26 *Nature*. [Scientists] studied a group of migraine sufferers, administering placebos and capsules containing phenylethylamine. Thirty of the 36 had no migraine reaction from the sugar capsules, while 18 of the 36 suffered a migraine attack after the phenylethylamine.

UPDATE: Foods that contain phenylethylamine, such as chocolate and cheese, contribute to some migraines. But scientists now know that many factors, including hormone fluctuations, stress and weather changes, can trigger attacks. Certain genes have also been found to increase migraine risk (*SN: 6/9/18, p. 5*). Although the process behind how migraines develop is still coming into focus, researchers have identified a key player in kicking things off: CGRP, a protein that helps transmit pain signals in the nervous system. Drugs targeting CGRP's activity, first approved by the U.S. Food and Drug Administration in 2018, have provided relief for many patients (*SN: 3/27/21, p. 16*).

TEASER

A stellar explosion may add a temporary new 'star' to the night sky this summer

A white dwarf (illustrated, left) pulls material off a red giant star. The accumulation of matter can trigger an eruption on the white dwarf.

Keep your eyes on the night sky this summer, scanning for the constellation Corona Borealis. If you are lucky, you may glimpse what appears to be a new star winking on in the dark.

The brightening point of light will not be a new star, but a nova eruption about 3,000 light-years from Earth. There, a white dwarf star orbiting a red giant star tears material from its larger companion. When enough mass collects on the white dwarf's surface, the rising pressure and temperature will trigger a blast that can be seen from Earth with the naked eye — but for only a few days to a week.

"This is a once in a lifetime opportunity," says astronomer Gerardo Juan Manuel Luna of the Universidad Nacional De Hurlingham in Argentina. "We are in the right time, in the right moment, with the right instruments."

The white dwarf and red giant constitute a binary system known as T Coronae Borealis, or T CrB. Astronomers think that the nova will occur by September. T CrB repeats its eruption about every 80 years. The last time this happened was in 1946 (SN: 2/23/46, p. 120).

T CrB experienced a sudden brightening in recent years that astronomers call a super active phase, followed by an apparent dip in activity, which signals the nova is probably imminent. The same pattern was observed before T CrB burst in 1946 and 1866. This time around, scientists plan to get a better view of the nearby nova than ever before.

Dozens of telescopes around the world and orbiting in space will fix T CrB in their sights. "We hope to be able to answer questions with this object that then might be relevant to all the other accreting and eruptive white dwarfs," says astrophysicist Jennifer Sokoloski of Columbia University.

One question is whether T CrB's white dwarf gains or loses mass following each successive nova. The eruption will eject material into space, but some of the mass ripped from the red giant may sink into the white dwarf, causing the small but dense star to gain mass over time. If this is the case, then repeating novas might ultimately lead to type 1a supernovas, which play an important role in the evolution of star systems and galaxies.

"That's the holy grail," Luna says. "After the eruption, say in the next five years when things are calmed down, we should be able to measure the mass again and see what happened."

There will be little warning before T CrB erupts — and scientists can't be sure that it will even happen soon. "Maybe we'll sit here holding our breath for the next 10 years," Sokoloski says. But if T CrB repeats past behavior, then anyone viewing the night sky from a dark place at the right moment could be the first to see this cosmic spectacle burst to life in this century.

— *Jay Bennett*

M. WEISS, CXC/NASA

INTRODUCING

Horned dinosaur evokes a Norse god

A newfound dinosaur species may not have been burdened with the glorious purpose of Loki—but it did bear an impressive set of horns reminiscent of the Norse trickster god.

Fossils of *Lokiceratops rangiformis* were unearthed in Montana's badlands. The dinosaur lived about 78 million years ago, when the region was a swampy floodplain bordering a vast seaway, paleontologist Mark Loewen and colleagues report June 20 in *PeerJ*. The dinosaur's most distinctive feature is its two bladelike horns, which jut out from between its eyes. The arrangement of the horns as well as the ornamentation along the bony neck frill at the back of the head differ from those of other horned dinosaurs from the same region and time.

It's becoming more clear that horned dinosaurs were using these bony features to attract mates or intimidate rivals of the same species, says Loewen, of the University of Utah in Salt Lake City. That sort of differentiation in ostentatious ornamentation "is the kind of thing that evolves on an island," he says. The new study suggests that this diversity might have resulted from the seaway cutting off this ancient swampland from other parts of the continent.

Some researchers aren't convinced that *L. rangiformis* is a new species. The differences between it and other horned dinosaurs from the region could indicate evolution within a single species or age-related changes among individuals of that species, says paleontologist Denver Fowler of the Dickinson Museum Center in North Dakota. "As we get more data, we'll get closer to the truth."

In the meantime, this obfuscation does seem like the sort of thing that a god of mischief might enjoy. So perhaps Loki is having the last laugh. —*Carolyn Gramling*

Lokiceratops rangiformis, bladelike horns jutting from its brow, wades in 78-million-year-old swamplands in this illustration.

HOW BIZARRE

Eye-opening video shows aging's toll

A Hitchcockian video of 64 eyeballs, all rolling and blinking in different directions, is providing a novel visual of one way eyes age. Previous lab work showed that pupil size shrinks as people get older, making the pupil less responsive to light. Now, a study has confirmed that what happens in the lab happens in real life, too.

More than 80 volunteers, ranging in age from 18 to 87, donned headgear that captured images of eyes and collected data on eye movement as they walked outdoors and inside. The video compilation of participants' eyes underscores how significantly pupil size differs among people, says neuroscientist Manuel Spitschan of the Max Planck Institute for Biological Cybernetics in Tübingen, Germany.

A video of dozens of eyeballs (some shown) has helped confirm that pupil size shrinks with age.

Analyzing the data revealed that pupil size decreases by a maximum of about 0.4 millimeters per decade, Spitschan's team reports June 19 in *Royal Society Open Science*. The change helps explain why it can be increasingly difficult to see in dim light as we age. —*Abdullahi Tsanni*

Watch dozens of eyeballs move around at **bit.ly/SN_Eyes**

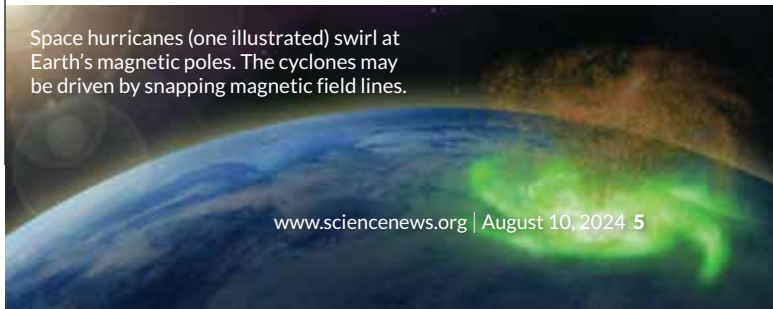
SAY WHAT?

Space hurricane \SPAY-s HER-ih-kane\ n.

A geomagnetic cyclone that occurs near Earth's magnetic poles

Hurricanes aren't just surface level. Earth's upper atmosphere contains storms of plasma dubbed "space hurricanes." Scientists first described a space hurricane in 2021: It was a cyclone-shaped aurora raining down electrons near the north magnetic pole. Such storms, it turns out, also swirl near the south magnetic pole.

Satellites captured 259 space hurricanes from 2005 to 2016, physicist Sheng Lu of Shandong University in China and colleagues report June 25 in the *Journal of Geophysical Research: Space Physics*. The team suspects the storms form when Earth's magnetic field lines, split by the solar wind, reconnect. That process roils ionized gas in the atmosphere, driving flows of electric current upward. Flows then bend and spin, leaving an "eye" at the center. —*Carolyn Gramling*



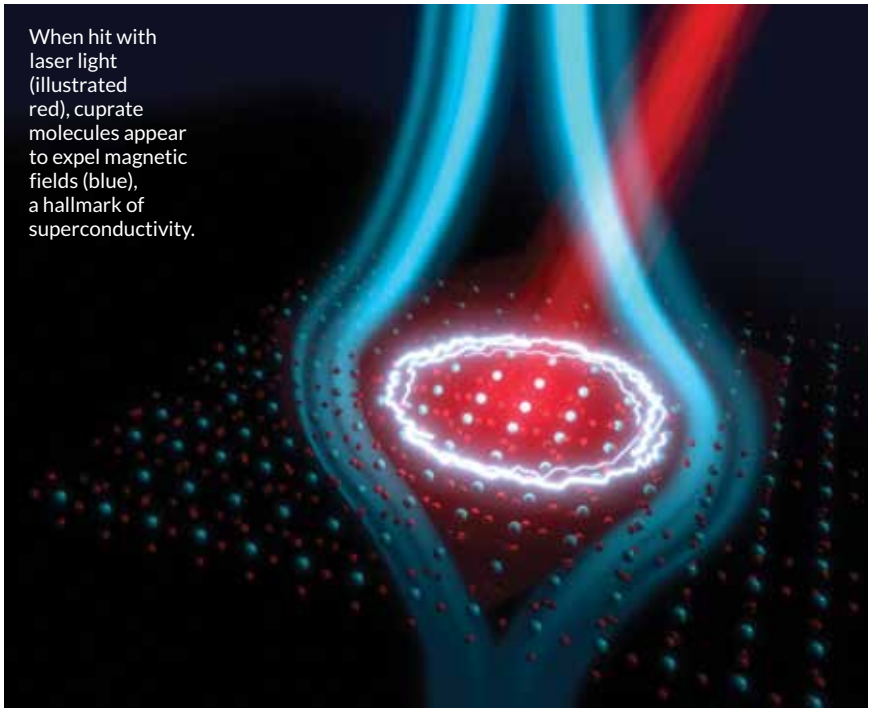
Space hurricanes (one illustrated) swirl at Earth's magnetic poles. The cyclones may be driven by snapping magnetic field lines.

CLOCKWISE FROM TOP: FABRIZIO LAVEZZI; QING-HE ZHANG/SHANDONG UNIV.; R. LAZAR *ET AL*/*ROYAL SOCIETY OPEN SCIENCE* 2024

PHYSICS

Light may spark superconductivity

A magnetic experiment strengthens the controversial claim



When hit with laser light (illustrated red), cuprate molecules appear to expel magnetic fields (blue), a hallmark of superconductivity.

SEBASTIAN FAVA, JÖRG M. HARMS

BY EMILY CONOVER

Brief blasts of light might turn some materials into fleeting superconductors. A new study strengthens the case for this controversial claim, first made more than a decade ago. But while some physicists are convinced, others remain skeptical.

Superconductors transmit electricity without resistance, typically only at low temperatures. Since 2011, some scientists have claimed that certain materials, when hit with intense, ultrashort laser pulses, can briefly become superconductors at temperatures far above their normal limit, including room temperature.

The previous research showed a temporary change in the reflectivity of cuprates — compounds containing copper and oxygen — when blasted with light. That change indicated a drop in resistance lasting mere trillionths of a second. Critics argued that the change could be caused by effects other than superconductivity.

The new work, described July 10 in *Nature*, claps back. One cuprate expels magnetic fields when hit with light, which is a hallmark of superconductivity known as the Meissner effect, physicist Andrea Cavalleri of the Max Planck Institute for the Structure and Dynamics of Matter in Hamburg and colleagues report.

The finding is "an unmistakable signature of superconductivity," says physicist Dmitri Basov of Columbia University.

But physicist Steve Dodge is more cautious. "They're seeing this change that lasts for [about] a picosecond, and it's not immediately obvious that it's the same thing as the Meissner effect," says Dodge, of Simon Fraser University in Burnaby, Canada.

Superconductors attract intense interest from physicists, in part due to the materials' technological potential. A superconductor that operates at high temperatures could allow for more efficient, energy-saving power transmission.

Scientists knew that light could disrupt superconductivity, but the idea that light could also birth it was unexpected and controversial. In previous studies, "things were a bit subjective, they kind of 'smelled' like a superconductor but … you couldn't really be sure," Cavalleri says.

So he and colleagues set their sights on the Meissner effect (SN: 8/8/15, *p.* 12). They studied a type of cuprate called yttrium barium copper oxide, or YBCO. This class of compounds has previously shown potential signs of light-induced superconductivity.

But precisely measuring magnetic field changes over a tiny fraction of a second is no easy feat. "No existing technique allows you to do this measurement," Cavalleri says.

The team devised a scheme that used a crystal of gallium phosphide placed next to the YBCO to measure magnetic fields. In a preexisting magnetic field, the researchers hit the YBCO with a laser and sent a second laser through the crystal. The trip through the crystal changed the orientation of that laser's electromagnetic waves in a way dictated by the magnetic field within the crystal. That effect allowed the team to determine how the magnetic field changed near the YBCO as it was bombarded with light at temperatures above the YBCO's normal superconducting limit.

If the YBCO became superconducting, it would expel magnetic fields from within due to the Meissner effect. That would result in a stronger magnetic field at the YBCO's edge, which is what the team found. The measurements had to be made extremely quickly to capture the short-lived Meissner effect, Basov says. "This is a brilliant concept and brilliant execution."

Something other than superconductivity could be responsible, Dodge contends. At high intensities of light, complex and unexpected phenomena can occur. Careful scrutiny is needed "to ensure that they're not mistaking some other effect for a Meissner effect," he says. What, exactly, is behind the change in the magnetic field is not clear. While Dodge is still skeptical of the superconductivity claim, he says "it's a worthwhile experiment because it raises some questions that I certainly don't know the answer to." ■

ASTRONOMY

A rare black hole lurks close by

The middling object could help reveal how galaxies evolve

BY LISA GROSSMAN

For the first time, astronomers have spotted a middleweight black hole in the nearby universe. The discovery could help solve the riddle of how even heftier black holes form and grow up with their host galaxies.

The black hole, which sits nearly 18,000 light-years from Earth in the center of star cluster Omega Centauri, is at least 8,200 times as massive as the sun. That puts it squarely in a rare category of intermediate-mass black holes, researchers report in the July 11 *Nature*.

Most of the black holes astronomers have detected fall into one of two categories. They're either stellar-mass black holes, with masses up to about 100 times that of the sun, or supermassive black holes, which reside in the centers of galaxies and clock in at hundreds of thousands to billions of times the mass of the sun.

Black holes with masses in the middle could help span the gap between the two categories and explain how the supermassive ones got so big. But these black holes are a little like Bigfoot: There have been many claimed sightings, but most turn out not to be real.

ESA, HUBBLE, NASA, M. HÄBERLE/MPIA

The star cluster Omega Centauri, shown in an image from the Hubble Space Telescope, hides a rare midweight black hole in its core (marked with a white box).

"There's this rather wide mass range, between 100 and 100,000 solar masses, where there are only very few detections," says astronomer Maximilian Häberle of the Max Planck Institute for Astronomy in Heidelberg, Germany. "It's interesting to find out whether they are there, and we just don't see them because they are hard to detect. Or maybe there's also a reason why they don't exist at all."

One reason to think midsize black holes should exist is because the supermassive black holes astronomers have spotted in the early universe didn't have time to grow so big if they were just eating gas and stars like black holes do today (SN: 2/13/21, p. 4). If those black holes grew from mergers of intermediate-mass seeds, that could solve the puzzle (SN: 6/3/23, p. 24).

"It's like a missing link that is needed to explain the existence of the supermassive black holes," says Texas-based astronomer and data scientist Eva Noyola, who was not involved in the new work. "If it's proven that [intermediate-mass black holes] happen in dense stellar clusters, you have a solution there that's pretty elegant and simple."

So astronomers have been hunting for midsize black holes for decades, and searching Omega Centauri specifically since at least 2008. As the most massive cluster of stars in the Milky Way, it's a relatively easy spot to search, and it may be the remnant core of another galaxy that merged with the Milky Way about 10 billion years ago (SN: 11/24/18, p. 8).

"It's basically a galactic nucleus frozen in time," says study coauthor Nadine Neumayer, also of the Max Planck Institute for Astronomy. Its black hole could be representative of all small galaxies' black holes 10 billion years ago. "It tells us immediately something about the seed mass for black holes."

But previous studies left it unclear whether Omega Centauri hosted a single medium-size black hole, or a bunch of smaller black holes close together.

Using 20 years of Hubble Space Telescope observations, Häberle and colleagues tracked the motions of 1.4 million individual stars in the cluster and searched for stars moving faster than expected.

Seven stars zip around the innermost regions of the cluster at speeds between 66 and 113 kilometers per second, which should have rocketed the stars out of the cluster altogether, the researchers found. The only way those stars could remain in the cluster is if a single massive object is holding them close, the team concludes.

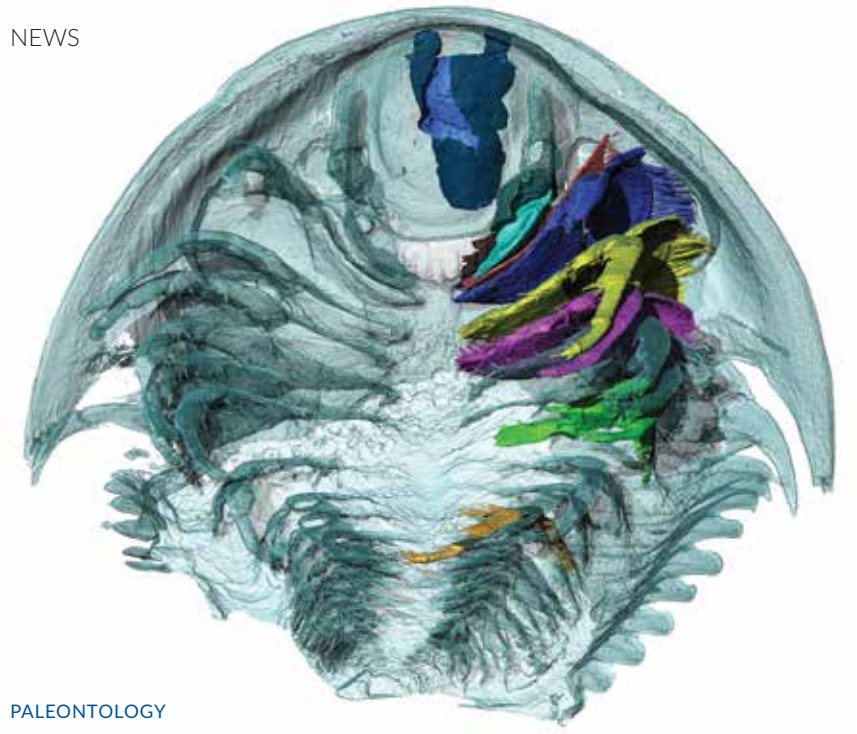
The observations of superfast stars, combined with other observations through the years, should resolve the debate about the black hole in Omega Centauri, says Noyola, who was on the team that first claimed to see the black hole in 2008 and faced skepticism when she and colleagues reported the result.

It wasn't until over a decade later that astronomers nabbed undeniable evidence of an intermediate-mass black hole. The first solid detection came from the LIGO gravitational-wave observatory, which recorded ripples in spacetime shaken off after two smaller black holes merged to form a single, 142-solar mass black hole (SN: 9/26/20, p. 7). But that collision occurred about 17 billion light-years from Earth, making it challenging to study.

From an astronomer's perspective, Omega Centauri's black hole has two advantages over that one: It's in our galactic neighborhood, and astronomers can continue to observe it. Häberle and colleagues are planning to use the James Webb Space Telescope, or JWST, to get more information on the orbiting stars' speeds, which should let them put better limits on the black hole's mass.

Another group, led by astrophysicist Oleg Kargaltsev of George Washington University in Washington, D.C., is using JWST to look for light emitted by superhot gas flowing into the black hole.

"It will be a completely independent, very different method of proving that there is an intermediate-mass black hole," Kargaltsev says. ■



In this 3-D reconstruction of a trilobite fossil, a collapsed part of the digestive system appears in blue. Other colors indicate different appendages.

PALEONTOLOGY

Pristine trilobite fossils arose from ash

A volcanic eruption buried the animals, preserving soft tissues

BY LUCAS VAN WYK JOEL

Paleontologists studying rocks from Morocco have unearthed the most exquisitely preserved trilobite fossils yet discovered. These lifelike fossils update our understanding of the evolution and biology of these extinct ocean-dwelling arthropods.

The details are so great that soft tissue parts, including the mouth and digestive tract, are clearly visible, researchers report in the June 28 *Science*. Such parts are typically lost during fossilization.

"These trilobite fossils represent the most complete specimens found to date, not only preserving the hard exoskeleton but also the soft parts in 3-D, such as the antennae, walking legs and the digestive system," says study coauthor John Paterson, a paleontologist at the University of New England in Armidale, Australia.

After dinosaurs, trilobites are perhaps the most recognizable fossil animals. They proliferated in the ocean for about 270 million years before going extinct at the end of the Paleozoic Era, some 252 million years ago.

Trilobite fossils are extremely common because their hard exoskeletons made it relatively easy for the animals to become fossils. But just as it's rare to discover any trace of preserved soft tissue in dinosaurs, so it is with trilobites.

To uncover how these trilobites became so well preserved, Paterson and colleagues turned to geologist Robert Gaines of Pomona College in Claremont, Calif. Gaines is an expert in how the soft parts of animals become fossils.

It happened like this: First a volcano exploded, and superheated ash flowed from the eruption into nearby coastal waters. The ash dissolved and then remineralized out of the water, covering the exposed trilobites and entombing them in a matter of hours to days.

The key step in this process, Gaines says, is that the ash hit water before hardening around the trilobites; without the cooling effects of ocean water, the hot ash would have burned the trilobites away.

Gaines studies similar fossil preservation in other, older specimens, such as *Aegirocassis*, an alien-like arthropod with what appears to be a strange baleen–style feeding apparatus. "I recognized the similarities immediately," Gaines says. "They pointed to the same process operating more than 20 million years earlier."

Besides being ready for a museum showcase, the fossils open new windows into trilobite biology and evolutionary history, says Nigel Hughes, a paleontologist at the University of California, Riverside who was not involved in the work.

"The clarity of the preservation is astonishing and is of fundamental importance," Hughes says. "It provides a level of preservation detail that unequivocally confirms a number of conjectures made based on less well-preserved material."

The fossils confirm, for instance, that trilobites ate using the many pairs of legs stretching from their head to their torso. They chewed food along a central groove while passing food particles toward a tiny mouth (SN: 11/4/23, *p.* 5).

"Food processing took place along the entire length of the animal," Hughes says.

This eating style differs from other arthropods, such as crustaceans, which have more specialized limbs along their body lengths, used for tasks from self-defense to swimming.

"We don't yet know for sure, but it seems likely that this basic limb style endured throughout the history of trilobites, and the lack of limb specialization may be part of the reason for their ultimate demise," Hughes says. Discovering more well-preserved trilobites would only help clarify the evolutionary story of these fossil icons.

This kind of pristine preservation may be more common than scientists think, Paterson says. Volcanoes, including ones near coasts, erupted relatively often over the vast stretches of geologic time.

"Geology and paleontology students at universities are often told that fossils are found only in sedimentary rocks," Paterson says. "But our new study completely contradicts that notion. I hope that our work will encourage others to reprogram their search image in the hunt for amazing fossils." ■

MATERIALS SCIENCE

Storing DNA *Jurassic Park*–style

Amberlike material preserves genetic data at room temp

BY PAYAL DHAR

Sometimes science fiction does inspire science research. À la *Jurassic Park*'s entombed mosquito, scientists have developed a method to store DNA in an amberlike material and extract it easily in a matter of hours. This storage method is cheaper and faster than existing options, researchers report in the June 26 *Journal of the American Chemical Society*.

Besides storing organisms' genetic information, DNA can potentially be used to store digital data such as text, photos, videos and more. The genetic material's storage density is many orders of magnitude higher than that of human-made devices. But DNA is also fragile and currently requires freezing temperatures and specialized equipment to store safely.

The new method, called Thermoset-REinforced Xeropreservation, or T-REX, encapsulates DNA in glassy polymer networks at room temperature. Similar to polystyrene plastic, the material doesn't break down easily in nature. To retrieve the DNA, scientists use a combination of benign chemicals that open up the polymer's structure.

Chemist James Banal of the California-based biotech start-up Cache DNA and colleagues put the polymer to the test by encasing a human genome and DNA sequences containing the *Jurassic Park* theme music within it. After seven days of being exposed to temperatures ranging from 55° to 75° Celsius at 70 percent humidity, the DNA samples were successfully extracted and sequenced.

T-REX appears to be efficient at storing DNA at room temperature, which could have broad-reaching impact, says computational biologist Dina Zielinski of Whitelab Genomics in Paris. It brings researchers "closer to practically being able to store nucleic acid for hundreds, even thousands, of years." ■

PALEONTOLOGY

What killed the last woolly mammoths?

Inbreeding wasn't actually the cause, a genetic analysis hints

BY CLAIRE YUAN

Four thousand years ago, on an island near Siberia, the world's last woolly mammoth took its final breath.

Living on that island, isolated from other mammoths, could have led to fatal levels of inbreeding and catastrophic population drops, resulting in extinction. A new study confirms that the population on Wrangel Island was inbred but suggests the mammoths were not doomed to die because of it. Instead, the population gradually lost harmful genetic mutations that would have affected survival, indicating that some other random event sealed the mammoths' fate, researchers report in the July 11 *Cell*.

Until about 10,000 years ago, the mammoths lived on mainland Siberia. Rising sea levels stranded populations on disparate islands, limiting genetic mixing.

"Genetic variation is the general toolbox that animals have in order to adapt to changes in the environment," says evolutionary geneticist Love Dalén of the Centre for Palaeogenetics in Stockholm. Previous research has suggested that isolation increased inbreeding, decreased genetic variation and made the mammoths more vulnerable to harmful genetic mutations, diseases and death. Dalén and colleagues reject this genetic meltdown model.

They analyzed 21 genomes extracted from woolly mammoth bone shards, tusks and teeth collected in Siberia. These genetic data cover the last 50,000 years of the mammoths' existence, including when some became marooned on Wrangel Island. By comparing the genomes with those of elephants and humans, the team estimated how genetic mutations may have harmed the mammoths and whether those mutations were purged over time.

Wrangel Island's population grew from about eight mammoths to as many as 300, then stayed level until the creatures went extinct. The most harmful genetic mutations became less frequent over time, the team found, probably because animals with those mutations didn't reproduce.

The study provides "really good evidence against the meltdown model, but it doesn't completely exclude that model," says evolutionary biologist Vincent Lynch of the University at Buffalo in New York. Minor genetic mutations could still have made the mammoths vulnerable to disease, climate shifts and the arrival of humans.

Dalén's team was unable to analyze the Wrangel Island population during its last 300 years. Technological advances, the scientists say, will eventually reveal the mammoths' entire genetic trajectory. ■

A study of woolly mammoth genomes extracted from tusks (one shown) and other remains suggests the mammoths on Siberia's Wrangel Island may not have died out due to inbreeding.

L. DALÉN

ENVIRONMENT

Landfills belch toxic 'forever chemicals'

Waste off-gas can carry more PFAS than leached liquids

BY NIKK OGASA

What's dumped in a landfill is supposed to stay there, but toxic "forever chemicals" are wafting from the waste into the air.

Per- and polyfluoroalkyl substances, or PFAS, have been detected in gas exuded by some Florida landfills in quantities comparable to or even greater than in liquids that seep from the waste, scientists report in the July 9 *Environmental Science & Technology Letters*. These chemicals have been linked to cancer, weakened immune systems, developmental problems in children and a tide of other harmful health effects (SN: 11/19/22, *p.* 18).

Systems that collect landfill gas are nowhere near as efficient as those that collect runoff, says environmental engineer Ashley Lin of the University of Florida in Gainesville. And the portion of gas that is captured on-site is not typically treated in ways intended to destroy PFAS, Lin says.

Owing to their prevalence in consumer products, toxic "forever chemicals" accumulate in landfills, where some eventually migrate from the waste into runoff liquid and gas.

"The real concern is with how we manage this really concentrated gas."

PFAS molecules contain links of carbon and fluorine atoms that are resistant to heat, grease and water, which has bolstered the chemicals' widespread use in consumer products, including raincoats, cosmetics and nonstick cookware. But those bonds also cause PFAS to linger in the environment, with some forms taking more than 1,000 years to degrade.

Unsurprisingly, these forever chemicals gather within most if not all U.S. landfills. A 2023 report by the U.S. Environmental Protection Agency indicated that runoff from over 200 landfills across the country contained PFAS and identified 63 types of PFAS across the sites. But few studies have investigated what types and quantities of PFAS escape as landfill gas.

In gas samples from three municipal solid waste sites, Lin and colleagues detected 13 types of PFAS at concentrations ranging from 210 to 940 parts per trillion. One class, fluorotelomer alcohols, dominated the samples, reaching concentrations that were somewhat comparable to those in soil fumes from near a PFAS manufacturing facility.

ENVIRONMENT

Plants don't store carbon very long

What the finding means for climate projections is unclear

BY CAROLYN GRAMLING

Earth's plants aren't holding onto carbon for as long as we thought.

An analysis of pulses of carbon-14 from nuclear bomb tests in the 20th century reveals that plants stock more carbon in short-lived tissues such as leaves than previously estimated, scientists report in the June 21 *Science*. But this carbon is probably more vulnerable to rerelease to the atmosphere than carbon in long-lived tissues, the team says, potentially altering estimates of how much anthropogenic carbon plants and soil can hold.

Since 1945, the United States, Russia and other countries have detonated more than 2,000 nuclear devices in weapons tests. Each explosion has sent a large spike of radioactive carbon-14, a variant of carbon, into the atmosphere. From there, the carbon has made its way through the oceans, plants and soils. The bursts, scientists realized, were a lot like pulses of radioactive medical tracers traveling through a human body. They offer a unique opportunity for researchers to follow the carbon, analyzing where and for how long it has been stored and released.

80
trillion kilograms
The estimated minimum amount of carbon that plants take up each year

That intel is now crucial. As the climate heats up due to rising levels of carbon dioxide and other greenhouse gases in the atmosphere, there is a need to understand how long Earth's terrestrial biosphere — its plants and soils — can sequester some of that carbon, says atmospheric scientist Heather Graven of Imperial College London.

Current climate models estimate that the terrestrial biosphere takes up about 30 percent of human-caused CO_2 emissions. Graven and colleagues wondered how well such models represent carbon-14 from the bomb tests. So the team focused on a brief span of time, from 1963 to 1967, during which there weren't any tests and thus no new pulses to confuse the data. The scientists also focused on just the plant-growth part of carbon storage.

Using data from aircraft, stratospheric balloons and ocean buoys, Graven and colleagues reassessed estimates of how much bomb carbon-14 entered the upper atmosphere during that time period, and how much moved into the lower atmosphere and into the oceans. From there, the team calculated how much must have

KOZMOAT98/GETTY IMAGES

The team also sampled runoff from the landfills and compared it with gas samples. Since gas and runoff harbor different types of PFAS, scientists focused on levels of fluorine. The PFAS building block was found in runoff and gas at comparable levels. But at one site, the gas contained roughly three times as much fluorine as the runoff did.

A landfill's location, the time of year and detection methods can all affect how much PFAS is found in gas and runoff, says Florentino De la Cruz, an environmental chemist at the University of North Florida in Jacksonville. But the new study makes it clear that landfill gas carries forever chemicals, he says. "That is no longer debatable." An EPA-funded nationwide sampling campaign is currently under way, he says.

Questions remain regarding the fate of the emitted PFAS. Captured landfill gas is often burned off, but whether that process destroys PFAS is unknown. As for escaped gas, it "gets diluted really, really fast," says environmental engineer Morton Barlaz of North Carolina State University in Raleigh. "The levels are so low that it's not likely to be causing a [health] impact." Still, Barlaz says, it's too early to say for sure. ■

entered the biosphere and used satellite data on vegetation and computer models to estimate where plants stored the carbon.

The results were startling, Graven says. Though plants pull in at least 80 trillion kilograms of carbon each year — possibly twice as much as current estimates — a lot of that carbon is shunted to leaves and thin roots. Those tissues are especially vulnerable to degradation that releases carbon back to the atmosphere. The carbon going into plants now "is not going to be there as long as we thought," Graven says, though for how long exactly is unclear. Still, the findings underscore the need to curb fossil fuel emissions, she says. "There is a limit of how much we can store in vegetation."

What the findings mean for climate projections is also unclear, says biogeochemist Lisa Welp of Purdue University in West Lafayette, Ind. But the study undermines confidence in how well climate models will be able to simulate plants' role. ■

MARC SOLOMON/PHOTODISC/GETTY IMAGES

ENVIRONMENT

Ephemeral streams fill up U.S. rivers

The crucial yet overlooked waterways are vulnerable to pollution

BY CLAIRE YUAN

The dry-looking streambed in your yard may play a major role in feeding U.S. rivers.

Channels that flow only in direct response to weather conditions like heavy rain, called ephemeral streams, contribute an average of 55 percent of the water in regional river systems in the United States, researchers report in the June 28 *Science*.

Last year, the U.S. Supreme Court ruled that some waterways — including these streams — are not federally protected from pollution under the Clean Water Act. Given ephemeral streams' big contribution to the nation's waterways, this decision could have a substantial ripple effect on the environment.

Previous research has shown that ephemeral streams play an important role in transporting sediment, chemicals and other materials to larger bodies of water. For many researchers who read the new study, "it was just a bit astounding how much of the water that we see in the perennially flowing streams and rivers has come from these channels that are typically dry," says Jud Harvey, a hydrologist at the U.S. Geological Survey in Reston, Va.

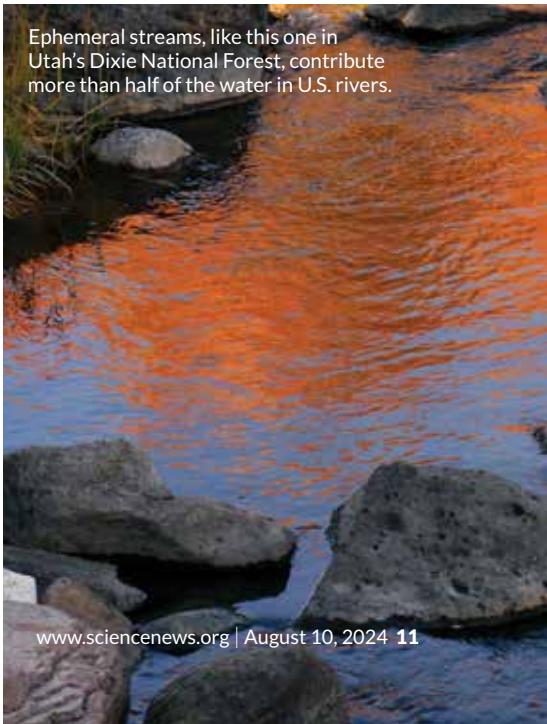
Hydrologist Craig Brinkerhoff of the Yale School of the Environment and colleagues used high-resolution maps of over 20 million U.S. waterways and a groundwater simulation to identify ephemeral streams, which sit above groundwater. The team then used another computer simulation to assess the volume of water coming from these weather-dependent channels. Following the flow of water through streams into regional rivers, "we kept track of those lateral contributions that specifically came from these ephemeral streams," Brinkerhoff says.

Once the contributions were logged, researchers calculated the fraction of the water that originally came from ephemeral streams.

The study is "pushing the envelope" to clarify these understudied channels, but its identification of them may not be entirely precise, says Ken Fritz, an ecologist at the U.S. Environmental Protection Agency in Cincinnati. For instance, the groundwater simulation wasn't meant to measure groundwater level fluctuations, so the researchers might have misidentified some streams as ephemeral, Fritz says.

One third of the U.S. population gets its drinking water from rivers and streams that the Clean Water Act seeks to protect from pollution. The new finding is "likely to have very significant implications on the ability of the United States — at the federal level — to ensure the continued protection of clean water," says Yale economist Matthew Kotchen, who coauthored the study.

Brinkerhoff and colleagues hope the work can guide federal water quality policy. "Not regulating [ephemeral streams] makes no sense if you want to decrease the pollutants in your waterways," says study coauthor Peter Raymond, who is an ecologist at Yale. "You really want to have your policy grounded in science, and it's currently not." ■



Ephemeral streams, like this one in Utah's Dixie National Forest, contribute more than half of the water in U.S. rivers.

NEUROSCIENCE

Psilocybin erases brain 'fingerprints'

Daylong change highlights the complexity of the drug's effects

BY LAURA SANDERS

Inside your skull, your brain hums along with its own unique pattern of activity, a neural fingerprint that's yours and yours alone. A heavy dose of psilocybin temporarily wipes the print clean.

The psychedelic drug psilocybin dramatically changes how collections of nerve cells work in the brain, eliminating normal communication between brain regions, a new brain-scanning study published July 17 in *Nature* shows. These brain images, taken before, during and after a high dose of the drug, expand scientists' understanding of the effects of psilocybin, which is being studied for its promise in treating depression and other mental health issues.

The brain-scanning protocol that the researchers used was intense. "We had a small number of people, just seven participants in the whole study, but an enormous amount of data on each one," says Joshua Siegel, a neuroscientist and psychiatrist at the Washington University School of Medicine in St. Louis. Each person underwent about 18 functional MRI brain scans over the course of the study.

That repeated scanning gives "an unprecedented view on how brain connectivity evolves after a dose of psilocybin," says Alex Kwan, a neuroscientist at Cornell University who wasn't involved in the research.

In the first part of the experiment, Siegel and colleagues recorded each person's baseline brain activity, the unique patterns that emerge (much like a fingerprint's whorls, loops and arches) when a person simply rests.

Psilocybin mushrooms contain a psychedelic compound that holds promise for treating mental health disorders.

Later in the study, the scientists gave healthy participants 25 milligrams of psilocybin, a key ingredient in some hallucinogenic mushrooms, and watched what happened in the scanner. For comparison, each participant also got a dose of methylphenidate — a generic form of the stimulant Ritalin — on a different day.

The effects of psilocybin were obvious, and big. "Psilocybin had humongous acute effects on the human brain," says neuroscientist Nico Dosenbach, also of the Washington University School of Medicine. "Way, way, way bigger than the active control," the methylphenidate.

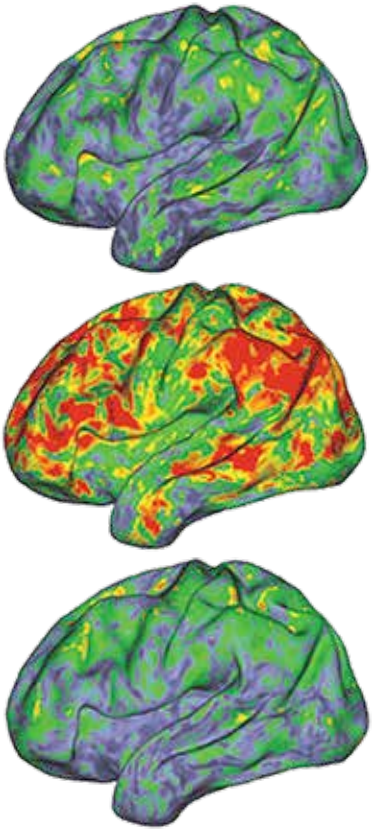
Some of the biggest observed changes occurred in a brain system known as the default mode network, or DMN. This coordinated group of brain regions is active when nothing particular is happening. Scientists think that the DMN has a role in creating our sense of self (SN: 7/18/09, p. 16).

"It's multiple parts of the brain across both hemispheres, but they're all activating and deactivating in a very organized, synchronous way," Siegel says. "And with psilocybin, it essentially becomes chaos."

Dosenbach can attest that the drug causes a loss of sense of self. Along with being a researcher on the study, he was one of the seven study participants, giving him an unusual perspective on psilocybin's effects. "You read about it, and you think about it and then you experience it, and you're like, 'Wow, that's even more real.'"

Signs of those experiences showed up in the MRI scans. The team saw that psilocybin seemed to wipe clean the participants' neural fingerprints. On the drug, people's individual brain patterns became less unique and showed similar signs of disruption. Dosenbach has an analogy to explain the changes: "You'd be like, 'That is my face, and that is your face.' And then you took a medicine, and we both had a puppy face."

A day after taking the drug, most of the psilocybin-induced brain changes were gone, Siegel says. But one change persisted for three weeks. There was diminished coordination between the DMN and a part of the hippocampus, a structure involved in memory.



A resting person's brain activity is steady with small variations (green and yellow, top model). Psilocybin elicits big changes (red, middle) in that pattern, which resolve after a day (bottom).

Researchers don't yet know how long this change might last, how it affects the brain overall or if it could hint at psilocybin's therapeutic effects. The change was not present in data from the four participants who came in for scans six to 12 months later, but the study didn't have enough data to say with certainty that it was gone.

The findings add to previous research on how psychedelic drugs change the brain and show that the effects are far from simple.

"Psilocybin is not simply tuning brain activity up or down," Kwan says. "The results paint a more complex and nuanced picture for how psychedelics change neural activity dynamics than previously thought."

Recent studies point to the promise of psychedelic drugs as therapies for depression, post-traumatic stress disorder, addiction and more (SN: 12/4/21, p. 20). Understanding how these drugs affect the brain hours, days and months after taking them may lead to better treatments. ■

FROM TOP: SARA MOSER/WASHINGTON UNIV.; YARPHOTO/ISTOCK/GETTY IMAGES PLUS

People who have never had COVID-19 are the exception to the rule. A new study suggests that in these people, a specific gene may spur the immune system to rapidly destroy the virus.

MICROSTOCKHUB/E+/GETTY IMAGES PLUS

HEALTH & MEDICINE

Clues emerge in a COVID-19 mystery

A gene may explain why some people have never gotten sick

BY JONATHAN LAMBERT

Those who've dodged COVID-19 for more than four years may have a newly discovered immune response to thank.

In a study that intentionally infected volunteers with SARS-CoV-2, the coronavirus that causes COVID-19, participants with elevated activity of a little-studied immunity gene didn't get a sustained infection after exposure to the virus, researchers report in the July 4 *Nature*. The study offers a detailed look at how the immune system responds to the coronavirus, and how variation in that response could explain why some people get sick while others don't.

The results stem from a challenge trial: In 2021, U.K. scientists exposed 36 young, healthy, unvaccinated volunteers who'd never gotten COVID-19 to the virus via the nose. While the initial goal was to establish how much virus it takes to kickstart an infection, 16 people had more extensive testing. Researchers tracked immunological players in the blood and lining of the nose before and after exposure, allowing a detailed view of when and where different players spur into action.

But only six of the 16 participants got sick. "Initially, we were very bummed, like, we're wasting all these experiments on people that we didn't actually infect," says biologist Rik Lindeboom of the Netherlands Cancer Institute in Amsterdam. But later, he and colleagues realized they'd stumbled across a unique opportunity to understand how some people who got an infectious dose of the virus managed to fend it off.

It's unclear how many people have avoided COVID-19. The most recent estimate from the U.S. Centers for Disease Control and Prevention suggests that by the end of 2023, nearly 13 percent of Americans hadn't acquired the virus.

Challenge trials are controversial, as some experts question the ethics of deliberately infecting people with a pathogen. But the data are incredibly valuable, says immunogeneticist Jill Hollenbach of the University of California, San Francisco. "It's so rare that we get to see a snapshot of what's actually happening in early infection," Hollenbach says, as challenge trials track people from the moment they encounter the pathogen.

> "We may be able to predict who is susceptible to infection just by looking at their gene signature for this particular gene."
>
> **AKIKO IWASAKI**

Of the participants who didn't get sick in the 2021 trial, seven people never tested positive for the virus while three got infections in their nose that their bodies quickly shut down. In the former group, the team detected widespread but subtle changes in immune cells called monocytes and MAIT cells. The transiently infected people mounted an interferon response in their noses within a day. Interferons help attract cells that fight the infection.

By contrast, people who got sick took an average of five days to marshal the same interferon response, which gave the virus time to spread beyond the nose. The discrepancy suggests that swift activity at the site of infection may help prevent the virus from getting a foothold, Lindeboom says.

Among those who didn't develop symptoms, Lindeboom isn't sure why some got briefly infected and others didn't. But before exposure, both groups exhibited elevated activity of the gene *HLA-DQA2* in specialized cells that help alert the immune system to pathogens. While it's unclear what this gene does, it has previously been linked to milder COVID-19 outcomes.

"We may be able to predict who is susceptible to infection just by looking at their gene signature for this particular gene," says immunologist Akiko Iwasaki of Yale University, who wasn't involved in the work.

A lot has changed since the 2021 trial. Virtually everyone has some immunity to the coronavirus from vaccination or infection, meaning most people's immune responses would probably differ from those traced in the study, Iwasaki says. A larger, more diverse study population also could show varied responses.

"For whatever reason, folks who have this different constellation of immune cells present in the [nose] prior to infection may be able to mount an immune response more quickly," Hollenbach says. "It's a lucky break."

In a sense, the study was also a lucky break for scientists. Subsequent trials have struggled to infect volunteers, given so many people now have some immunity to the coronavirus. "That's what makes this study so unique," Lindeboom says. "We'll hopefully never be in the position to do this kind of study for SARS-CoV-2 again." ■

ARCHAEOLOGY

Population boom didn't doom Rapa Nui

Scientists dispute the idea that early islanders caused an 'ecocide'

BY BRUCE BOWER

Early settlers of Rapa Nui are famous for having created massive stone statues on the island. They have also gotten a bad rap as instigators of a population boom that led to ecological and social disaster.

A new analysis of the island's landscape suggests Polynesian seafarers who reached Rapa Nui, once known as Easter Island, around 800 years ago maintained a modest farming system and a small but stable population of no more than about 3,900 individuals until Europeans showed up in 1722, researchers report in the June 21 *Science Advances*.

The finding challenges a popular idea that Rapa Nui communities grew so large that they exhausted available resources, devastating the island society by the time Europeans arrived in what's been called an ecocide event, say archaeologist Dylan Davis of Columbia University and colleagues. The new population estimate is in line with accounts written by early European visitors, who suggested that about 3,000 people lived on the island.

But other researchers contend that the investigation relies on data that are too limited to draw conclusions about how many people agricultural activities could have supported. It has been difficult to estimate how many early settlers inhabited Rapa Nui because knowledge remains limited about different farming practices on the island and the range of crops that were cultivated.

Previous studies used various climate and soil measures to address that agricultural mystery. Researchers know crops were grown in rock gardens, where the rocks enriched volcanic soil, protected cultivated sweet potatoes from wind, prevented evaporation of rainwater and minimized weed growth. But the total number of rock gardens and all of their locations have yet to be determined.

One investigation estimated that before Europeans arrived, rock gardens covered 2.5 to 12.7 percent of Rapa Nui's roughly 164-square-kilometer surface. A second study suggested that about 19 percent of the island was suitable for growing crops, and precontact populations could have ranged from about 3,500 to 17,500 or more.

In 2019 and 2023, Davis and colleagues conducted ground surveys on Rapa Nui to identify chemical and geologic features that characterized rock gardens and other parts of the landscape. Using that data, the team trained three machine learning models to find rock gardens across the island in satellite images that had detailed information about vegetation and soil composition. Those images portray different infrared wavelengths that can detect signature features of rock gardens, such as spots on the landscape with higher moisture and nitrogen levels. The best-performing model correctly identified rock gardens that had already been recorded in ground surveys about 83 percent of the time.

The analysis revealed that rock gardens covered less than 0.76 square kilometers, or less than one-half of a percent of Rapa Nui. A rough calculation of the nutritional value of sweet potatoes grown in rock gardens, supplemented with seafood and less nutritious crops such as bananas, indicates a maximum population of 3,901 individuals, Davis estimates.

"Rock gardening made Rapa Nui soils productive enough to grow sweet potatoes, but we don't find that this cultivation technique was sufficient to support large numbers of people," says coauthor Carl Lipo, an archaeologist at Binghamton University in New York.

But the team underestimates how much of Rapa Nui was covered by rock gardens, and thus how many people could have lived there in precontact times, says archaeologist Christopher Stevenson of Virginia Commonwealth University in Richmond. The training data did not include rock gardens in upland parts of the island, he contends. For instance, rock gardens dot the midslopes of Rapa Nui's largest volcano, "but according to the new paper, there are no rock gardens there," Stevenson says. Thus, the model probably underestimated the true number of rock gardens.

The paper also does not account for other cultivation practices or whether the rock gardens were used simultaneously or at different times, say archaeologists Sarah Sherwood of the University of the South in Sewanee, Tenn., and Jo Anne Van Tilburg of UCLA. Davis' team cannot exclude the possibility that "rock gardens were sparsely used or unsuccessful adaptations that inadequately fed a fast-growing population," the pair wrote in an email to *Science News*.

All of the researchers agree that advanced satellite imagery and continued study of cultivation areas on Rapa Nui will bring precontact human numbers into better focus. ■

Rapa Nui's famous stone statues watched over a population that grew sweet potatoes on a modest scale and peaked at about 3,900 individuals, a new study suggests. That's too few people to have triggered a previously hypothesized ecological disaster, researchers contend.

CHAKARIN WATTANAMONGKOL/MOMENT/GETTY IMAGES

EARTH

Quake rerouted Ganges River

A similar event today could threaten 170 million people

BY SID PERKINS

The Ganges River in India and Bangladesh shifted abruptly around 2,500 years ago due to a distant yet massive earthquake, new geologic evidence suggests.

This ancient shift occurred in the Ganges Delta, about 200 kilometers from where the river empties into the Bay of Bengal. Quake-driven shifts of other rivers have been observed in more recent times, but only farther upstream. If such shifts were to occur in river deltas today, the resulting flooding could threaten hundreds of millions of people worldwide who live in cities built on these low-lying areas.

As rivers chew their way across the landscape, they naturally wander. Course changes can unfold gradually over years to centuries, says geophysicist Elizabeth Chamberlain of Wageningen University & Research in the Netherlands. Earthquake-triggered jumps can occur in days or weeks.

Old waterways can fill with sediment over time, but evidence of their existence typically remains, Chamberlain says. While looking at satellite images of the Ganges Delta, she and colleagues spotted a crescent-shaped depression about 45 kilometers from the river's current location. It measured up to nearly 2 kilometers wide and stretched for dozens of kilometers. At one time, the dip had probably been a main channel of the Ganges, the team thought.

While doing fieldwork nearby in 2018, the researchers decided to check out the depression and take samples. Then, good luck struck. On the drive home, they spotted a pit that someone was about to fill with water to make a pond. One flank displayed seismites, vertical bands of light-colored sand within horizontal layers of mud. These features are remnants of ancient sand volcanoes, which formed when seismic waves from distant earthquakes pressurized subterranean layers of watery sand, forcing the slurry upward through layers of silty mud.

Sometimes called sand blows, seismites are difficult to explain but for an earthquake, says sedimentologist John Shaw of the University of Arkansas in Fayetteville. "They just don't happen for no reason."

Based on the width of the sand blows, the depth of the overlying sediments and the distance to the nearest major fault zone, the quake that formed the seismites was probably magnitude 7 or 8, Chamberlain's team reports June 17 in *Nature Communications*. Analyses of sand grains in the seismites suggest that the temblor occurred about 2,500 years ago. Because the lowest, oldest mud layer in the channel was deposited at the same time the seismites formed, the team linked the quake to the change in the river's path.

If a similar shift happened now in this low-lying area, the resulting floods could threaten up to 170 million people, Chamberlain says. And much of the infrastructure is exceptionally vulnerable to quakes because it is built on mounds of dredged river sediments.

The risk adds to threats of flooded deltas that come with rising sea levels due to climate change. It's a big concern, Shaw says. "How do you anticipate and prepare for events that you haven't experienced?" ■

P.B. HAVELKOVÁ *ET AL/SCIENTIFIC REPORTS* 2024, DRAWING BY JOLANA MALÁTKOVÁ

ANTHROPOLOGY

Egyptian scribes worked to the bone

The lifework of ancient Egyptian scribes is written on their bones. Years spent hunched over papyrus scrolls and making hieroglyphs left skeletal wear and tear from head to toe, researchers report June 27 in *Scientific Reports*.

Scientists from the Czech Republic examined the remains of 69 men entombed in the necropolis at Abusir, Egypt, dating from 2700 to 2180 B.C. Titles, paintings, tools and statues in the tombs denoted 30 of the skeletons as scribes, high-ranking people who could read and write.

The job wasn't physically demanding, but over time, it took its toll on select body parts (red areas in the illustration above). Arthritis in the right thumb probably resulted from pinching pens, while damage to the right shoulder resulted from creating hieroglyphs, the researchers say. Sitting cross-legged or kneeling, usually on the left leg with the right leg squatting, made the right knee and right ankle arthritic. Pitting, ridges or spurs on the bony point at the bottom of the pelvis indicate that the scribes often rested on the left hip.

Bone spurs and other damage to the upper spine probably came from bending over scrolls. Chewing on brushes and thrusting the head forward caused arthritis of the jaw. At 64 percent, the rate of jaw arthritis in scribes was more than double the rate in ancient non-scribes and modern people.

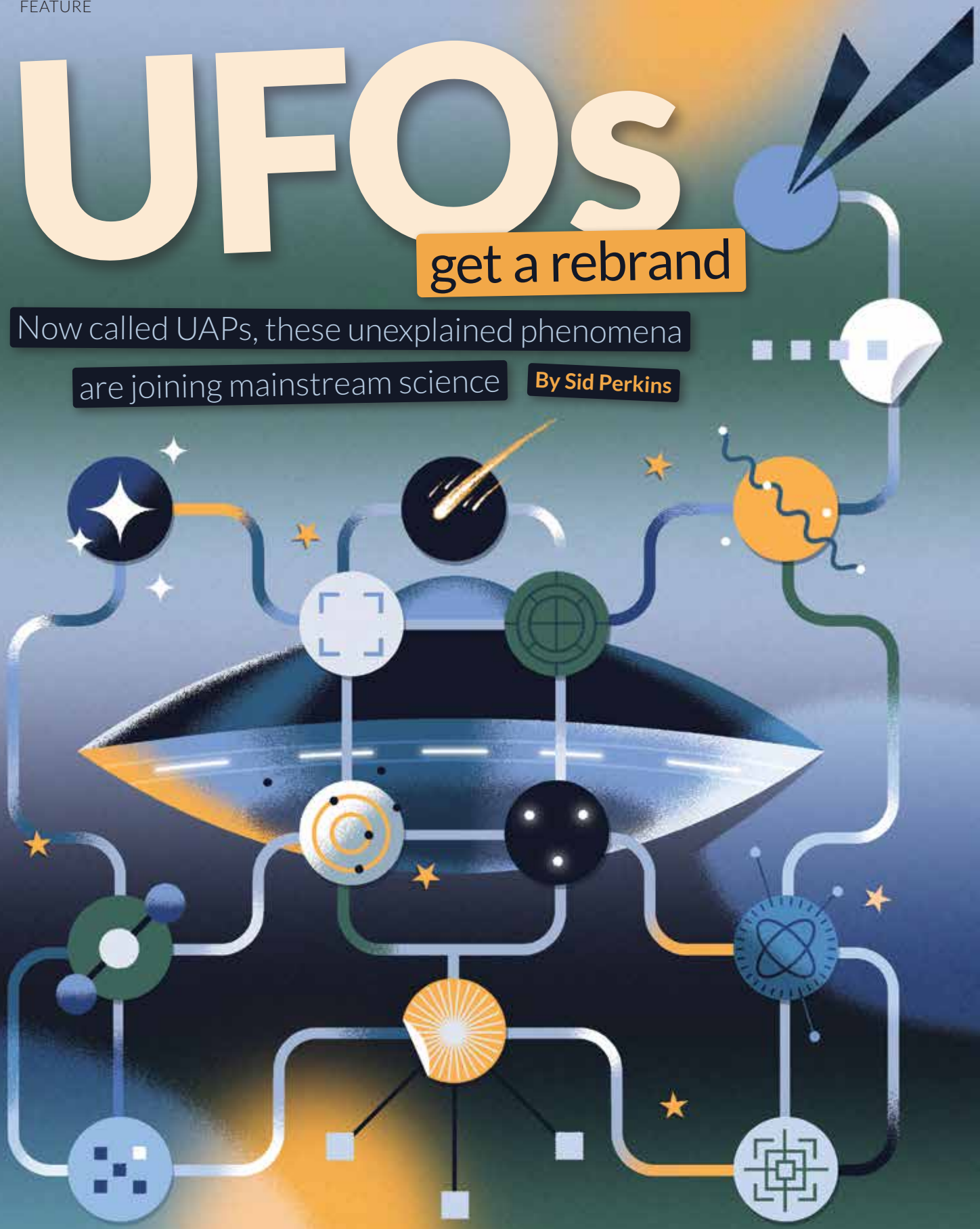
People today might take heed of the ancient Egyptian scribes' neck and jaw issues to sit a bit straighter and look up from their phones once in a while.

— Tina Hesman Saey

UFOs get a rebrand

Now called UAPs, these unexplained phenomena are joining mainstream science

By Sid Perkins



For millennia, humans have seen inexplicable things in the sky. Some have been beautiful, some have been terrifying, and some — like auroras and solar eclipses before they were understood scientifically — have been both. Today's aircraft, balloons, drones, satellites and more only increase the chances of spotting something confounding overhead.

In the United States, unidentified flying objects, or UFOs, came into the national spotlight in the late 1940s and early '50s. A series of incidents, including a supposedly crashed alien spaceship near Roswell, N.M., generated something of an American obsession. The Roswell UFO turned out to be part of a classified program, the remnants of a balloon monitoring the atmosphere for signs of clandestine Russian nuclear tests. But it and other reported sightings prompted the U.S. government to launch various projects and panels to investigate such claims, as *Science News* reported in 1966 (SN: 10/22/66, *p.* 331), as well as kicking off hobby groups and conspiracy theories.

In the decades since, UFOs have often come to be dismissed by scientists as the province of wackos and thus unworthy of study. The term UFO has a smirk factor to it, says Iain Boyd, an aerospace engineer at the University of Colorado Boulder and director of the school's Center for National Security Initiatives.

But government agencies and officials are trying to change that attitude. Among the biggest concerns is that the stigma associated with reporting a sighting has the side effect of stifling reports from pilots or citizens who might have valuable information about potential threats in U.S. air space — such as the Chinese spy balloon that traversed North America and made headlines last year.

"If there's something interfering with flights, people or cargo, that's a problem," Boyd says.

To help reduce the stigma, many serious investigators now refer to UFOs as "unidentified anomalous phenomena," or UAPs, coined by the U.S. Department of Defense in 2022. "The term UAP brings science to the issue," Boyd says. It also rightly broadens the view to include natural atmospheric phenomena as well as things outside the atmosphere, such as satellites and particularly bright planets such as Venus.

Investigators of all types have a lot of questions about UAPs that they believe deserve serious scientific scrutiny: Which UAPs are something real and which are merely artifacts of the sensors that detect them? If real, which may be a threat to aviation? A threat to national security? Do they point to some unknown natural phenomena?

Answers may be forthcoming. In June 2022, NASA announced an independent study to determine how the agency could lend its scientific expertise to the study of UAPs. Meanwhile, military and commercial pilots have felt more comfortable making reports and even providing videos taken during close encounters. Some of those reports were discussed as part of congressional hearings in 2022 and 2023, which were covered widely by the media and in part focused on more government transparency (SN: 7/2/22, *p.* 13). Those were the first open hearings since the mid-1960s.

Americans for Safe Aerospace, an advocacy organization with a focus on UAPs, supports legislation that would help provide a way for pilots to confidentially report potential sightings to the government.

And government agencies increasingly recognize publicly that strange phenomena in the skies are worthy of attention — whether the phenomena are signs of aliens or not. In 2022, the Pentagon established the All-domain Anomaly Resolution Office to serve as a clearinghouse for government reports of UAPs and for analysts determining if UAPs pose threats. The National UFO Reporting Center, a nonprofit established in 1974, and other organizations continue to collate reports from the public.

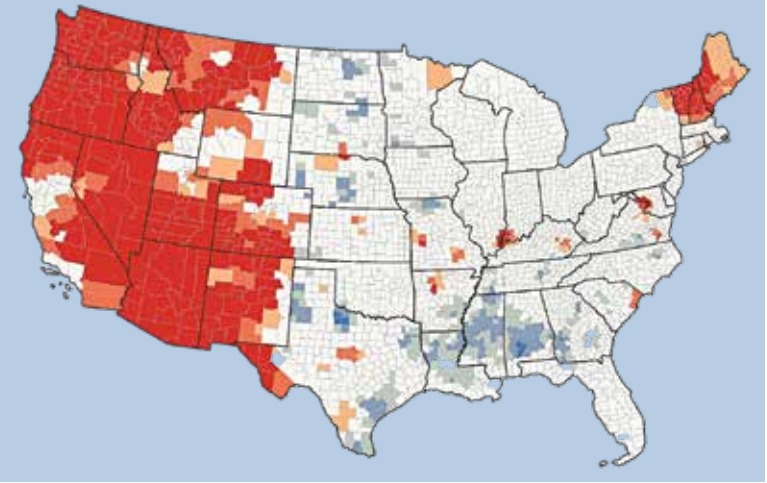
By bringing UAPs into the realm of science, the hope is to make the unexplained explainable.

Where to look

Since its founding, the National UFO Reporting Center has kept a database of UAP sightings, including past and recent incidents reported through

In their sights An analysis of nearly 99,000 reported UAP sightings pinpointed U.S. counties with a particularly high number of reports per 10,000 people (reddish counties), a low number of reports (blues) and an average number (white). One factor that appears to boost the number of UAP sightings is proximity to an airport or military installation, a hint that aircraft may account for many UAPs.

UAP sighting hot spots and cold spots by county, 2001–2020



R.M. MEDINA, S.C. BREWER AND S.M. KIRKPATRICK/*SCIENTIFIC REPORTS* 2023 (CC BY 4.0)

Illustration by ***Matt Chinworth***

its telephone hotline, the mail and online. The database includes almost 123,000 sightings in the United States from June 1930 through June 2022. It's a trove of data that few if any peer-reviewed scientific studies have used, says Richard Medina, a geographer at the University of Utah in Salt Lake City.

For a study reported in 2023, Medina and colleagues scoured the database to see if they could identify which factors, if any, might affect the number of sightings in a particular area. They focused on the almost 99,000 reports, or about 80 percent of the total, that came from the continental United States from 2001 through 2020. They stuck to the continental United States because tree cover was a factor they were studying, and detailed maps of forested land aren't available for Alaska's interior.

First, the researchers calculated the number of UAP sightings that occurred in each county in the Lower 48 states for the 20-year period. Then, they tried to correlate the number of sightings per 10,000 people that lived in each county with environmental factors.

As expected, UAP sightings weren't as frequent in counties with a lot of tree cover and large amounts of nighttime light pollution, the researchers reported in *Scientific Reports*. Average cloud cover didn't seem to affect the number of sightings one way or another—but maybe that's because the team looked at average cloud cover over the course of the year, not the amount of cloud cover at the time of the sighting, Medina suggests.

What did boost the number of sightings substantially was proximity to airports or military installations. Although this analysis doesn't specifically say that many UAPs in such areas can be attributed to aircraft associated with those facilities, the data are suggestive, Medina notes. At such sites, aircraft are likely to be closer to the ground and more visible than at other places, he adds.

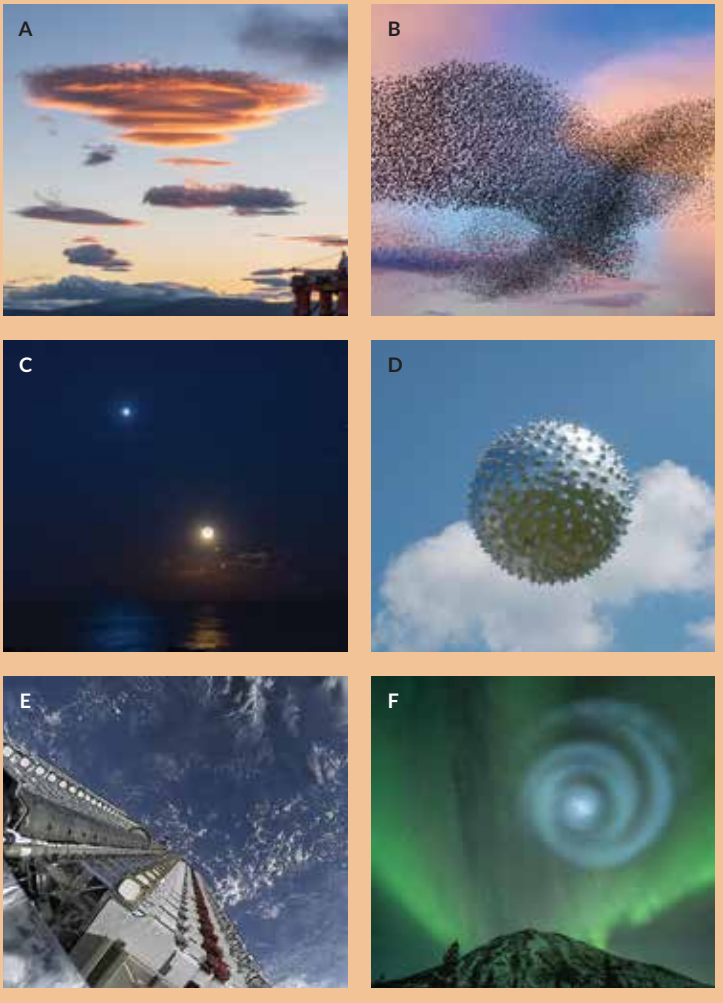
And many of those aircraft could have been classified or experimental craft, according to a report issued earlier this year by the All-domain Anomaly Resolution Office. After undertaking an analysis of reports made to or by the government since 1945, that office found that many sightings could be attributed to never-before-seen craft such as rockets, drones or aircraft incorporating stealth technologies. The analysis found no evidence that any UAPs were signs of extraterrestrials and no evidence that the U.S. government ever had access to alien technology. A second report, with new analyses focused on more recent sightings, will be released later this year.

Solving mysteries

The task of pinning down the sources of UAPs has become easier thanks to the ever-growing analytical prowess of computers and advanced visualization tools. "What used to take months of analysis before can now be done in just a few minutes," says Mick West, a retired software engineer in Sacramento, Calif., who runs the website Metabunk.org, where people can post and discuss UAPs and other unusual phenomena.

Explained anomalous phenomena

Although many UAPs remain puzzling, experts have identified some common sources. Saucer-shaped lenticular clouds (A), birds in flight (B), thermal fluctuations in the atmosphere and other natural phenomena explain some sightings, as do celestial objects like Venus (C). And while no alien technology has been linked to UAPs, human tech has, including weather balloons (D), satellites (E), drones, airborne trash and military aircraft. Last year, a particularly spooky spiral (F) in the sky over northwestern Canada turned out to be vapor from unspent fuel released from a SpaceX rocket.



CLOCKWISE FROM TOP LEFT: FIONA MCALLISTER PHOTOGRAPHY/GETTY IMAGES; DIANA ROBINSON PHOTOGRAPHY/GETTY IMAGES; NASA; TODD SALAT; SPACEX; NORIAKIMASUMOTO/GETTY IMAGES

Take, for instance, an enigmatic sighting of lights in the sky over the Great Plains one night early in 2023. Video of the UAP taken by a commercial pilot in flight caused a stir when it was posted online soon after the sighting, West says.

Whoever posted the video didn't include specifics about the sighting, other than to say it was taken somewhere over the central United States on a particular date. A pattern of lights on the ground, which turned out to be warning lights atop turbines in a large wind farm, helped investigators on Metabunk locate the plane as somewhere in western Oklahoma. Certain details about the sighting, such as flashes of lightning on the distant horizon, wouldn't have occurred on the supposed date of the video, West notes. Using public meteorological databases about the times, dates and locations where lightning strikes occur, the Metabunk crew figured out the video actually had been taken a few days earlier than reported. The date, in turn, helped the group figure out which flight the video was taken from.

Then, knowing the date, time and precise coordinates, West and collaborators used computer simulations to re-create what the sky would have looked like in the direction where the UAP was seen. The mystery lights were actually a cluster of Starlink satellites reflecting sunlight from below the horizon as they swooped across the sky. With the first batch launched in 2019, Starlink satellites now circle Earth in the thousands, providing internet service for locales worldwide (SN: 3/28/20, p. 24). Their movements and patterns in the sky "are still a mystery to some pilots," West says.

West suggests that people are often too quick to jump from "I saw some lights in the sky" to "Aliens!" With so many possibilities for what UAPs might be — optical illusions, meteorological phenomena and aviation-related sightings, plus more — the experience generally turns out to be more mundane than observers imagine, West says.

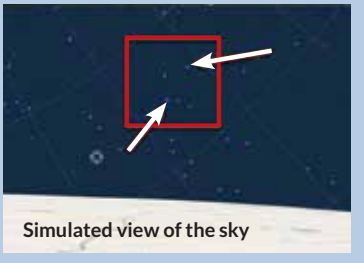
"We're not really looking for aliens," he explains. "We're looking to explain what people are seeing."

Missing data

Good data are key to deciphering UAPs, but they're often in short supply. Although many reports by pilots include images taken by onboard sensors or with handheld video cameras, those instruments often aren't sophisticated enough to capture the necessary details. The same is true for sightings reported from the ground, where the specifics of a presumed object's direction and speed as well as general environmental conditions are often lacking.

Not an alien

In 2023, a commercial airline pilot took a video of a UAP (white arrows, bottom left), which was posted to the website Metabunk.org. Using the pattern of lights on the ground, Metabunk sleuths determined the UAP was filmed above Oklahoma. Further investigation revealed the date of the flight and flight path (yellow line, right). Computer simulations of the sky helped pinpoint Starlink internet satellites as the source of the mystery lights.



MICK WEST

By contrast, NASA has a wealth of data from satellites that monitor Earth. Though they don't have the resolution to spot relatively small objects the size of most UAPs, the satellites are poised to play a supporting role, says astrophysicist Thomas Zurbuchen. Now at ETH Zurich, he's a former associate administrator of NASA's Science Mission Directorate. NASA satellites could be key in providing details on any environmental conditions that may coincide with UAPs, according to the NASA team's report, released in September 2023. Data collected by commercial satellites can play a similar role.

Gathering and analyzing data is a good way to address what UAPs are, Zurbuchen says. "We should be excited about things we don't understand, whether they're natural phenomena, balloons or other things," he says. "We currently don't understand what's flying in our airspace, not to the level that's needed."

Boyd also emphasizes the need for better data. The sensors typically used on planes today "weren't designed to detect UAPs, and the signals that we do pick up are sometimes hard to interpret," he says. Yet getting the right data may prove challenging and expensive. Integrating new types of sensors into the

already-complicated electronic systems of military and commercial aircraft would be something of a "needle-in-a-haystack type of endeavor," Boyd says. "There are more than 100,000 flights per day; how many have actually seen anything?"

Perhaps ground-based instruments are the way to go. Several research teams are developing suites of instruments that can observe a broad range of characteristics and be deployed to sites where UAPs are frequently seen. Some of these packages could be ready to deploy late this year.

"We're not really looking for aliens. We're looking to explain what people are seeing."

MICK WEST

Wes Watters, a planetary scientist at Wellesley College in Massachusetts, is on one team now developing such instrument packages. The observatories are intended to "determine whether there are measurable phenomena in or near Earth's atmosphere that can be confidently classified as scientific anomalies," he and colleagues proposed in the March 2023 *Journal of Astronomical Instrumentation*. Or, in simpler terms, "to figure out what's normal versus what's not normal," he explains.

Designing such observatories is complicated by the fact that not all UAPs are the same. But previous fieldwork, as well as the observations made by people during UAP sightings, is a rich source of information about what measurements could be useful, Watters says. Besides sensors for detecting and characterizing a UAP itself, instrument packages will collect weather data, which could help researchers interpret the other measurements.

Watters and colleagues are developing three styles of instrument packages as part of the Galileo Project. Led by Harvard University astronomer Avi Loeb, the project seeks to bring the search for signs of extraterrestrial technologies into mainstream scientific research. The most elaborate instrument package will sport arrays of wide-field cameras for targeting aerial objects and triangulating their positions; narrow-field cameras for tracking objects across the sky; radio antennas and receivers; microphones that can detect sound across a wide range of wavelengths; and computers that can integrate, process and analyze data. These weather-resistant systems will function autonomously 24/7 and be deployed at sites with electrical power and internet connectivity.

An independent team of experts (shown meeting in 2023) suggested NASA help fill in gaps in collecting UAP data.

JOEL KOWSKY/NASA

These observatories will likely cost around $250,000 each and be deployed to at least three sites for up to five years.

A second, more portable option will be designed for rapid deployment for up to two weeks to sites that don't have access to electrical power or internet. Each costing about $25,000, these simpler packages will be monitored daily, with data recorded and then processed later and elsewhere. The instruments won't necessarily be weatherized, restricting their operation to mild-weather locales.

The third, simplest and least expensive package will host low-end, consumer-grade sensors and instruments, Watters says. They'll be easy to maintain, monitor the sky within a radius of five kilometers and operate continuously for up to a year, relying on solar and battery power if need be. Groups of these packages can be networked together to cover a broad region. Each package will probably cost about $2,500.

With these sorts of instrument packages — and open minds, Watters suggests — researchers are bound to make new discoveries. "It's impossible to make sense of these phenomena until we collect the right kinds of data," he says.

In their 2023 report, Watters and colleagues noted that though several teams are developing or using instrument packages, none have yet reported detection of UAPs in peer-reviewed papers. The Galileo Project, including Watters' team's research, is funded by private donations, including a recently received $575,000 grant to establish and monitor a ground-based observatory somewhere in the Pittsburgh area.

The goal is not to explain away UAPs, Watters says. Instead, he notes, "we're about identifying and characterizing what they are or might be." ■

Explore more

- Read NASA's UAP report at science.nasa.gov/uap

Sid Perkins is a freelance science writer based in Crossville, Tenn.

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A fungal disease nearly wiped out the Sierra Nevada yellow-legged frog (one shown in Yosemite National Park in 2008). But the species has evolved natural immunity to the disease, and a reintroduction project has returned the frog to ponds and lakes across the High Sierra.

Bouncing BACK

R. KNAPP

A frog's story of surviving a fungal pandemic offers hope for other species

By Martin J. Kernan

Slimy heralds of hope are hopping around Yosemite National Park.

Being a frog hasn't been easy in the High Sierra or in many other places ever since a fungal parasite began exterminating frogs in the United States, Australia and Central America 30 or so years ago. But now some impacted species are beginning to recover with the help of innovative conservation strategies. Sierra Nevada yellow-legged frogs are once again thriving after being driven to the brink of extinction. And biologists are capitalizing on their success by spreading the survivors like seeds across remote wilderness areas of Northern California, where the fungal epidemic arrived by the early 2000s.

Roland Knapp, a biologist at the University of California, Santa Barbara, was there to witness the carnage. "I saw these massive frog die-offs in which over the course of two weeks or so entire frog populations were wiped out before my eyes."

The killer: the chytrid fungus *Batrachochytrium dendrobatidis*, or Bd for short. It can destroy frog skin, choke off the frog's supply of electrolytes and induce a fatal heart attack within a couple weeks.

Probably originating in East Asia, the fungus is thought to have gone global through the pet trade (SN: 6/9/18, p. 7). Conservationists have searched in vain for a silver bullet solution. Antifungal ointment can save individuals, and Bd can be scrubbed from isolated bodies of water. But these Band-Aids have done little to stop the hemorrhaging losses of frog biodiversity around the world.

All told, Bd has been implicated in the population declines of at least 500 amphibian species, including 90 possible extinctions — making it perhaps the most devastating pathogen on record to ever afflict vertebrates, researchers reported in 2019 (SN: 4/27/19, p. 5). And that's on top of habitat loss, pollution and climate change, which also beset amphibians. At last count, about 200 species of frogs have gone extinct since the 1970s.

Like a load-bearing Jenga piece, if frogs go, entire ecosystems may collapse. A world devoid of frogs will leave a gap in the food chain no other class of organisms can fill. Without these insect eaters, swarms of bugs could overrun wild places like Yosemite. In the tropics, more people could get diseases like malaria, spread by mosquitoes (SN: 11/5/22, p. 10). The algae normally eaten by tadpoles could grow out of control. And deprived of frogs as meals, snakes, carnivorous birds and furry predators of all kinds, including the occasional down-on-its-luck bear, could starve.

Like a load-bearing Jenga piece, if frogs go, entire ecosystems may collapse.

But "amphibians are incredibly tough in many ways," says Vance Vredenburg, an ecologist at San Francisco State University who along with Knapp tracked the decline of Sierra Nevada yellow-legged frogs. "If you look at the big, big picture, they've made it through the last four major mass extinctions on Earth as a lineage."

Indeed, some yellow-legged frogs survive Bd, and since 2006, Knapp has been using them to found new colonies. On foot or by helicopter, he ferries frogs to remote mountain lakes and drops off his mottled brown cargo in waters swimming with fungal spores. Ultimately, he hopes the transplants go forth, multiply and return the High Sierra to its natural state — a landscape jumping with frogs.

Knapp and colleagues say these survivors evolved immunity to Bd. Other species in Australia and Central America may be doing the same, though none seem to be rebounding at the rate of the Sierra Nevada frogs. If researchers can identify individuals carrying the genetic mutations driving this adaptation, they may be able to help other struggling frog populations grow.

"We're at a critical point where if we can start linking these candidate resistance genes in frogs with their immune system functions, we could go for bolder conservation actions such as breeding for specific genetic variation we are confident will increase resilience," says Anna Savage of the University of Central Florida in Orlando, who studies how genes influence frogs' immune response to Bd.

Saving frogs is slippery business

The High Sierra was once a Shangri-la for Sierra Nevada yellow-legged frogs (*Rana sierrae*) — perhaps the most abundant vertebrate above 1,800 meters. The

Biologist Roland Knapp and his colleagues capture Sierra Nevada yellow-legged frogs that are naturally resistant to Bd. The ones shown here in 2023 (left) and 2018 (right) are about to be released in Yosemite National Park in areas where the frogs have disappeared.

frogs arrived at this haven sometime within the last 10,000 years, when they climbed the waterfalls that kept out fish and reached crystal pools surrounded by glacier-carved granite peaks. The newcomers adapted to live nine months of the year under thick ice at near-freezing temperatures. In summer, the frogs emerge from the depths to bask on rocky shorelines or hang out in clear shallows to soak up the sun.

The water became more dangerous for the frogs in the late 1800s. Back then, sportsmen were angling to fish in the High Sierra. But there was one problem — no fish. So fish stocking commenced, first by hauling up trout in milk canisters slung over mules and then eventually by airplanes bombing lakes with trout hatchlings.

Knapp set out in the mid-1990s to investigate why the frogs were disappearing. He and Vredenburg collected data revealing that trout have a ravenous appetite for tadpoles and bite-size froglets. The pair convinced the then-named California Department of Fish and Game plus the National Park Service to remove every trout from numerous lakes and ponds in protected areas of the High Sierra. By the late 1990s, frog populations showed signs of recovery. But then Bd fungus crept into the water in the early 2000s, erasing the gains.

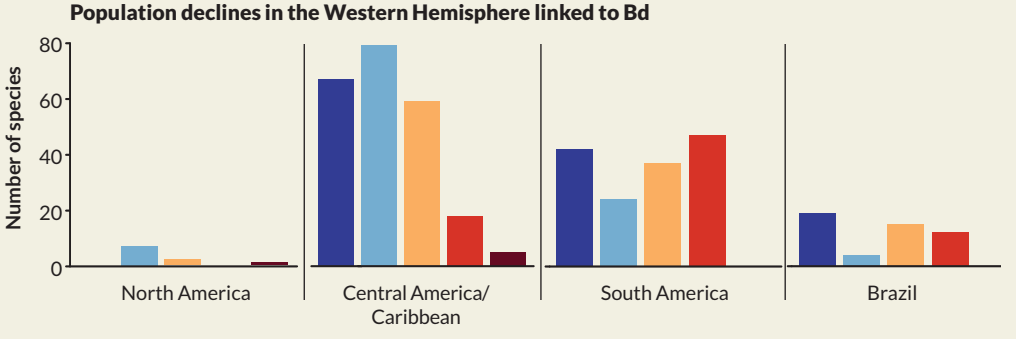
"To have the dark cloud of Bd arrive on the scene and make the situation almost infinitely more complicated … it was nightmarish," Knapp says.

But in the midst of his despair, he noticed something "wildly different." Hardy descendants of frogs that had survived the onslaught of both trout and Bd, he says, were "recovering to a point where the populations had hundreds or even thousands of adult frogs and thousands of tadpoles."

And they were doing it in water suffused with the fungus. "They were clearly able to suppress the infection," he says, "and as a result they were surviving."

Knapp wanted to see if these survivors could live in places where the species had disappeared. From 2006 through 2020, taking 30 or so Bd-immune frogs at a time, he moved them to 12 lakes spread across Yosemite National Park for a total of 24 reintroductions, trekking nearly 15 kilometers in some instances across difficult terrain. A few frogs died in the wet cloth bags he initially used for transport. Switching to plastic containers and using a helicopter to shorten the longest journeys saved lives.

In 2016, he stood on the shore of one of those lakes — names and locations haven't been disclosed



Staggering toll The Bd fungus has contributed to population declines in at least 500 species of frogs and toads. The Western Hemisphere, especially Central and South America, has been hardest hit. The graphs above tally the number of species in each region, with Brazilian species separated out, based on how severely the population has declined. Worldwide, the fungus has been implicated in 90 possible extinctions.

FROM TOP: R. KNAPP; B.C. SCHEELE *ET AL/SCIENCE* 2019

to protect the transplants — and watched a new cohort of hundreds of Sierra Nevada yellow-legged frogs jump into the water. They weren't the big, old frogs he had brought 10 years earlier. They were smaller, younger adults — the progeny of that initial generation.

Knapp knew the experiment had been a success. "That was the first indication that a population had in fact become established. It was head-exploding," he says. Since then, he has had similar successes at other lakes. To be exact, nine new colonies out of the 12 reintroduced populations flourished.

A statistical model based on the ebb and flow of frog density predicts that more than half of transplanted colonies will last for 50 years or more, Knapp and colleagues reported in a paper posted in 2023 to bioRxiv.org.

But even after inspecting over 2,000 potential new habitats, selecting the right one for translocation is still difficult, Knapp says. And the failures stick with him. "It's a super frustrating outcome. I'm basically throwing frog lives away because I lack some bit of understanding that would've told me I was missing something that's constraining the ability of frogs to persist," he says. For instance, finding lakes that don't freeze to the bottom is vital to ensure the frogs have a place to spend the winter. "It's pretty clear to me," he says, "that we need to learn from these naturally recovering populations."

Which frogs have the right genetic stuff?

Of course, the most pressing thing to learn is, how does the Sierra Nevada yellow-legged frog fight off Bd? One possible explanation: Communities of beneficial bacteria that live on the frog's skin outcompete the fungus. Another: Glands in the skin secrete antifungal chemicals, though Bd may be able to suppress this defense.

Erica Bree Rosenblum, a molecular geneticist at the University of California, Berkeley, argues the answer hides in the frog's genetic code. In studying the DNA of Bd survivors, she's found mutations that don't appear in the DNA of Sierra Nevada yellow-legged frogs from areas untouched by the epidemic. These differences in DNA sequence — the order of the chemical letters, or bases, that make up the genetic code — show up in statistical patterns called signatures of selection. It's a sign that a region of the genome has evolved due to some selective pressure, say, a deadly disease.

"The frogs that survive better have certain variations in their genomes," Rosenblum says. "Since they're the ones surviving, they're passing their genes down, and over time the whole population

Hanging out in saunas helps an Australian frog resist Bd

Tiny brick saunas are the latest tool scientists are testing to help frogs survive the chytrid fungus known as Bd.

By spending time in a sun-warmed shelter, green and golden bell frogs (*Litoria aurea*) in Australia warmed up enough to fight off infections, researchers report June 26 in *Nature*.

Bd thrives at relatively cool temperatures and isn't viable above 30° Celsius. Given a choice, bell frogs prefer temperatures around 29°. In winter, when temperatures drop, infection rates spike.

Conservation biologist Anthony Waddle of Macquarie University in Sydney and colleagues set up 12 outdoor habitats. Each oasis included water, artificial plants and shelters made of black masonry bricks inside little greenhouses. Four habitats held only healthy frogs, while the remaining eight contained a mix of healthy frogs and Bd-infected ones.

At around 20° to 25° outside, the bricks provided frogs with up to an additional 15 to 20 degrees of warmth. Access to the saunas helped infected frogs fight off disease. After clearing an infection, they were less susceptible to future bouts of the disease. Frogs that fought off an infection were 23 times as likely to survive reinfection as frogs who had never contracted Bd, the team found.

The froggy spas are relatively inexpensive and easy to build, but not every species will benefit from a balmy hideout, says amphibian biologist Cori Richards-Zawacki of the University of Pittsburgh. Some Bd-affected species that prefer cooler environs might not take to the shelters and could even become more susceptible to the fungus at higher temperatures.

"Chytrid is a huge, massive problem," Waddle says. The study isn't a one-size-fits-all solution, he adds, "but it is a glimmer of hope." — *Skyler Ware*

Warming up in a brick sauna raises the body temperature of green and golden bell frogs in Australia, helping them fight off a Bd infection.

A. WADDLE

is changing towards having these more favorable genetic mutations." It's a classic case of evolution by natural selection.

In the Sierra Nevada yellow-legged frogs, Rosenblum identified eight genes in a region of the genome called the major histocompatibility complex, or MHC, that show up as a signature of selection. MHC genes play important roles in the immune system, and any of the eight genes could be giving frogs an edge against Bd.

One gene stands out as the blueprint for tiny sentries on cell surfaces called glycoproteins, which bind to pathogens and present them to white blood cells for destruction. Another gene instructs the building of interferons. These proteins, active in frog skin, sound alarm bells when they detect an intruder like Bd, mobilizing other immune defenses.

Pinpointing the biological mechanism that's saving frogs' lives would be a leap.

Rosenblum's findings explain why Sierra Nevada yellow-legged frogs are recovering, but not how. At this stage she can't pinpoint the biological mechanism that's saving frogs' lives — that would be a leap.

"My expectation with this situation is that it's a pretty complex trait. There's not going to be a single smoking gun. There's lots of changes in the genomes that are happening," Rosenblum says.

Finding hope for other endangered frogs

Other threatened frogs may be evolving immunity to Bd as well. And the hunt to find resistant individuals continues, especially in *R. sierrae*'s close cousin, the mountain yellow-legged frog (*Rana muscosa*). That species is in a much more precarious situation in Southern California, says Talisin Hammond, a conservation biologist at the San Diego Zoo Wildlife Alliance. Habitat loss culled their ranks, and Bd's arrival compounded their predicament. Now a few holdout populations totaling a couple hundred frogs eke out an existence amid invasive bullfrogs (which carry and transmit Bd), wildfires and perennial droughts. Occasionally, someone finds a doomed school of tadpoles in a dried-out stream bed and rushes it to the San Diego Zoo or other facilities that host *R. muscosa* breeding programs.

At the San Diego Zoo, large tanks beyond public view hold tadpoles that hatch and grow. Breeding occurs there too, with careful attention to degrees of kinship so the species's genetic diversity is maintained. With so few *R. muscosa* frogs left, there's a high risk of inbreeding.

Frogs reared in captivity are trained in simulated habitats to increase their chances of survival in the wild. Confront one with a rubber snake — and cues

In the early 2000s, the Bd fungus began killing off Sierra Nevada yellow-legged frogs, emptying many lakes in the High Sierra. But after a reintroduction project, the frogs are now thriving, and several lakes are once again full of tadpoles (shown) and adult frogs. "It's head-exploding," Roland Knapp says of the project's success.

R. KNAPP

from a live one — and it becomes wary of predators. Add rushing water to the tank from time to time, and mobility improves.

The frogs' immune systems can learn as well, so recently scientists purposely infected frogs with Bd and then bathed them in lifesaving antifungal ointment before release. The exposure in this safe environment is like a vaccine, priming the immune system for a future showdown with Bd. But unlike inborn immunity, the treatment may not last over a frog's lifetime and can't be passed on to offspring.

If researchers can identify the genes driving *R. sierrae*'s comeback, that might allow the San Diego Zoo and others to breed *R. muscosa* frogs with greater immunity to Bd, says Cynthia Steiner, associate director of conservation genetics at the San Diego Zoo Wildlife Alliance. She plans to compare the two species' genomes and hopes "some of these genes — the genetic variants providing populations with more levels of resistance — are also present in our populations," she says.

Meanwhile, frogs at the epicenter of Bd destruction in the misty, moss-covered cloud forests of Panama and Costa Rica are on the verge of mounting their own comeback. There, at least nine of the 40 or more frog species that mostly disappeared more than 20 years ago have begun to reemerge, including the dazzling harlequins (SN: 12/3/22, *p.* 6), which come in an assortment of vibrant colors.

Jamie Voyles, a biologist at the University of Nevada, Reno, investigates their recovery, though she doesn't have the resources to attempt relocations like Knapp's. And besides, the frogs in these forests can be wildly difficult to catch, possibly complicating efforts to transplant survivors. Take the Panama rocket frog. "You have to sit in one spot, be as still as possible, and then lightning quick to catch them by hand or plastic bag once you learn their jumping pattern," Voyles says. Other types are so elusive that catching one is mostly dumb luck.

Like Steiner, Voyles would like to replicate Knapp's success once researchers like Rosenblum uncover the survivors' secrets. "What is it that they had or were doing right to make it through that huge evolutionary selective sweep that wiped out everybody else?" she asks.

In 1998, biologist and veterinarian Lee Berger of the University of Melbourne was among the first scientists to discover the killer fungus. Since then, she has worked tirelessly to protect Bd-ravaged populations in Australia, such as the boldly yellow-and-black southern corroboree frogs. She celebrates Knapp's work as an example of how humans can help frogs along: "We've only just begun figuring out ways to return ecologically important species to the landscape."

Like the frogs of the High Sierra, some species in Central and South America appear to be recovering from the Bd onslaught. Biologist Jamie Voyles has seen a rebound in some harlequin frogs (three harlequin species, shown).

As Knapp continues to transplant frogs, he wants their growing numbers to inspire other frog biologists. "In this world of Bd-caused declines," he says, "it seemed to me really important to put out this positive example of how we can in fact, at least in this one system, and hopefully in many other systems in the future, use these naturally recovering populations to effect broader-scale, more sustainable long-term recovery." ■

Explore more

- Roland A. Knapp *et al.* "Reintroduction of resistant frogs facilitates landscape-scale recovery in the presence of a lethal fungal disease." bioRxiv.org. December 23, 2023.

Martin J. Kernan is a freelance science and history writer based in central New York.

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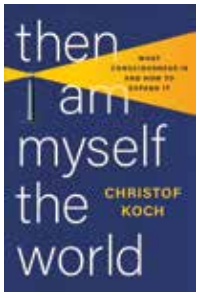

Then I Am Myself the World
Christof Koch
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Where does consciousness come from?

The human brain is the most complex information integrator known in the universe. With 86 billion neurons and 100 trillion connections between them, the brain gives us our rich subjective experiences and our capacity for free will — our consciousness.

Despite being a universal human phenomenon, consciousness is notoriously difficult to describe, and scientists still debate how it arises. In *Then I Am Myself the World*, neuroscientist Christof Koch offers the latest entry into the long list of books attempting to demystify the origins of our inner lives. While the topic can be a head-scratcher, Koch's adept use of analogies and entertaining anecdotes — complete with his own near-death experience and psychedelic drug trips — make the book a compelling and surprisingly light read.

Koch challenges some common conceptions of consciousness. Take the idea that the brain is like a computer, in which consciousness is software that's programmed into the hardware of our neurons. This concept, he writes, dominates the tech industry and movies alike, where humans are akin to self-aware robots like Rachael in the science fiction film *Blade Runner*. Reducing consciousness to a function, in which a person is a "Turing machine made flesh … a robot unaware of its programming," leaves Koch cold.

Instead of separate software and hardware, he argues, the brain is the structure of consciousness. Koch draws on integrated information theory, or IIT, a consciousness model first proposed by neuroscientist Giulio Tononi in the early 2000s, to make the case. The mind-bending theory suggests that consciousness is the act of a brain's system of neurons merging sensory, emotional and cognitive information.

Key to understanding IIT is the idea of "causal power." Because networks of neurons integrate information, their electrochemical activity can influence conscious experiences. And consciousness, in turn, can affect brain networks because what we feel or remember impacts these networks in real time (like how being hungry can influence the brain's mood-processing regions to make us feel "hangry.")

Because IIT suggests consciousness arises from information integration, Koch argues the experience is not limited to the human brain and is present in other animals. But the interconnectivity of neurons determines the strength of the causal power and thus the organism's level of consciousness. "Take my dog. It doesn't have a well-developed notion of self. It doesn't worry what's going to happen next weekend. But it has states of pain and joy," so it's certainly conscious, Koch told me in an interview. As brains become more complex, the amount of integrated information becomes vastly bigger. So humans, whose brain networks have among the highest known level of interconnectivity, have a more expanded consciousness than a dog, he says.

A provocative conclusion here is that any system that integrates information — including a computer — has the potential to be conscious. The very mechanism of integrating information is experience, Koch explains. So you can measure a system's consciousness by measuring the amount of integrated information within it.

Recently, Koch did just that, calculating the consciousness of AI algorithms. The generative AI ChatGPT, he claims, has an "itsy, bitsy, little bit of consciousness," but experiences the world something much less than a worm with only 300 neurons.

As an AI learns more information and performs more complex tasks, it becomes increasingly sophisticated. But it cannot reach or even simulate human-level consciousness, Koch says. Think of it this way: You can simulate a black hole on a computer, but it doesn't mean you're going to be sucked into a real black hole. If you simulate a human brain in an AI system, it won't be conscious — it's a deepfake, he says.

The underlying hardware explains why. A computer's network of transistors, which regulate the flow of electrical signals within the machine, don't have the causal power necessary to give rise to human-level consciousness, Koch says. Each transistor connects to only a handful of other transistors, whereas one neuron can interact with thousands of others.

Though much of the book explores abstract and philosophical aspects of consciousness, Koch asserts that the topic has real-world value. Detecting basic levels of consciousness in comatose people, for one, could help doctors and family members determine the course of treatment.

Ultimately, *Then I Am Myself the World* contends that the subjective experiences that make us conscious are what transform us and the paths of our lives. Our conscious experiences are real and precious, Koch writes, if nothing more than because "we matter to ourselves."

— *Fred Schwaller*

Consciousness may not be a uniquely human experience. Other animals and even computers have the potential to be conscious, neuroscientist Christof Koch argues.

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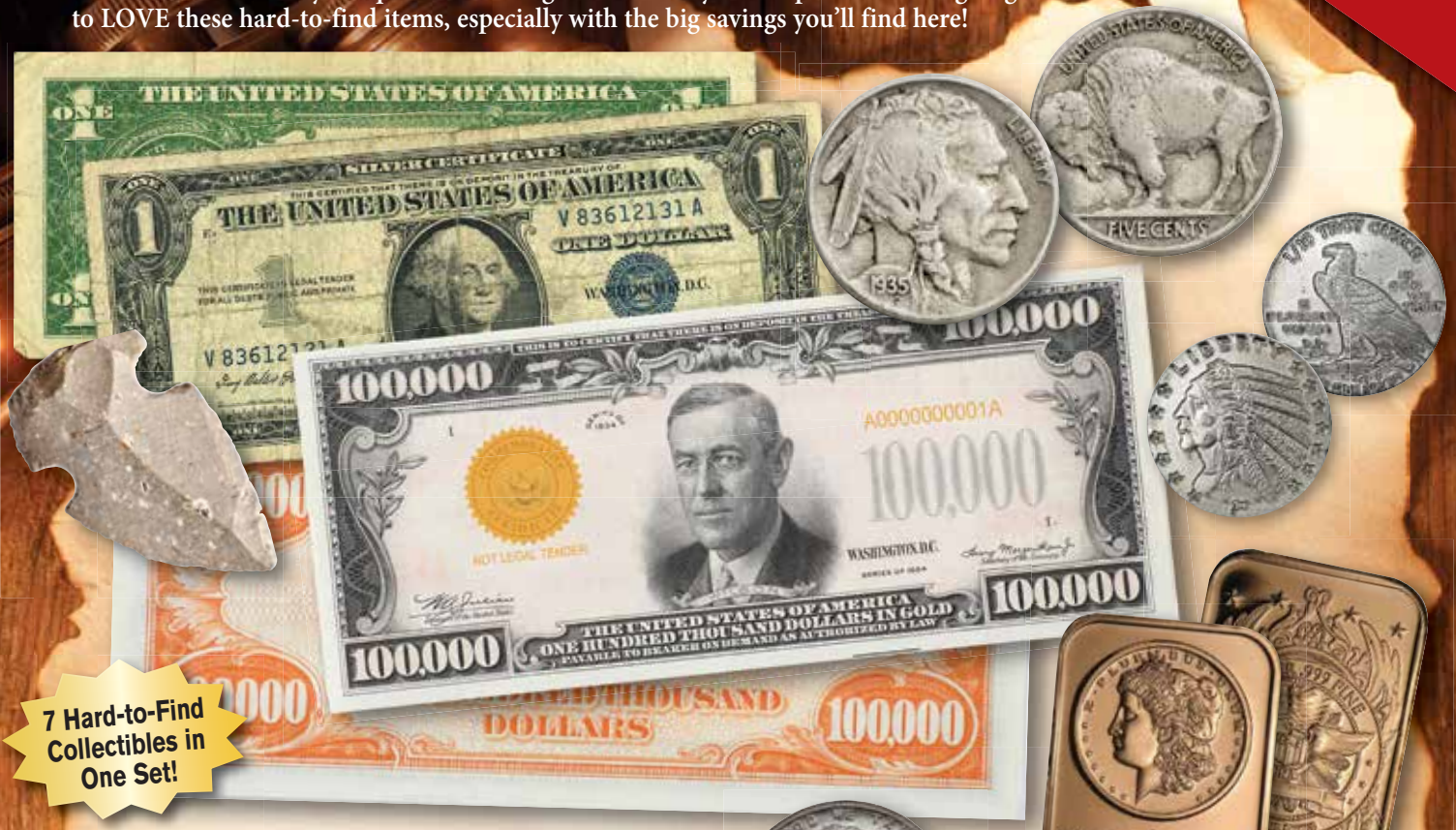

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Each year, the Society for Science relies on the local scientific community to provide volunteers, including interpreters and judges, to ensure the weeklong event is a success. In 2025, Regeneron ISEF will take place in Columbus from May 10 to 16, and we need your help.

The support provided by our volunteers makes a difference. Allan Goldstein (pictured above), a participant of the 1984 ISEF, shared: "ISEF played such an important part in my life during high school."

To volunteer at Regeneron ISEF 2025 in Columbus, Ohio, please visit: www.societyforscience.org/Columbus

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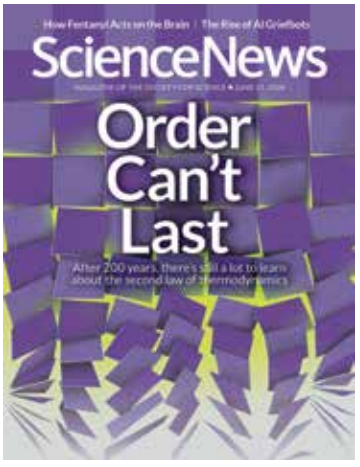

JUNE 15, 2024

A sign of our past?

*Deaf experimental psychologist Rain Bosworth has found that babies have an intrinsic ability to recognize sign language, **Meghan Rosen** reported in "Primed to sign" (SN: 6/15/24, p. 24).*

Reader **Suzanne Lijek** wondered if our innate sensitivity to sign language could stem from its use by ancient humans.

Our ancestors probably communicated through both gestures and speech, says cognitive neuroscientist **Karen Emmorey** of San Diego State University. This could be why all speakers (signers included) gesture, no matter the language, she says. But exactly how language emerged is still a question. Some scientists think spoken language evolved from vocal communications like grunts and alarm calls. Others argue that our ancestors learned first to communicate through gestures, laying scaffolding in the brain for spoken language to evolve. But why speech became dominant is unclear. "If gestures were first, then we might all be signers, since sign languages have all the expressive capabilities of spoken languages," **Emmorey** says. Instead, gesture and speech probably evolved together, she suggests.

Full circle

*The shape of our universe might be complex, like a doughnut, **Emily Conover** reported in "The universe may loop back on itself" (SN: 6/15/24, p. 15).*

Reader **Jim Schmitz** asked if this loopiness could let scientists spot distant objects in outer space by simply looking in the opposite direction.

That is one of the original ideas for how to search for cosmic topology, says theoretical physicist **Glenn Starkman** of Case Western Reserve University in Cleveland. "If you can see the same object in two directions on the sky and recognize it, that would be proof that you can see around the universe." Scientists have tried, but it's challenging. The object might appear at different points in its history and from different perspectives, **Starkman** says. He likens it to "seeing a picture of your friend from the back when they were a baby and hoping to recognize them." As searches came up empty, scientists concluded that the universe is too big to see a distant object from two directions.

Correction

"What's the human speed limit?" incorrectly stated that Usain Bolt's top speed during his 2009 record-setting run was nearly 40 kilometers per hour (SN: 7/13/24 & 7/27/24, p. 36). That was actually Bolt's average running speed. His top speed was 44.72 km/h.

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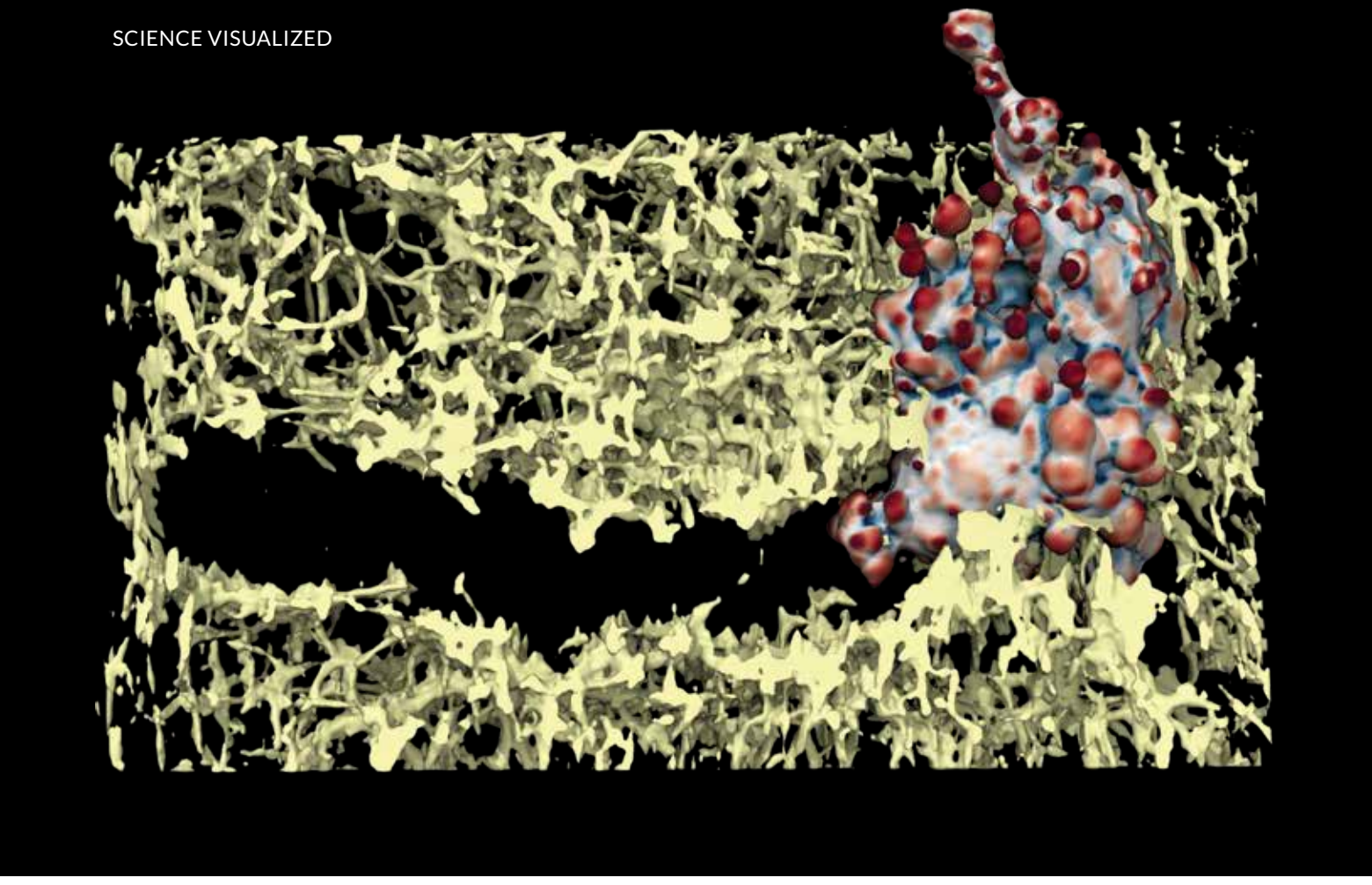

Some cancer cells pack quite a punch

Imagine tiny fists punching their way through your body.

For some cancer patients, this may be a reality. The digital reconstruction above, published June 12 in *Developmental Cell*, shows a melanoma cell using fleshy membrane protrusions (red) to tunnel through tissue (yellow).

Cells have various modes of movement. Some deform their cell bodies to squeeze through tight spaces; others hack their way through with proteins that chemically erode surrounding tissue. Though researchers knew melanoma cells could form bumps that help the cells move, computational cell biologist Gaudenz Danuser and colleagues set out to clarify how these protrusions work.

The protrusions, or blebs, are bubbles that form at cracks in a cell's cytoskeleton. That network of protein filaments, as well as the cell membrane, separate the relatively high-pressure cell interior from lower pressure outside. When a crack forms in the cytoskeleton, the internal pressure pushes the membrane outward, forming a bleb.

By developing a new type of microscope, the team captured how human melanoma cells use blebs to move, says Danuser, of the University of Texas Southwestern Medical Center in Dallas. Most microscopes hold samples in place with hard surfaces, and that additional pressure may alter the cells' behavior. The new microscope allows a soft gel to secure the cells instead.

The researchers saw that the blebs "extend and retract about every 20 seconds," says Meghan Driscoll, a pharmacologist at the University of Minnesota Twin Cities in Minneapolis. "Over hours, the balloons are [mechanically] degrading enough material to create a tunnel that the cell can move through."

Additional measurements revealed increased levels of an enzyme involved in cell signaling near the front of the cancer cells. This led Driscoll, Danuser and colleagues to hypothesize that melanoma is driven forward by a continual cycle of bleb formation and sensing resistance from the tissue ahead.

Blebs can form anywhere on the cell, but only those toward the front will meet a surface (those in back protrude into an empty tunnel). Separate molecular adhesions that act like little feet allow the cell to sense the tunnel surface and signal where the front is, Danuser says. Then the cell will "amplify the formation of the balloons only where you really need the balloon," with larger blebs concentrated toward the direction of travel.

The "mechanically driven type of reinforcement" that keeps the blebs forming at the front of the cell is a "pretty novel aspect of this work," says Jeremy Logue, a cancer biologist at Albany Medical College in New York who was not involved in the research. "I think certainly that hasn't really been appreciated to this level." — *Claire Yuan*

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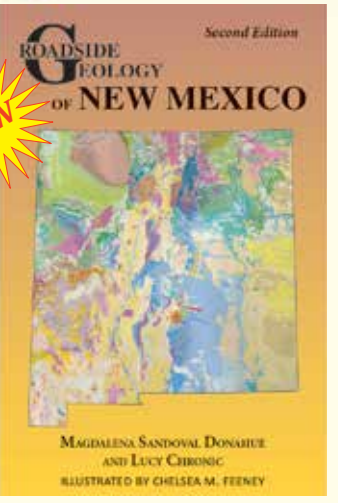

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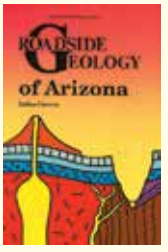

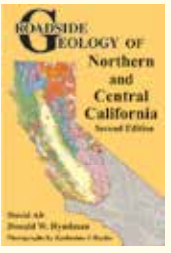

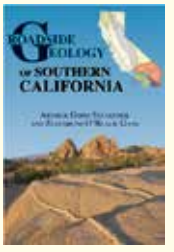

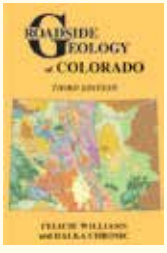

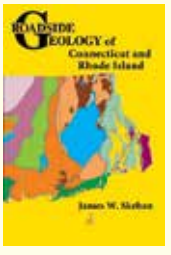

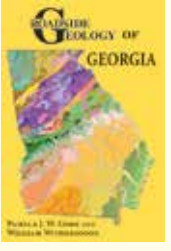

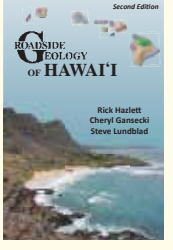

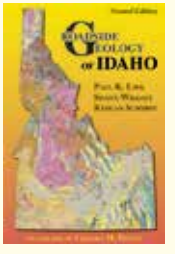

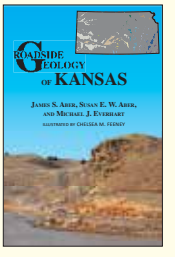

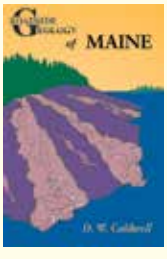

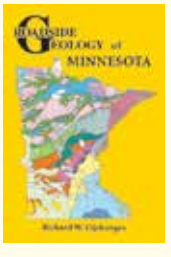

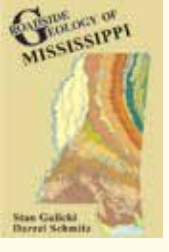

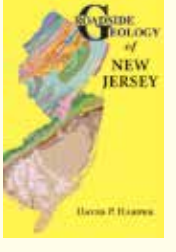

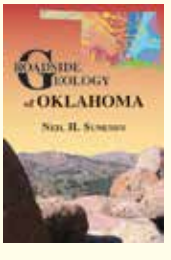

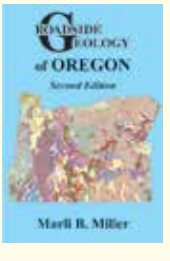

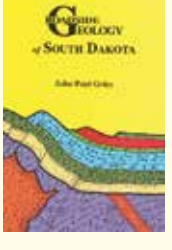

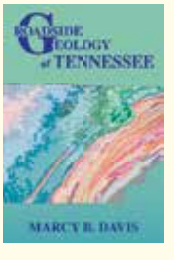

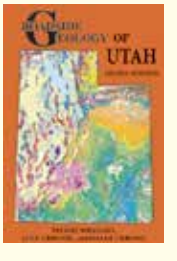

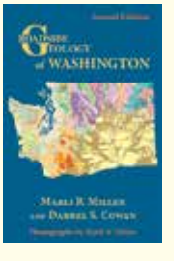

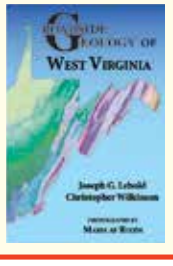

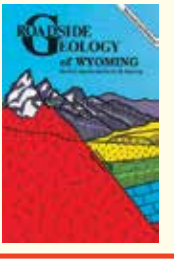

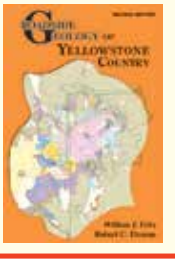

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