Vampire Bats on the Run | Transporting Antimatter

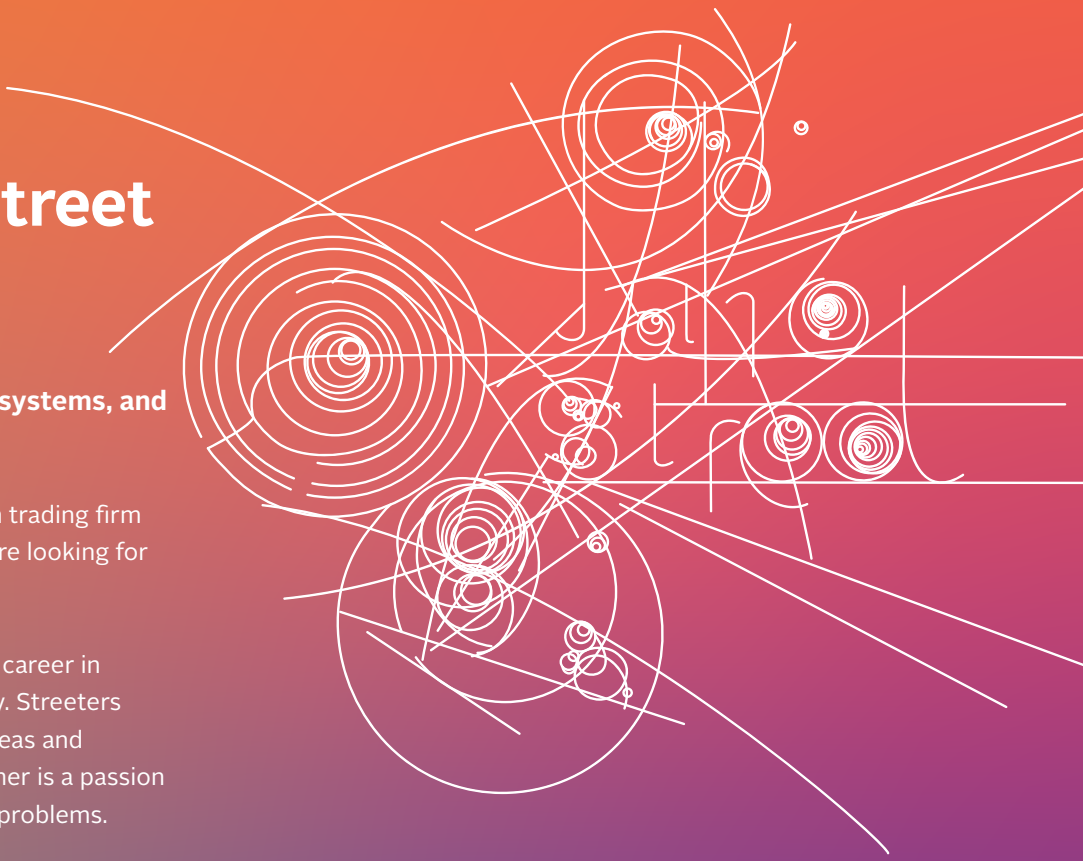
Science News

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ DECEMBER 14, 2024 & DECEMBER 28, 2024

UNBEARABLY HOT

In 2024, record-breaking heat had deadly consequences

Jane Street



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VOL. 206 | NO. 10

ScienceNews

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2024 Year in Review

14 TOP STORIES: Extreme heat waves took a toll on people across the world, popular weight-loss drugs signaled that they may help the body in other ways, and researchers rang the alarm about energy-hungry generative AI.

PLUS: Read about the year's exploits in space, scientific firsts and more.

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COVER Climate change–fueled heat waves killed scores of people and upended daily life this year. *md zakirul mazed konok/Alamy Stock Photo*

FROM TOP: AARON FAVILA/AP PHOTO; JOSEPH S. WILSON; MANU SAN FÉLIX/NATIONAL GEOGRAPHIC PRISTINE SEAS

Looking back on the year in science and what's next

Each year we dedicate the final issue of *Science News* to reviewing the big stories in science, technology and medicine. And each year, I marvel at the many significant news events and research discoveries crammed into a year.

Most significant: The growing tyranny of heat. For the second year in a row, our planet experienced the hottest year on record, a fact that threatened lives worldwide (Page 20). In some places, the heat sparked drought, which lowered city water supplies and fueled wildfires. In other places such as Europe, it brought intense rainfall and disastrous flooding. Higher ocean temperatures bulked up hurricanes, and cases of mosquito-borne diseases soared (Page 26).

The links between extreme heat and climate change are increasingly clear. A surprising new wrinkle this year is the soaring use of generative AI. Chatbots are energy hungry, with a single ChatGPT query slurping up way more energy than a Google search (Page 23). Experts we spoke with are weighing the potential benefits of the technology, from enhanced productivity to improved health care, against the resulting carbon emissions.

And there was much news on medications like Ozempic and Wegovy. Their popularity has soared for diabetes treatment and weight loss, but they may also help treat heart, kidney and liver disease, and maybe even rein in addiction (Page 16). These drugs work by mimicking a gut hormone, and more like them are in the works, potentially leading to a widening range of health benefits. Scientists are keeping an eye out for results from a number of clinical trials, including some testing whether the drugs help combat Alzheimer's disease.

There was a lot going on in space, too, with government agencies and private companies landing multiple craft on the moon. That effort included China's Chang'e 6 mission, which collected the first samples from the far side of the moon. Human space missions had mixed success. SpaceX carried four civilians to the International Space Station and tackled the first all-civilian spacewalk. But Boeing's Starliner craft had less luck. Its two astronauts took off for an eight-day mission in June, but problems with the craft will keep them on the space station until February (Page 28).

And no year-end issue is complete without our favorite books of 2024, a perennial hit (Page 34). This year's faves include *Then I Am Myself the World*, in which a neuroscientist argues that consciousness is all about being able to integrate information — implying that computers might become sentient, too, at least to some degree. Other tomes explore why humans need art; offer a first-person account of what it's like to have face blindness; and investigate why some societies in the eastern Mediterranean and Near East thrived while others descended into chaos at the end of the Late Bronze Age around 1200 B.C.

We also invested time this year in surveying readers and other efforts to enhance your print magazine experience. We're putting the final touches on exciting improvements in our January issue. I can't wait for you to see them and, as always, I welcome your feedback. Write to us at editors@sciencenews.org.

— *Nancy Shute, Editor in Chief*

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SOCIETY FOR SCIENCE

We've Found the Most Beautiful Endangered Species

Theirs sold at auction for $226,000. Ours is JUST $29! Curious? Read on!

To art nouveau jewelers at the turn of the last century, nothing was more beautiful than the dragonfly. In the dragonfly's long body and outstretched wings, jewelers found the perfect setting for valuable stones. These jewelers' dragonfly designs have become timeless statements of style; a dragonfly pendant designed by French jeweler René Lalique recently sold at auction for $226,000. Inspired by his stunning artistry, we've crafted our Dragonfly Nouvelle Collection, an elegant jewelry set for **JUST $29!**

True artisanship in Austrian crystal and yellow gold. This necklace and earring set features gorgeous multicolored enamel paired with Austrian crystals and a yellow gold finish. Ask any jeweler and they'll tell you it takes true artisanship to properly blend the blues and purples found in this enamel. While art nouveau dragonflies are hard to come by, we're helping to repopulate their numbers with this artfully stylized depiction of some of nature's smallest wonders!

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Buy the pendant, get the earrings FREE. If Stauer were a normal company, we'd sell the necklace and earrings for $199 each, but because we engage the world's best artisans and cut out the middlemen to sell directly to you, we're offering the necklace for **JUST $29!** Even better: If you buy within the next few days, we'll throw in the earrings for **FREE!** That's a nearly $400 value for **JUST $29!**

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  Chain: 18" + 2", lobster clasp.
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Excerpt from the December 21 & 28, 1974 issue of *Science News*

50 YEARS AGO

Surface features of a distant star

Thanks to high-speed photography and modern data processing, [astronomers] are beginning to be able to suppress the effects of [a star] twinkling.... The star involved is one of the most prominent in the sky, big, red Betelgeuse.... What was found are large-scale hot and cold regions, that may be convection currents in the star's atmosphere.

UPDATE: Powerful ground- and space-based telescopes have since let scientists observe the surfaces of giant stars in the Milky Way, including Betelgeuse and R Doradus, in even greater detail. Those observations confirmed that surface spots are related to convection, bubbles of hot and cold gas rising and sinking in a star's atmosphere (*SN: 10/19/24, p. 16*). In November, scientists reported the first close-up image of a star outside of our galaxy. Using the Very Large Telescope in Chile, astronomers spotted a star puffing out dust and gas in the Large Magellanic Cloud — a small galaxy that orbits our own. That suggests the star, named WOH G64, may be dying (*SN Online: 11/21/24*).

SCIENCE STATS

Traffic may threaten bees

Tens of millions of bees are estimated to be killed each day by vehicles — and that's just in the western United States.

The findings, reported November 7 in *Sustainable Environment*, show how cars may be contributing to the widespread loss of bees, essential pollinators of both wild plants and a third of the world's crops.

Scientists have documented the ongoing "insect apocalypse" in part by counting dead insects along roadsides. But such studies have focused on forested landscapes and are often biased toward larger species. Bee diversity, however, is highest in arid, more open regions, and most bees are tiny — just 2 to 25 millimeters long.

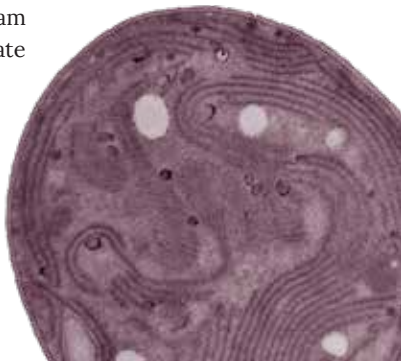
Evolutionary ecologist Joseph Wilson of Utah State University in Tooele and colleagues decided to investigate bee deaths. They attached sticky paper to the bumpers of midsize vehicles and drove stretches of highway, paved roads with slower speeds and unpaved roads during daylight hours when bees are known to be active. The team undertook 29 trips around Utah in spring and summer, traveling more than 9,400 kilometers, and identified struck bees down to the genus level. Every trip resulted in at least one bee fatality, with representatives of 14 genera (some shown).

One car driving between Salt Lake City and Moab might kill 50 to 175 bees, the researchers estimate. Based on traffic data from the Utah Department of Transportation, that amounts to several million fatalities when scaled to the 94,000 cars traveling that route each day. Millions more cars make up Utah's daily traffic, and similar road trips occur in nearby states, so the total estimate of bees killed each day in the region is probably in the tens of millions, the team concludes. — *Amanda Heidt*

INTRODUCING

A mutant cyanobacterium has an appetite for carbon

Stand back, ordinary ocean-dwelling, oxygen-spewing organisms: There's a new Hulkish mutant in town. What's more, this mutant — dubbed "Chonkus" — may have just the right combination of traits to help fight climate change, microbiologists report in the November *Applied and Environmental Microbiology*. Max Schubert, formerly of the Wyss Institute at Harvard University, and colleagues discovered Chonkus off the coast of Italy's Vulcano Island, where groundwater rich in volcanic gases seeps into the sea. Water samples from those seeps contained a mutant strain of *Synechococcus elongatus*, a photosynthesizing bacterium that's at the base of ocean food webs and a favorite lab organism because of how quickly it grows. Chonkus is a superpowered version, lab cultures revealed. Its cells are larger than those of other fast-growing cyanobacteria, and it builds larger colonies. The mutant also stores more carbon than other strains, in granules within its cells. Chonkus is so heavy that it sinks rapidly in liquid. Those traits could make the mutant effective at sequestering carbon in the ocean, the team says. When it comes to forestalling the worst effects of climate change, such organisms may not be the heroes we deserve — but they might just be the heroes we need. — *Carolyn Gramling*



Chonkus, a mutant strain of cyanobacteria shown in this colorized microscope image, stores carbon in granules (large white spots) and sinks quickly in the ocean.

FROM TOP: JOSEPH S. WILSON; WYSS INSTITUTE AT HARVARD UNIV.

THE SCIENCE LIFE

Two students prove an ancient math rule

Two years ago, a couple of high school classmates each composed a mathematical marvel, a trigonometric proof of the Pythagorean theorem. Now, they're unveiling 10 more.

For over 2,000 years, such proofs were considered impossible. And yet, Ne'Kiya Jackson and Calcea Johnson published their new proofs October 27 in the *American Mathematical Monthly*.

Jackson is now a pharmacy student at Xavier University of Louisiana in New Orleans. Johnson is studying environmental engineering at Louisiana State University in Baton Rouge.

Mathematical proofs are sequences of statements that demonstrate an assertion is true or false. Pythagoras' theorem, $a^2 + b^2 = c^2$, relates the length of a right triangle's hypotenuse to those of its other two sides. It has been proved many times with algebra and geometry.

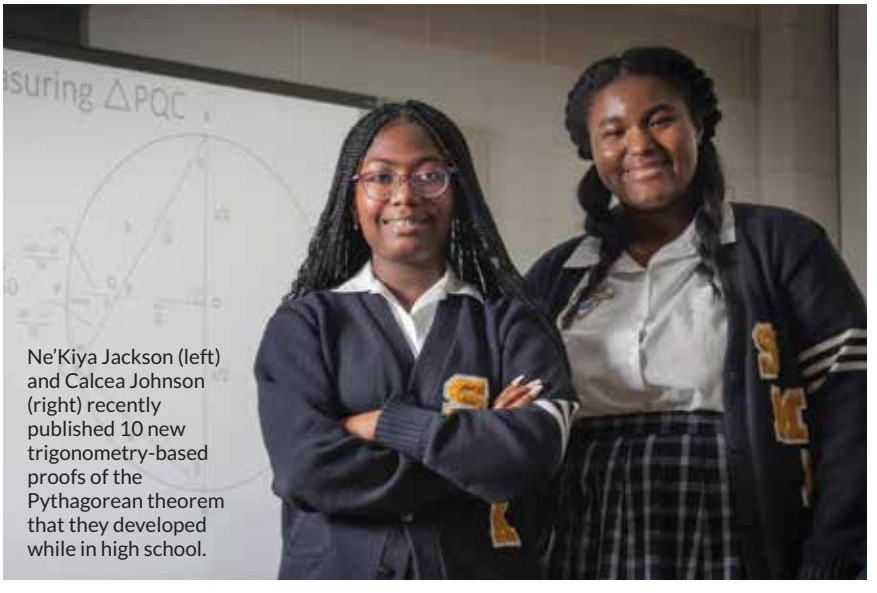
But in 1927, mathematician Elisha Loomis asserted that the feat could not be done using rules from trigonometry, a subset of geometry that deals with the relationships between angles and side lengths of triangles. He believed that the theorem is so fundamental to trigonometry that any trigonometry-based attempt to prove the theorem would have to first assume it was true.

Jackson and Johnson conceived the first of their trigonometry-based proofs in 2022, while seniors at St. Mary's Academy in New Orleans. At that time, only two other trigonometric proofs of Pythagoras' theorem existed, presented by mathematicians Jason Zimba in 2009 and Nuno Luzia in 2015. Working on the initial proofs "sparked the creative process," Jackson says, "and from there, we developed additional proofs."

In 2023, the duo set out to publish their findings in a peer-reviewed journal. "It was important to me to have our proofs published to solidify that our work is correct and respectable," Johnson says.

According to Jackson and Johnson, trigonometric terms can be defined in two different ways, and this can complicate efforts to prove Pythagoras' theorem. By focusing on just one of these methods, they developed four proofs for right triangles with sides of different lengths and one for right triangles with two equal sides. The pair also leave another five proofs "for the interested reader to discover," they wrote. The paper includes a clear direction towards those proofs.

Jackson hopes that the paper's publication will inspire other students to "see that obstacles are part of the process," she says. "Stick with it, and you might find yourself achieving more than you thought possible." — *Nikk Ogasa*



Ne'Kiya Jackson (left) and Calcea Johnson (right) recently published 10 new trigonometry-based proofs of the Pythagorean theorem that they developed while in high school.

BRETT DUKE/*THE TIMES-PICAYUNE*

TEASER

An app could help you lucid dream

If you want to have a dream where you know you're dreaming, you might be in luck. A phone app still in testing seems to boost users' odds of having lucid dreams.

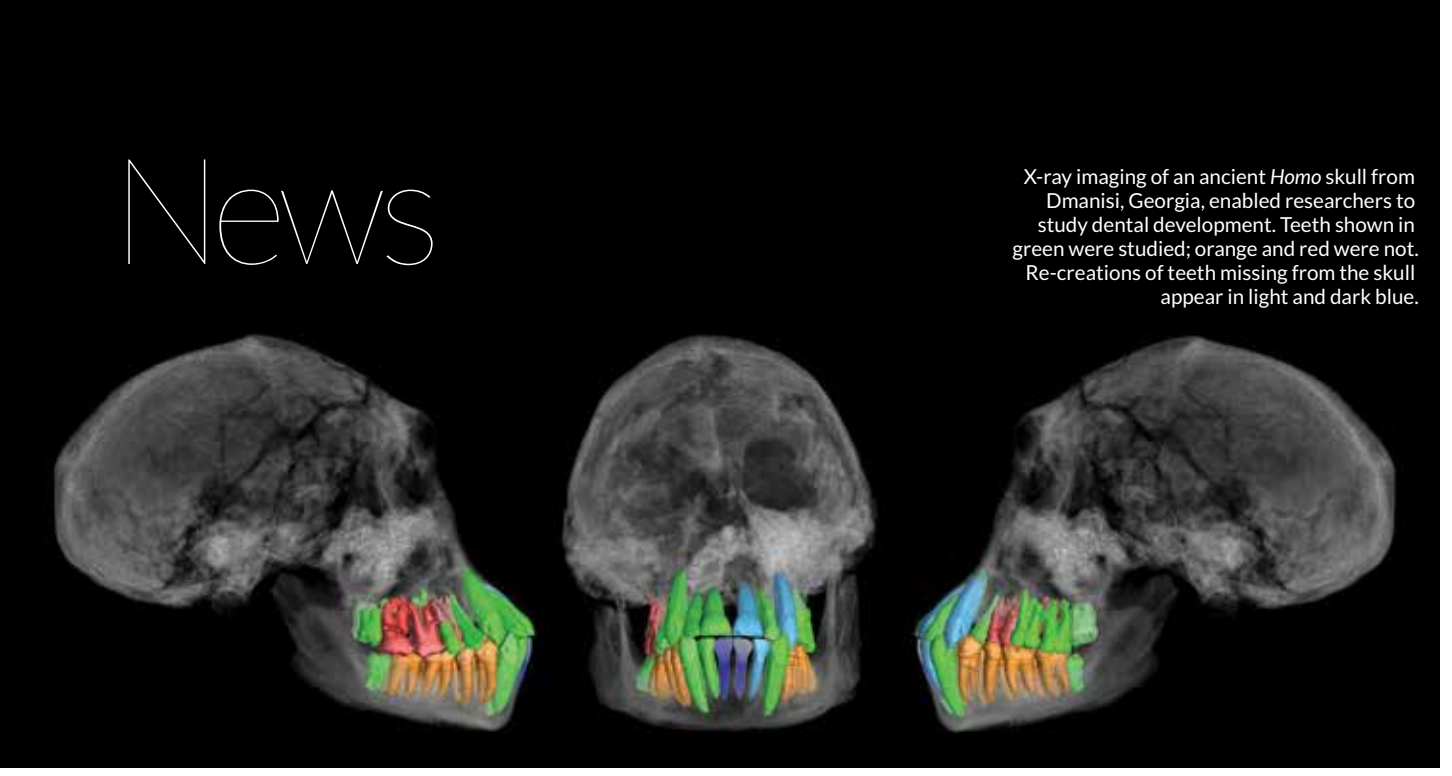
Before bed, the app has users listen to a specific sound, such as a series of beeps, and practice associating that cue with a keen awareness of their thoughts and body. When the app plays that sound six hours later, it's meant to reactivate that self-awareness, coaxing sleeping users to become lucid mid-dream.

These types of sensory cues have proved fairly effective for inducing lucid dreams in sleep studies. But a researcher usually tracks someone's sleep to play sounds during the REM stage, when lucid dreams are most likely. New experiments show that a rough approximation of the technique using an app can promote lucid dreaming at home, researchers report in the October *Consciousness and Cognition*.

Neuroscientist Karen Konkoly of Northwestern University in Evanston, Ill., and colleagues built and tested the app. In one experiment, 19 people used it every night for a week. During the previous week, the group reported an average of 0.74 lucid dreams. During the week of app use, that ramped up to an average of 2.11 lucid dreams. But it wasn't completely clear that the app's sound cues led to that increase. So the team ran another experiment with 112 people.

Everyone got lucidity-triggering sounds from training while they slept the first night. But on the second night, the app switched things up. Only 40 people heard sounds from training while they slept. Another 35 got new sounds. The final 37 heard no sounds.

The first night, 17 percent of participants reported lucid dreams. The second night, people who heard training sounds kept up that rate of lucid dreaming while just 5 percent of the people in the other two groups had lucid dreams, hinting that the real sound cues were indeed behind the app's effectiveness. — *Maria Temming*



X-ray imaging of an ancient *Homo* skull from Dmanisi, Georgia, enabled researchers to study dental development. Teeth shown in green were studied; orange and red were not. Re-creations of teeth missing from the skull appear in light and dark blue.

VINCENT BEYRAND AND PAUL TAFFOREAU/EUROPEAN SYNCHROTRON RADIATION FACILITY, GRENOBLE, FRANCE

ANTHROPOLOGY

An ancient late bloomer sparks debate

Fossil teeth raise questions about human development's origins

BY BRUCE BOWER

An extended childhood, a hallmark of human development, may have gotten off to an ancient and unusual start.

One of the earliest known members of the *Homo* genus experienced delayed, humanlike tooth development during childhood before undergoing a more chimplike dental growth spurt, a new study concludes.

The fossil teeth of a roughly 11-year-old individual reveal slowed development of premolar and molar teeth up to about age 5, followed by faster development of those same teeth. That slower start represented an initial evolutionary foray into extending growth during childhood, say paleoanthropologist Christoph Zollikofer of the University of Zurich and colleagues.

Their results, based on X-ray imaging technology that examined microscopic growth lines inside the fossil teeth, appear November 13 in *Nature*.

The youngster's skull, along with four others unearthed at the Dmanisi site in the nation of Georgia, dates to between 1.85 million and 1.77 million years ago. While some researchers classify these fossils as *Homo erectus*, Zollikofer's group regards the Dmanisi specimens as an undetermined *Homo* species. *Homo sapiens* originated much more recently, around 300,000 years ago.

Although a popular idea holds that a long childhood, slow dental development and an extended life span evolved along with brain expansion in *H. sapiens*, "that might not have been the case in early *Homo*," Zollikofer says. *Homo* individuals at Dmanisi possessed only slightly larger brains than those of modern chimps.

Zollikofer's team provides the first "fairly complete" reconstruction of an ancient hominid's dental development, says paleoanthropologist Kevin Kuykendall of the University of Sheffield in England. Previous studies of ancient hominid dental development have focused on fossil individuals no older than about age 4, Kuykendall says.

X-ray imaging allowed the researchers to estimate the extent of tooth growth at different ages during the life of the youth, who died just before reaching dental maturity between 12 and 13 ½ years of age.

In contrast, dental maturity in people today occurs between age 18 and 22. Chimps reach dental maturity between 11 and 13 years of age.

If Dmanisi individuals were our direct ancestors, then shared childcare including grandmothers and unrelated helpers may have spurred the initial evolution of a longer childhood, Zollikofer suspects. Much later, childhood growth slowed further as *H. sapiens*' brains grew bigger.

If early *Homo* at Dmanisi belonged to a dead-end line, "then Dmanisi looks like a first evolutionary experiment with extended childhood," Zollikofer says.

Those scenarios are possible, Kuykendall says. But finding that a slow start to tooth growth did not substantially delay dental maturity could instead denote one of many ways in which tooth development evolved among ancient hominids, including early *Homo* species that ventured into diverse habitats, he contends. For instance, variations in available foods or age at weaning, rather than shared childcare, could have shaped dental development in early *Homo* groups, Kuykendall says.

But paleoanthropologist Tanya Smith of Griffith University in Australia says the study fails to show that the Dmanisi youth had an extended childhood. She points to the estimate that the first molar erupted at around age 3 ½, closer to that of chimps than humans. Other studies indicate that the timing of first molar eruption strongly predicts many aspects of dental and physical development, putting Dmanisi on a chimplike trajectory, she says. ■

COSMOLOGY

Dark energy still puzzles scientists

An analysis reaffirms that the enigma may change over time

BY EMILY CONOVER

Scientists could be wrong about dark energy. But they're right about gravity, a new study suggests.

Dark energy, the mysterious phenomenon that causes the expansion of the cosmos to accelerate, is widely thought to have had a constant density throughout the history of the universe. But dark energy may instead be waning, researchers from the Dark Energy Spectroscopic Instrument, or DESI, collaboration report November 19 in a batch of papers posted to the project's website and to arXiv.org.

The finding reaffirms an April report from the same team that had come to a similar conclusion (see Page 30). Simultaneously, the new analysis—a more thorough look at the same data used in the earlier report—confirms that the DESI data agree with general relativity, Albert Einstein's theory of gravity, with no evidence for alternative, "modified gravity" theories.

DESI makes a 3-D map of galaxies throughout the cosmos. The project's previous analysis focused only on one type of information gleaned from that map: baryon acoustic oscillations, sound waves in the early universe that left imprints on the cosmos that are visible today (*SN: 3/30/19, p. 11*).

The new analysis adds information on how galaxies and other structures evolve over cosmic history. "This is the first time we are sensitive to how structure grows with time," says cosmologist Dragan Huterer of the University of Michigan in Ann Arbor. "This is significant because the growth of structure is well known to be very sensitive to dark energy and gravity."

In both the original and new analyses, the researchers found signs of a variation in dark energy's equation of state, the relationship between its pressure and density over time. "We are pointing at the same conclusion, and this is … completely reassuring," says cosmologist Pauline Zarrouk of CNRS and the Laboratoire de Physique Nucléaire et de Hautes Énergies in Paris. Because the two analyses are based on the same data, "if we were not seeing the same [conclusion], that would really be an issue," Zarrouk says. In both cases, the team combined DESI's data with other cosmological data, including data on the cosmic microwave background, the oldest light in the universe.

With the first result, DESI researchers were sticking out their necks, says physicist Daniel Scolnic of Duke University. "They're not backing away from that. A lot of times when there's some big result in cosmology, it feels like a month later … it's gone." But with DESI, "their necks are still out. I really respect that and appreciate that," Scolnic says.

If dark energy is confirmed to vary, it would send a jolt through cosmology, overthrowing scientists' accepted theory, called the standard cosmological model. That theory has been extremely successful at describing the cosmos, but it includes poorly understood components, like dark energy and the likewise unidentified source of mass called dark matter.

In an attempt at a more satisfying explanation of the cosmos, some scientists are tweaking general relativity, in which gravity is the result of mass warping spacetime. Modified gravity theories could do away with the need for dark matter or dark energy. But the structure formation that DESI observed was consistent with that predicted by general relativity. And there's no evidence for modified gravity, although the theories are not fully ruled out.

In the new study, a puzzle persists about the masses of neutrinos, lightweight subatomic particles that are plentiful in the cosmos. Like DESI's first analysis, the new findings indicate that the sum of the masses of the three types of neutrinos is smaller than expected, at least by some accounts (*SN: 10/19/24, p. 18*). That could hint that cosmologists have misunderstood something about the nature of the cosmos or about neutrinos themselves.

In 2025, the DESI collaboration plans to release results based on the project's first three years of data. That will be a true test of how robust the results are, including whether dark energy indeed changes over time.

Scolnic envisions the standard cosmological model as a bonfire. While scientists had been enjoying sitting around the warm glow, with the DESI results, sparks have begun to fly.

"This is when you tell everyone, 'Let's just take a step back from the bonfire, just to be safe,'" Scolnic says. "'We're not throwing water on the whole thing, but definitely just one step back.'" ■

T. SLOVINSKÝ, KPNO/AURA/NSF NOIRLAB

A new analysis of data from the Dark Energy Spectroscopic Instrument on the Mayall telescope (shown) in Arizona upholds general relativity but hints that dark energy's density varies over time.

Starlink satellites (vertical lines) fly over New Mexico in this time lapse photo. The satellites are built to be short-lived.

M. LEWINSKY/WIKIMEDIA COMMONS (CC BY 4.0)

ENVIRONMENT

Do dying satellites harm Earth's sky?

Burning debris may have ripple effects on atmospheric chemistry

BY CAROLYN GRAMLING

Earth's space junk may be wreaking havoc on the stratosphere.

The rapid surge in satellite megaconstellations is connecting much of the world to broadband internet. But each year, hundreds of those satellites die, burning up in the atmosphere as they fall. And each year, more and more satellites are being launched to replace them.

The dying satellites don't just wink out into the ether. Each one leaves a bit of itself behind.

The satellites' fiery death throes, along with a steep rise in the number of rocket launches, are adding a glut of ozone-destroying and climate-altering pollutants to the stratosphere, researchers say. What that means for the planet's atmospheric chemistry — including its ultraviolet light–shielding ozone layer — isn't yet clear. But scientists are racing to find out.

"The launches are growing so quickly," says Daniel Murphy, an atmospheric scientist at the National Oceanographic and Atmospheric Administration's Chemical Sciences Laboratory in Boulder, Colo. "In the last couple of years, there have been roughly 500 re-entry events per year, and people are talking about 10,000 in the not-too-distant future. That's about one an hour. So we'd like to understand the implications as soon as possible."

Currently, there are about 10,000 active satellites in orbit around the planet. Two-thirds belong to Starlink, SpaceX's megaconstellation (SN: 4/8/23, *p.* 5). Another 630 are part of London-based Eutelsat OneWeb. Other internet projects intend to catch up quickly: In August, China launched the first 18 satellites for its Qianfan, or "Thousand Sails," constellation, ultimately planned to comprise at least 12,000 satellites. Another planned Chinese project, known as Honghu-3, aims to link up to 10,000 satellites.

By some estimates, there may be as many as 100,000 satellites in near-Earth orbit by the 2030s, with possibly half a million circling the planet in the decades to follow.

These internet satellites are disposable by design. They may serve a few years in a constellation network before being decommissioned — sunk into a lower orbit until they ultimately fall to a fiery death through the sky. Each disintegrating satellite injects metals into the atmosphere, many of which are metals either not typically found there or ones that are being added in much greater abundances than are naturally introduced.

The first step to understanding the scope of the problem is identifying the traces of burned-up spacecraft, and whether those traces are comparable or even detectable against the background of natural meteorite debris from space.

That research is just getting started.

In 2023, Murphy and colleagues presented definitive evidence that metals specifically from spacecraft, rather than just natural sources, were indeed aloft in the stratosphere, the layer of atmosphere extending from six to 20 kilometers above Earth's surface. Stratospheric particles of sulfuric acid in the upper atmosphere over the Arctic turned out to contain over 20 different elements consistent with spacecraft production. Those elements, Murphy says, included niobium and hafnium, both refined from mineral ores for use in heat-resistant alloys. Other metals such as lithium, lead, aluminum and copper — which can be present naturally — were found in abundances far

exceeding what might organically waft in via cosmic dust.

And the evidence of erstwhile spacecraft is accumulating. From 2020 to 2022, scientists tracked a stratospheric rise in pollutants, corresponding to the rapid rise in satellite launches.

Emissions of aluminum and nitrogen oxides from satellite re-entries nearly doubled from 3.3 billion grams in 2020 to 5.6 billion grams in 2022, atmospheric chemist Connor Barker of University College London and colleagues reported in April in Vienna at a meeting of the European Geophysical Union. By 2022, re-entry inputs of nitrogen oxides, they found, were equivalent to about a third of the natural inputs of the gases from meteors. And aluminum oxide inputs were surpassing natural inputs by a factor of seven.

Pollutant emissions from rocket launches are also on the rise, Barker's team found. Propellant consumption nearly doubled from 2020 to 2022, from 38 billion grams to 67 billion grams. Those launch emissions can include pollutants such as black carbon, nitrogen oxides, carbon monoxide, aluminum oxide and a variety of chlorine gases.

The spacecraft debris could have a variety of ripple effects through the chemistry of the stratosphere. It could spell bad news for the ozone layer in particular. Aluminum oxide, for example, is a by-product of the oxidation during re-entry of aluminum-based spacecraft components, says José Ferreira, an aerospace engineer at the University of Southern California in Los Angeles. "And we know that aluminum oxides are catalysts for ozone depletion."

This new threat to the ozone layer is particularly frustrating in the wake of the success of the Montreal Protocol, a 1987 agreement to ban the production and emissions of known ozone-destroying chemicals. By 2016, the annual hole in the ozone layer that forms over Antarctica was already showing signs of healing, on track to completely close up within about 50 years (SN: 12/24/16 & 1/7/17, *p.* 28).

There are myriad other ways that spacecraft pollutants might tinker with the atmosphere's complex chemical brew, Murphy says. Soot emitted from rocket engines absorbs solar energy, which can warm the atmosphere. Copper and other metals released during the incineration of spacecraft wiring and alloys are known to be powerful catalysts for chemical reactions in the atmosphere. Among other things, those metals could promote the creation of the tiny particles that act as the seeds of clouds.

There's not much direct information on which of these reactions might already be happening. The data that do exist are destined for computer simulations that track the life cycle of these pollutants and their interactions in the atmosphere. Murphy's team is also planning more flights in 2025 to continue tracking the growing inventory of spacecraft debris.

Ferreira is considering ways to incorporate an environmental impact assessment into the design phase of space missions. "If we identify up-front that a component or a chemical will be detrimental to the atmosphere, we can either find an alternative or invest in research into more environmentally friendly options," he says.

For now, the question of impacts from the scattered stuff of satellites is so new that there hasn't yet been much funding to address it, Murphy says. But, he adds, "I think it needs to happen fast. It'd be really good to know these things before these satellites are built and launched." ■

JPL

PLANETARY SCIENCE

Uranus made a weird first impression

Some of Uranus' known oddities may be due to bad timing. When Voyager 2 flew by in 1986, the probe spotted intense radiation belts and a lack of plasma in Uranus' magnetosphere — the magnetic fields that surround planets. Turns out, Uranus may have been in an unusual state, scientists report November 11 in *Nature Astronomy*. An analysis of Voyager 2 data from months before the flyby reveal that intensifying pressure from the solar wind would have compressed the magnetosphere, which could account for the weird flyby observations. Uranus is in the state in which the probe found it (photo from the flyby shown) about 4 percent of the time, the team calculates, so much of what's known about the magnetosphere probably isn't typical. — *Lisa Grossman*

ANIMALS

Clams build their own fiber optics

Shell structure discovery may inspire internet innovations

BY ELIE DOLGIN

In a discovery that blurs the line between biology and technology, scientists have found that small, heart-shaped clams use fiber optic–like structures to channel sunlight through their shells in much the same way that telecommunications companies use fiber optics to deliver high-speed internet into homes.

This innovation, the first known example of bundled fiber optics in a living creature, helps to explain how heart cockles — a walnut-sized bivalve found in shallow waters across the Indian and Pacific oceans — harness sunlight to nourish the symbiotic algae living within the shells while protecting them from harmful ultraviolet rays. In return, the algae provide the clams with sugars and other nutrients.

The finding offers potential insights for the development of bioinspired optical systems in the future, researchers report November 19 in *Nature Communications*.

Heart cockles (*Corculum cardissa*) are best known for their distinctive shell shape. A close look reveals the shells are pockmarked with "windows," minute, transparent structures that permit light to pass through. This architecture is rooted in the special properties of aragonite, a crystalline form of calcium carbonate. These aragonite crystals are arranged in micrometer-sized tubes that function like fiber-optic cables, guiding light with exceptional precision, while filtering out harmful UV radiation.

Evolutionary biophysicist Dakota McCoy of the University of Chicago and colleagues performed microscope experiments demonstrating that the sun-facing side of the shell allows more than twice as much photosynthetically useful light to penetrate inside as it does UV light.

Computer simulations suggest the arrangement of the fiber optic–like structures represents an evolutionary trade-off, finely tuned to balance the shell's mechanical strength with its ability to efficiently transmit light.

McCoy and others envision leveraging the properties of aragonite or its intricate lattice structures to create materials with superior optical performance. One quality they hope to replicate is aragonite's ability to channel light without reflective coatings. Such coatings are needed on telecommunications cables to confine light signals, but aragonite naturally possesses its own optical containment features.

"By mimicking the bundled fiber structures found in heart cockles, we could develop systems that offer enhanced light collection," says Boon Ooi, a photonics researcher at the King Abdullah University of Science and Technology in Saudi Arabia.

"Billions of years of product design have gone into this," McCoy points out. Tapping into the heart cockles' shell design, she says, could lead to unmatched light-transmission capabilities — leaving the human end-users happy as clams. ■

A vampire bat working out on a bat-friendly treadmill helped scientists figure out the quirks of digesting high-blood diets.

PRICE SEWELL

ANIMALS

Why scientists put bats on treadmills

Giving bloodsuckers a workout sheds light on metabolism

BY SUSAN MILIUS

Vampire bats have become such specialized bloodsuckers that they metabolize food more like some blood-feeding flies than like other mammals, a new study shows.

The common vampire bat (*Desmodus rotundus*) doesn't stick to flying. It also scurries along the ground to steal blood from cattle, horses and other mammals. That scurrying behavior let researchers, who were curious about bat metabolism, coax vampires to run on a treadmill — at least for a little while.

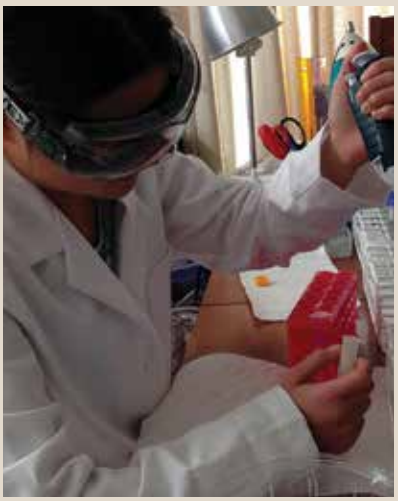
Up to 60 percent of the carbon dioxide the bats exhaled during a workout came from metabolizing fuel other than the carbohydrates or fats that typically power a running mammal, the team reports in the Nov. 6 *Biology Letters*. Instead, much of the energy came from a recent high-protein meal of cow blood; the gases contained telltale traces from amino acids, the building blocks of proteins.

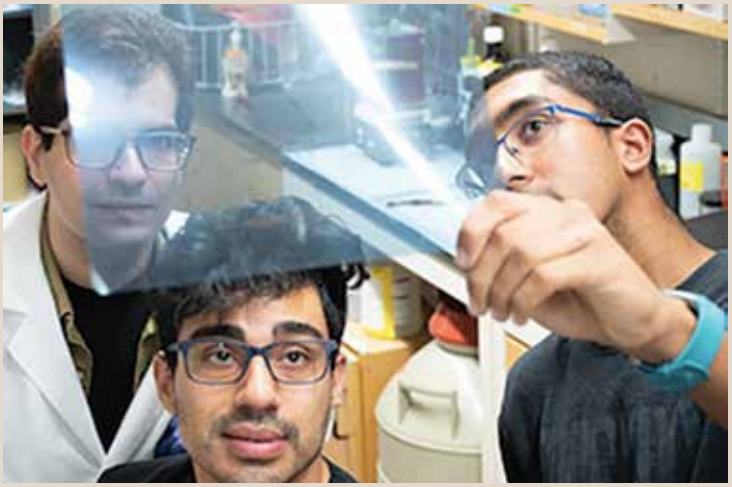
The ratio of carbon dioxide exhaled to oxygen used stayed steady as researchers pushed the treadmill pace from walking to running. That steadiness is a sign that bats weren't fueling their exertions the usual mammal way. Gas ratios typically change as exercise gets more strenuous, and mammals shift from burning mostly lipids to relying more on carbs.

Vampire bats power along by metabolizing a recent blood meal, much like blood-feeding tsetse flies. That's a first for mammals, says study coauthor Ken Welch, an ecological physiologist at the University of Toronto. It makes sense to Welch that any ancestral ability to use sugar by-products and fats weakened over time in vampire bats. Yet such heavy reliance on amino acids, which aren't as easy to access quickly, means the bats could be more susceptible to starvation. ■

Watch a vampire bat use a treadmill at **bit.ly/SN_Bats**

2025 Student Research Showcase





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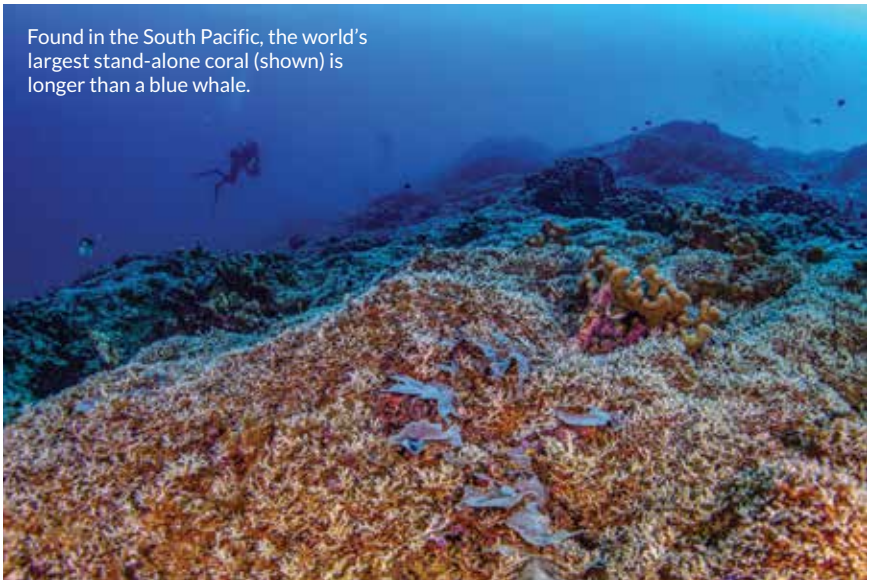
OCEANS

A colossal coral sets a new record

Off the coast of the Solomon Islands lurks a centuries-old being that is so immense, it can be seen from space.

At about 34 meters wide, 32 meters long and 6 meters high, a shoulder-blade coral (*Pavona clavus*) is the world's largest stand-alone coral, the National Geographic Society's Pristine Seas team announced November 14. Those dimensions make the coral longer than an average blue whale and dwarf the next largest-known coral, Big Momma — a 22-meter-wide coral in American Samoa. The newfound coral is made up of nearly a billion coral polyps and may be up to 500 years old, the team estimates. — *Nikk Ogasa*



Found in the South Pacific, the world's largest stand-alone coral (shown) is longer than a blue whale.

NEUROSCIENCE

Probing brains that don't mix senses

Growing up, Roberto S. Luciani had hints that his brain worked differently than most people's. He didn't relate when people complained about a movie character looking different than what they'd pictured from the book, for instance.

It wasn't until Luciani was a teenager that things finally clicked. His mother was telling him about a movielike dream she had. "I asked her what she meant and quickly realized my visual imagery was not functioning like hers," he says.

Luciani has a condition called aphantasia, an inability to picture objects, people and scenes in the mind. When he was growing up, the term didn't even exist. Now a cognitive scientist at the University of Glasgow in Scotland, Luciani and other researchers are getting a clearer picture of how some brains work, including those with aphantasia.

Luciani's team explored the connections between hearing and seeing. In most brains, auditory information influences activity in brain areas that handle vision. But in people with aphantasia, this connection isn't as strong, the researchers report in the Nov. 4 *Current Biology*.

While in a brain scanner, blindfolded people listened to three sound scenes: a forest full of birds, a crowd of people and a city street. In 10 people without aphantasia, the scenes created reliable neural hallmarks in the visual cortex. But in 23 people with aphantasia, the hallmarks were weaker. The results could help explain how brains with and without aphantasia differ. — *Laura Sanders*

PARTICLE PHYSICS

Antimatter could travel by truck

A truck full of antimatter would make for a seriously epic road trip. And researchers are now one step closer to hauling the substance by motor vehicle.

Scientists at CERN, near Geneva, have demonstrated the ability to transport a cloud of subatomic particles aboard a truck, using protons as a stand-in for their antimatter counterparts, antiprotons.

Several experiments at CERN study antiprotons to check for any unexpected discrepancies with their matter partners. Such studies, scientists hope, could lead to a better understanding of why matter is common but antimatter is rare.

But antiprotons are a precious resource. CERN is the only place where the particles can be trapped and studied. Scientists would like the option to take them elsewhere to access outside equipment and ideal experimental conditions.

Because antimatter annihilates upon contact with normal matter, it must be suspended by electromagnetic fields in a vacuum chamber. Scientists with the BASE-STEP project built a trap that could do just that while bumping down the road and that was small enough to fit on a truck.

Physicists used the trap to successfully schlep a cloud of 70 protons on a trip of about four kilometers around the laboratory site and back again, CERN announced October 25. A future experiment will test antiprotons. — *Emily Conover*

PARTICLE PHYSICS

Muons are getting a move on

In a step toward new types of particle physics experiments, scientists accelerated a beam of muons. That raises hopes the subatomic particles, heavy cousins of electrons, could be slammed together at future particle colliders to unlock physics secrets.

Muons in particle beams initially go every which way, so scientists first had to figure out how to cool them down and then reaccelerate the particles in the same direction. At the Japan Proton Accelerator Research Complex in Tokai, researchers sent muons into an aerogel, creating muonium — an atomlike combination of positively charged muons and negatively charged electrons. Next, a laser stripped away the electrons, leaving behind cooled muons that electromagnetic fields then accelerated. The muons reached a speed of roughly 12,000 kilometers per second, the team reports October 15 at arXiv.org. That's about 4 percent of the speed of light. — *Emily Conover*

MANU SAN FÉLIX/NATIONAL GEOGRAPHIC PRISTINE SEAS

Meet the Beauty in the Beast

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Year in Review

Looking back on the year in science, a few things seemed inescapable: oppressive heat waves, viral outbreaks, the surging popularity of generative artificial intelligence. These events may seem disparate, but they have something in common: global warming. This year's record-high temperatures wouldn't have been possible without human-caused climate change. Heat waves upended people's daily lives while longer-term warming supercharged the spread of dengue and other mosquito-borne diseases, resulting in record numbers of infections this year. You might wonder how generative AI fits in. For all its promise, this energy-intensive technology produces a lot of climate-warming carbon emissions. Researchers are now asking whether the technology's purported benefits are worth the environmental cost. The path to more sustainable AI — and a more climate-friendly future — isn't straightforward. But it isn't impossible, and scientists are working on solutions.

Other highlights in 2024 remind us there's still plenty of joy and wonder to be found in the world. Space missions revealed new details about our planetary neighbors. Archaeologists dug up dirt on human ancestors. And charismatic critters charmed our socks off.

— Cassie Martin, Deputy Managing Editor

FROM LEFT: NANTIYA RATTANATUM/GETTY IMAGES; IMAGINECHINA LIMITED/ALAMY STOCK PHOTO

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First-of-a-kind feats

Each year, scientists break new ground in their quest to understand life and the mysteries of the cosmos. Here are seven milestones in 2024 that caught our attention **BY SOPHIE HARTLEY**

Reading a fruit fly's mind

The first complete map of a fruit fly's brain details all 139,255 nerve cells and the 54.5 million connections between them. It's the largest brain map made of any animal, even though the fruit fly's brain is poppy seed–sized (*SN: 11/2/24, p. 32*). The map could lead to a deeper understanding of how information flows in the brain.

Nuclear timekeeping

Scientific clockmakers debuted the world's first prototype nuclear clock. While the prototype isn't a fully operational timepiece, its development showed scientists the precise frequency of light required to set off fluctuations in the energy levels of atomic nuclei (*SN: 10/5/24, p. 7*).

New nitrogen factory

A eukaryote has joined some bacteria and archaea in the nitrogen fixation club. A type of marine alga has an internal factory that transforms nitrogen into ammonia, a biologically usable form (*SN Online: 4/11/24*). The factory probably started as a separate life-form that entered a symbiotic relationship with the eukaryote. Over millennia, the two may have become so intertwined that they became one organism.

Ultrarare decay

By smashing protons into a fixed target, physicists witnessed a predicted but never-before-confirmed form of particle decay. The collision produced subatomic particles called kaons. Those kaons decayed into an uncommon combination of three other types of particles at a rate of about 13 in 100 billion times (*SN: 10/19/24, p. 16*). Continued investigation into the decay might help unveil new physics.

Recycling dead weight

The *Cyathea rojasiana* tree fern is the first plant known to turn its dead leaves into roots. The leaves sprout rootlets, which the fern may use to search out nutrients in the soil of Panamanian forests (*SN: 2/24/24, p. 5*).

PANDA PROTECTION

For the first time, researchers transformed the skin cells of giant pandas into stem cells that can be coaxed into any other type of cell in the body. Being able to take skin cells and end up with, say, the precursors of sperm and egg cells gives conservationists a leg up in defending the bears from extinction by boosting breeding (*SN: 10/19/24, p. 10*).

Black hole awakening

In a sleepy galaxy not too far away, a supermassive black hole appears to be gradually waking up, providing astrophysicists with their first peek of a black hole transitioning from dim and quiet to bright and active. When supermassive black holes consume material such as stars, they usually glow for only a few days to weeks. But lucky for scientists, this black hole has remained luminous for years. While researchers are not completely certain why the black hole continues to glow, they're following the situation closely and hoping to glean some insights into how black holes grow (*SN: 7/13/24 & 7/27/24, p. 7*). ■

BEYOND WEIGHT LOSS

Wegovy and its relatives may aid the body in other ways. Researchers are looking ahead with cautious optimism

BY MEGHAN ROSEN

The drugs Wegovy and Ozempic are taken via injection pens. Ozempic pens are shown on the production line at a factory in Denmark.

CHARLOTTE DE LA FUENTE/*NEW YORK TIMES*/REDUX PICTURES

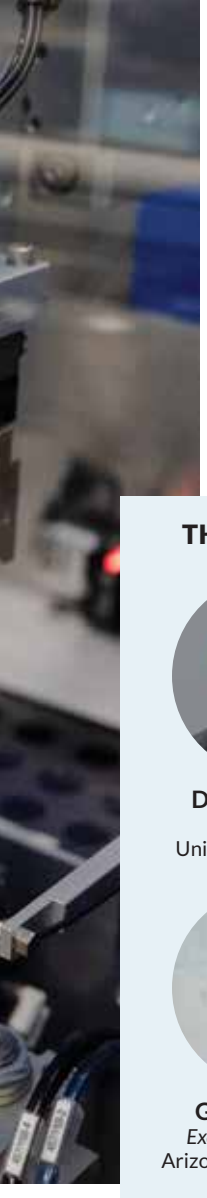
Popularity of the diabetes and weight-loss drug semaglutide has continued to surge this year. You've probably seen ads on social media or heard from friends who've tried top-selling brand-name versions, Ozempic and the higher-dose variety Wegovy (*SN: 6/29/24, p. 5*).

Semaglutide and its many relatives mimic the gut hormone GLP-1. But this drug family is nothing new. The U.S. Food and Drug Administration approved an early cousin of semaglutide for diabetes nearly 20 years ago, and another, liraglutide, for weight loss a decade later. Liraglutide's approval was important, says endocrinologist Daniel Drucker of the University of Toronto, because "it showed that maybe these drugs have another utility beyond glucose control."

In the last few years, that promise has panned out. Clinical trials in people with diabetes and obesity have shown that semaglutide and its newer cousins can help people shed a lot of weight, relatively safely. That's not the norm, historically. Before these drugs, obesity therapeutics were "riddled with safety issues," Drucker says. The drug regimen known as fen-phen, for example, could cause leaky heart valves. These and some other drugs for weight loss have been pulled from the market.

The story of GLP-1 drugs may have a different ending. And these medications' potential benefits seem to go well beyond weight loss. Though the drugs tend to make people feel full and eat less, there's evidence they may also help treat diseases that affect the heart, kidney, liver and more. It's not yet clear all the ways these drugs might aid the body, but some effects may be independent of weight loss. Studies suggest semaglutide could even curb addiction and inflammation (*SN: 10/19/24, p. 6*). And clinical trials testing if the drugs have neuroprotective effects in people with Parkinson's and Alzheimer's are in the works. So are more powerful medications. The FDA has already approved one such drug—tirzepatide (sold as Zepbound)—which acts like two gut hormones, GLP-1 and GIP. And drugs that mimic three or even four hormones are coming.

To get a sense of where the field is heading, *Science News* spoke with Drucker and three other experts: physician-scientist Lorenzo Leggio of the National Institute on Drug Abuse in Baltimore, exercise physiologist Glenn Gaesser of Arizona State University in Phoenix and endocrinologist Maria Daniela Hurtado Andrade of the Mayo Clinic in Jacksonville, Fla. The conversations have been edited for length and clarity.



GLP-1 drugs have been studied for decades, but they became household names only recently. What changed?

Drucker: It was really the clinical trial data on semaglutide. That's where we saw for the first time many people getting double-digit weight loss. [People taking semaglutide for obesity can lose about 15 percent of their body weight, on average.] Prior to that, that simply had not been achievable in the obesity therapeutic space, unless you went for bariatric surgery.

Semaglutide was the first medicine that said to people, wow, this is something different.

Now there's evidence that it can have cardiovascular benefits and potentially even help people with addiction.

Drucker: The SELECT trial in overweight or obese people [reported in 2023] showed a 20 percent reduction in heart attack, strokes and cardiovascular death, and a 19 percent reduction in all-cause mortality. So this has really changed the game. We have never seen anything like this in obesity medicine.

Leggio: It seems that this class of drugs has a broad effect across multiple addictive disorders. This work is very promising, but it is work in progress.

The obesity clinical trials clearly show these medications are effective. But that doesn't mean that everybody responded. You have patients who have profound weight loss, and patients who do not.

I anticipate that even if this medication works for Parkinson's, Alzheimer's and addictions, not all patients will respond. We will have to understand who may or may not respond, and for what patients [the drugs] may be unsafe to take.

Are there other hints about the potential of these drugs that intrigue you?

Hurtado Andrade: We already have evidence on tirzepatide and obstructive sleep apnea, and there is more data coming out about the beneficial effects of these medications on metabolic-associated liver dysfunction.

I'm sure we're going to hear more as time goes by. There will probably be data on osteoarthritis. I'm sure there will be data on cancer.

Drucker: I find the inflammation story really exciting. I get emails every week or so from people with some disease, generally inflammation related.

This week's email was from a woman with lipedema, which is inflammation of fat in your lower extremities. It can be very disabling. She said she took one dose of semaglutide and started to feel better immediately. She started to see her inflammation go away. Then she had to stop the drug because she lost her insurance, and everything came right back.

There's still a ton of fascinating science to explore, whether it's inflammation or alcohol dependence or narcotics or smoking, compulsive behaviors, neuropsychiatric conditions. But it's very early days.

What studies and clinical trial results are you watching for?

Drucker: I would be most excited if the Alzheimer's trials came back positive.

We have hundreds of millions of people faced with the looming burden of Alzheimer's disease, either in loved ones or themselves. We don't have anything easy for them to take that's safe yet might really delay the progression of their disease. I don't know if semaglutide will do that. But it's being studied in two trials [evoke and evoke+], which will probably report out at the end of 2025.

To me, that's the most exciting, huge issue on the landscape. So that's where I would watch.

Hurtado Andrade: I'm looking forward to seeing the cardiovascular outcomes with tirzepatide, because it seems to be a more effective [weight-loss] medication compared to semaglutide.

Gaesser: I would like to see studies that look at [individuals on] the drugs with and without exercise long-term. How active are they? How much time do they spend in sedentary behaviors? How much time do they spend in light-, moderate- and vigorous-intensity behaviors? I want to see if [the drugs] change behavior.

THE EXPERTS

Daniel Drucker
Endocrinologist
University of Toronto

Glenn Gaesser
Exercise physiologist
Arizona State University

Maria Daniela Hurtado Andrade
Endocrinologist
Mayo Clinic

Lorenzo Leggio
Physician scientist
National Institute on Drug Abuse

FROM TOP: PRINCESS ASTURIAS FOUNDATION; COURTESY OF ARIZONA STATE UNIV.; MAYO CLINIC; NIAAA

How does exercise factor in with these drugs?

Gaesser: One of the major health problems in this country and perhaps worldwide is not so much that we weigh too much, but that we aren't active enough. And when you look at a number of populations across the board, it seems like fitness is more important than slimness in terms of health outcomes. So, what's going to happen with the millions of people taking these GLP-1 drugs? They may lose a lot of weight, but is that going to make them any more active?

How many people do you foresee eventually taking these drugs?

Gaesser: I think that we're going to have a lot more people wanting to take these drugs. I mean, the obsession with weight loss in our country is nothing new. Certainly in the United States, the cost and availability of these drugs are huge issues.

Drucker: If you're living with type 2 diabetes or obesity, there's substantial evidence that these drugs are helpful beyond controlling your blood sugar and body weight. But should the rest of us be taking them? Well, let's see what the Parkinson's trials show. Let's see what the Alzheimer's trials show. Let's see what the metabolic liver disease trials show. Let's just wait for the data. It's going to come in steady buckets over the next couple of years.

We really want to make sure that the right people are using the medicines for the absolute best indications that are proven beyond a shadow of doubt.

> "The near-future question that we are trying to answer is, do these medications work for addiction?"
>
> **LORENZO LEGGIO**

As newer medications come out, do you have concerns about side effects?

Drucker: The safety of today's GLP-1–based medicines is very well established. Side effects are predominantly nausea, vomiting and diarrhea. But once we start [targeting multiple hormones], then you have to step back and say, I don't fully know the safety of these medicines. They're manipulating additional circuits. So we must always scrutinize the safety in large trials and then look at the real-world data.

Hurtado Andrade: This family of medications has been around for more than two decades, and we haven't had any surprises. That doesn't mean that we are not going to have surprises with newer drugs, but we already know a lot about the potential adverse events.

Gaesser: There may be some adverse effects on muscle mass and bone density.

Leggio: For the addiction scientific community, one question is: [What happens when] you combine these medications with addictive drugs that may interact pharmacologically in the body? We have to be even more mindful of potential side effects.

What big questions would you like answered?

Drucker: We're going to have like a half a dozen drugs that will produce 25 percent weight loss or more on average. [In a recent clinical trial of the experimental obesity drug retatrutide, participants lost more than 24 percent of their body weight, on average.] And then the question will be, what's the difference between them? Will they all be equally effective for heart disease, kidney disease, metabolic liver disease, Parkinson's, Alzheimer's, sleep apnea, or are we going to start to see differences?

Hurtado Andrade: Most studies that have been done with these medications are biased towards middle-aged adults. We certainly need to have more data in different age groups.

[Also, recent data] suggest that the cardiovascular benefits of semaglutide may be weight independent. I'm not surprised by this. We have GLP-1 receptors all over our body and what these medications do is activate GLP-1 receptors. I'm interested in understanding if we can have other beneficial effects throughout our body that are also weight independent.

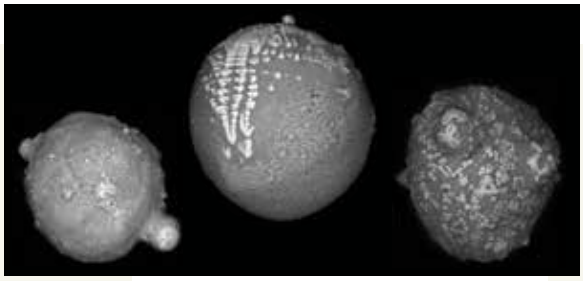
Leggio: The near-future question that we are trying to answer is, do these medications work for addiction? We are optimistic but also cautious, because we know from history that sometimes very promising medications fail to show efficacy. And so it's important that we don't put the cart before the horse.

Gaesser: The drugs haven't really been studied in healthy populations — individuals who are absolutely free of disease and have no medical conditions, just excess weight. I don't know what the new drugs will show once [scientists] start randomized controlled trials in individuals that are reasonably healthy but just want to lose weight.

And I don't think taking the drug and losing weight makes unhealthy individuals equivalent to [healthy] individuals who have never taken it — and certainly not a healthy person who is exercising regularly and has a modest to high level of fitness. I don't think the drugs will ever be able to match something like that. ■

Best of the –ests

From tracing the origins of photosynthesis to tying the world's smallest molecular knot, these record-setting feats captured the imagination **BY ANDREA TAMAYO**



COURTESY OF M. VAN GINNEKEN

ANCIENT AIRBURST
Some 2.5 million years ago, an asteroid combusted in Earth's atmosphere before it could hit the ground and leave a crater, making the event the oldest known mid-air explosion (*SN: 3/9/24, p. 5*). A study of 116 microscopic rocks (three shown) from Antarctica found minerals that suggest the pebbles are the asteroid's remnants.

The dawn of photosynthesis
Microfossils in Australia harbor the oldest evidence of photosynthesis. Fossilized bacteria dating to about 1.75 billion years ago preserve structures that resemble thylakoid membranes, which help modern cyanobacteria convert sunlight into oxygen (*SN: 1/27/24, p. 7*).

Fastest backflip
Dicyrtomina minuta springtails can launch themselves up to 60 millimeters in the air and spin at a rate of up to 368 times per second, making the arthropods the fastest known backflippers (*SN: 10/5/24, p. 4*). An appendage on the underbelly helps the miniature gymnasts lift off while another helps them stick the landing.

Wee-est frog
At just 6.5 millimeters long, a Brazilian flea toad (*Brachycephalus pulex*) has been crowned the world's smallest known frog (*SN: 3/23/24, p. 4*). Petite enough to sit on a pinkie fingernail, the amphibian beat the previous champion by about a millimeter.

Large genome, small package
The largest known genetic instruction manual belongs to a tiny fern. *Tmesipteris oblanceolata* is 15 centimeters long but possesses a genome that is 50 times as large as humans' (*SN: 6/29/24, p. 4*).

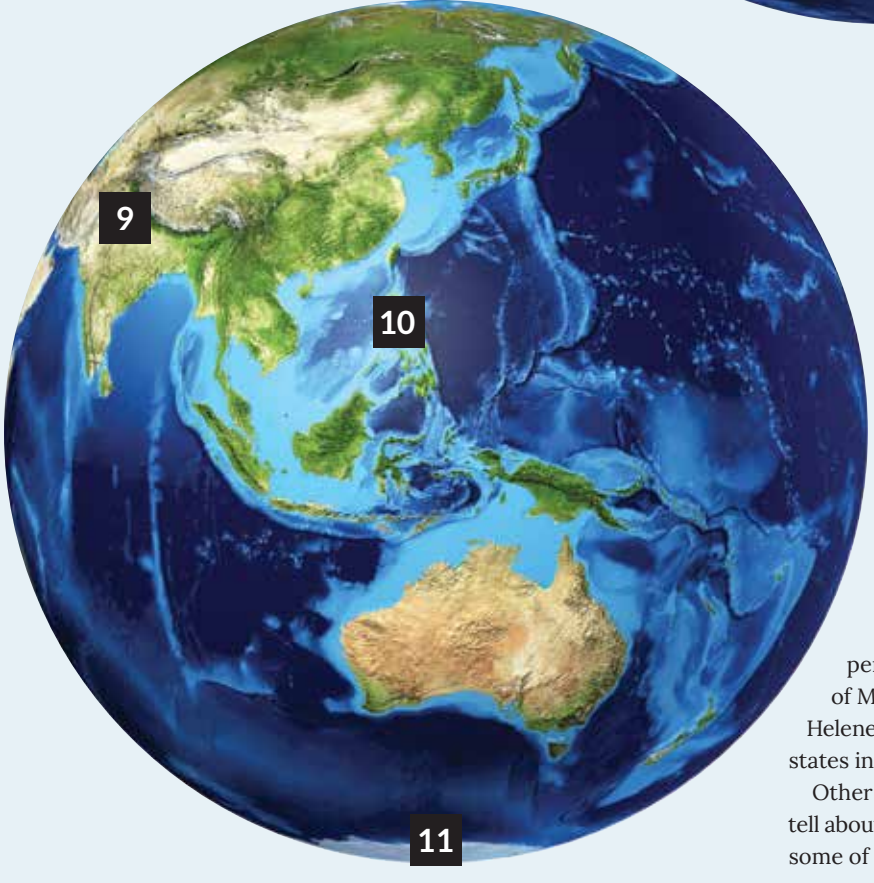
Oldest bioluminescence
Bioluminescence has a new birthday. Ancestors of a group of deep-sea corals glowed in the dark 540 million years ago, scientists say (*SN: 6/1/24, p. 5*). Scientists had thought that animal bioluminescence began about 267 million years ago.

Supersmall knot
Scientists created the smallest molecular knot yet. The string of 54 gold, phosphorus, oxygen and carbon atoms pretzels over itself three times (*SN: 2/24/24, p. 4*).

THE TOLL OF 2024'S HEAT

Scorching temperatures across the world set troubling new records. This is what it felt like

BY CAROLYN GRAMLING AND NIKK OGASA



Over and over, the numbers tell the same story: 2024 was Earth's hottest year on record, knocking the previous record holder—2023—out of the top spot (SN: 12/16/23 & 12/30/23, p. 17). But temperatures alone can't describe the human cost: humidity that challenges the body's ability to cool itself; nighttime temps that rob people of sleep; power outages; wildfire smoke; ruined crops; rising cases of mosquito-borne disease (see Page 26).

Meanwhile, record-breaking water temperatures in the Atlantic Ocean and the Gulf of Mexico fueled hurricanes Helene and Milton. Helene's torrential rains caused flooding across six states in the U.S. Southeast, killing over 200 people.

Other parts of the world have their own stories to tell about the impact of 2024's extreme heat. Here are some of those accounts.

LEONELLO/ISTOCK/GETTY IMAGES

1 PHOENIX | *May–September*
Arizona's capital experienced 113 straight days of daytime temperatures topping 100° Fahrenheit, with hundreds of heat-related deaths recorded. Phoenix has one of the world's largest urban heat-island magnitudes: City temperatures are about 12 degrees higher than those in surrounding rural areas.

2 MEXICO CITY | *May–June*
An extreme heat wave, on top of an extended drought, caused blackouts and was linked to over 120 deaths. The resulting water scarcity raised fears that North America's largest metropolis was just weeks from Day Zero — a theoretical day when the region would run out of water.

3 SÃO PAULO | *August–September*
Extreme heat in the Southern Hemisphere's winter plus prolonged drought fueled wildfires in Brazil's Amazon rainforest. Fine particles in São Paulo's air were 14 times the World Health Organization's recommended limit, causing the city to be ranked as the world's most polluted for four consecutive days, from September 9 to September 12.

A boy in Delhi pours water on himself to cool off during a heat wave in May. The territory set a record-high temperature of nearly 122° F.

A vendor in Manila opens an umbrella to block the sun amid a 15-day heat wave in April. The heat wave would have been impossible without human-caused climate change, scientists say.

4 RIO DE JANEIRO | *March*
During a heat wave in Brazil, the maximum measured temperature reached 107.6° F. But it felt even hotter. The heat index — a measurement that also includes humidity — soared to a record 144.1° F, testing the limits of humans' heat tolerance.

5 PARIS | *July–August*
Temperatures during the Olympics may not have broken records, but they were still scorching. Without climate change, Paris would have been about 5 degrees cooler, researchers determined. That made the Games more dangerous for athletes. Europe is the world's fastest-warming continent, heating at a rate twice the global average.

6 LONGYEARBYEN | *July–August*
August temps in the world's northernmost settlement, on Norway's Spitsbergen Island, were the highest ever recorded for that month, soaring to 68° F — more than 3 degrees higher than the previous record, set in 1997. In July, ice caps there broke the all-time record for daily melting, losing ice at a rate five times the norm.

7 BAMAKO | *February–April*
Heat waves across West Africa's Sahel region caused power cuts and spikes in hospital admissions. From April 1 to April 4, a hospital in Mali's capital recorded a total of 102 deaths; the previous year, the hospital noted 130 deaths for all of April. Climate change amped up daytime highs by 2.7 degrees and kept nights 3.6 degrees warmer than usual.

8 GAZA | *April*
A three-day heat wave exacerbated the humanitarian crisis in Palestine. Nearly 2 million displaced people in refugee camps and overcrowded shelters lacked protection from the heat and faced water and food shortages, power outages, limited access to health care and spikes in waterborne diseases.

9 DELHI | *May–June*
India's capital territory endured 40 straight days of daytime highs reaching 104° F, with a new record set on May 28 of 121.8° F. The unrelenting heat killed over 100 people, the nonprofit organization HeatWatch India estimates.

10 MANILA | *April*
The Philippines' megalopolis of over 14 million people sweltered through a deadly 15-day heat wave, an event that would have been impossible without climate change. The heat brought water shortages, crop losses and school closures.

11 EAST ANTARCTICA | *July*
At winter's peak, temperatures across a big chunk of the continent hovered at –4° F, about 50 degrees higher than normal. The event was the largest temperature anomaly anywhere this year. ■

FROM TOP: AARON FAVILA/AP PHOTO; SONU MEHTA/*HINDUSTAN TIMES*/GETTY IMAGES

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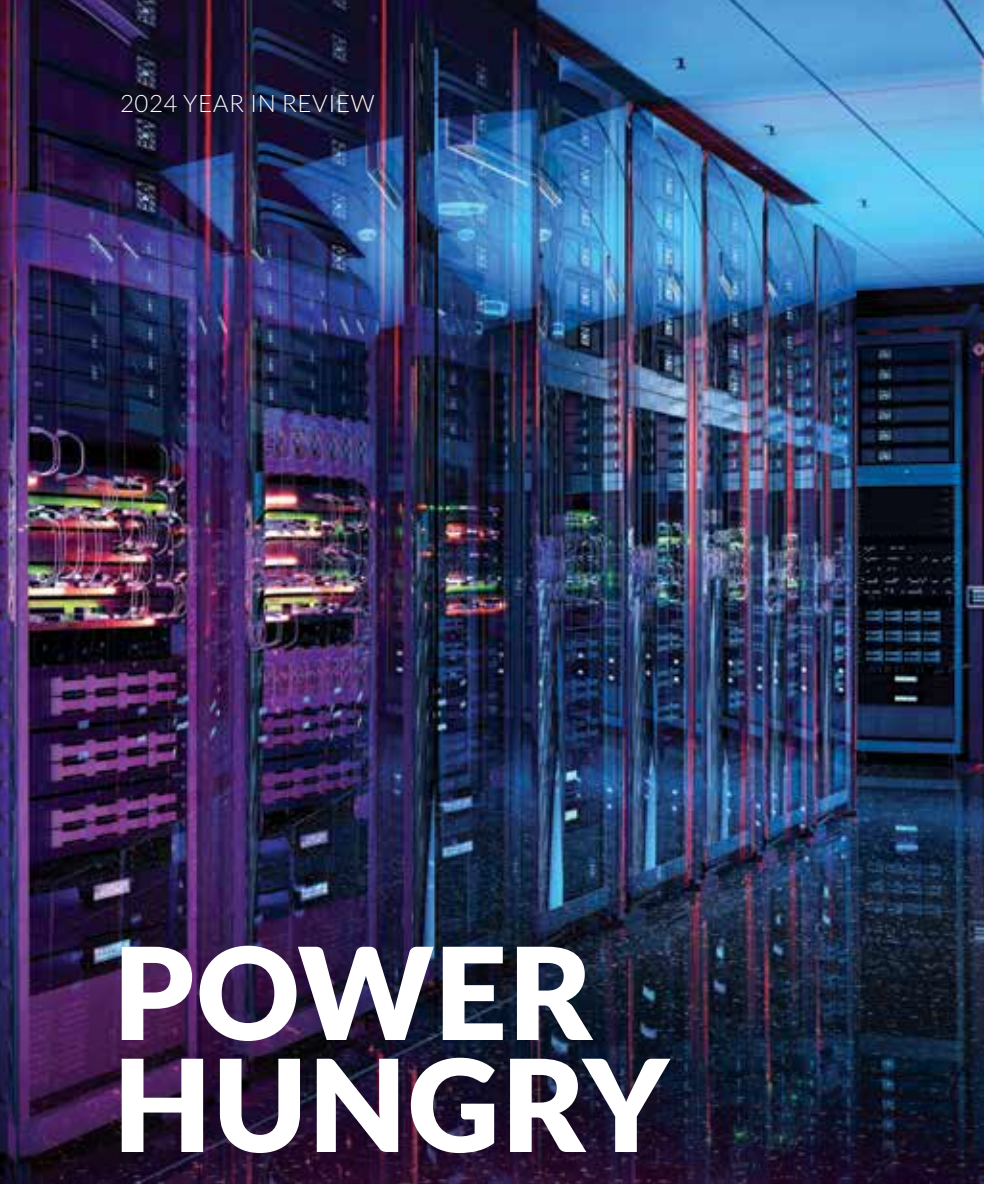


POWER HUNGRY

As the use of generative AI goes up, the need for more data centers and electricity also rises.

QUANTIC69/ISTOCK/GETTY IMAGES

Is the promise of generative AI enough to justify its vast — and growing — energy consumption? **BY LAUREN LEFFER**

It might seem like magic. Type a request into ChatGPT, click a button and — presto! — here's a five-paragraph analysis of Shakespeare's *Hamlet* and, as an added bonus, it's written in iambic pentameter. Or tell DALL-E about the chimeric animal from your dream, and out comes an image of a gecko-wolf-starfish hybrid. If you're feeling down, call up the digital "ghost" of your deceased grandmother and receive some comfort (SN: 6/15/24, *p.* 10).

Despite how it may appear, none of this materializes out of thin air. Every interaction with a chatbot or other generative AI system funnels through wires and cables to a data center — a warehouse full of server stacks that pass these prompts through the billions (and potentially trillions) of parameters that dictate how a generative model responds.

Processing and answering prompts eats up electricity, as does the supporting infrastructure like fans and air conditioning that cool the whirring servers. In addition to big utility bills, the result is a lot of climate-warming carbon emissions. Electricity generation and server cooling also suck up tons of water, which is used in fossil fuel and nuclear energy production, and for evaporative or liquid heat dissipation systems.

This year, as the popularity of generative AI continued to surge, environmentalists sounded the alarm about this resource-hungry technology. The debate over how to weigh the costs against the less tangible benefits that generative AI brings, such as increased productivity and information access, is steeped in ideological divisions over the purpose and value of technology.

Advocates argue this latest revolution in AI is a societal good, even a necessity, that's bringing us closer than ever to artificial general intelligence, hypercapable computer systems that some argue could be a paradigm-shifting technology on par with the printing press or the internet.

Generative AI "is an accelerator for anything you want to do," says Rick Stevens, an associate lab director at Argonne National Laboratory and a computer scientist at the University of Chicago. In his view, the tech has already enabled major productivity gains for businesses and researchers.

One analysis found 40 percent gains in performance when skilled workers used AI tools, he notes. AI assistants can boost vocabulary learning in schools, he adds. Or help physicians diagnose and treat patients, and improve access to medical information, says Charlotte Blease, an interdisciplinary researcher at Uppsala University in Sweden who studies health data. Generative AI might even help city planners cut down on traffic (and reduce carbon emissions in the process), or help government agencies better forecast the weather, says Priya Donti, an electrical engineer and computer scientist at MIT and cofounder of the nonprofit Climate Change AI. The list goes on.

Now, at this critical juncture, experts from fields as varied as economics, computer engineering and sustainability are working to assess the true burden of the technology.

How much energy does AI consume?

ChatGPT and other generative tools are power hungry, says Alex de Vries, founder of the research and consulting agency Digiconomist and a Ph.D. candidate at Vrije Universiteit Amsterdam. "The larger you make these models — the more parameters, the more data — the better they perform. But of course, bigger also requires more computational resources to train and run them, requiring more power," says de Vries, who studies the environmental impact of technologies like cryptocurrency and AI. "Bigger is better works for generative AI, but it doesn't work for the environment."

Training generative AI models to spit out an analysis of Shakespeare or the image of a fantastical animal is costly. The process involves developing an AI architecture, amassing and storing reams of digital data and then having the AI system ingest and incorporate that data — which can amount to everything publicly available on the internet — into its decision-making processes. Honing models to be more humanlike and avoid unsafe responses takes additional effort.

All told, training a single model uses more energy than 100 U.S. homes in a year. Querying ChatGPT uses about 10 times as much energy as a standard online search, according to the International Energy Agency. Composing an email with an AI chatbot can take seven times as much energy as fully charging an iPhone 16, some researchers estimate.

Though training is clearly a big resource suck, when millions of people rely on chatbots for everyday tasks, it adds up, says Shaolei Ren, an electrical and computer engineer at the University of California, Riverside. So much so that the AI sector could soon draw as much energy annually as the Netherlands, de Vries estimated in 2023 in *Joule*. Given generative AI's rapid growth, the current trajectory already exceeds the prediction.

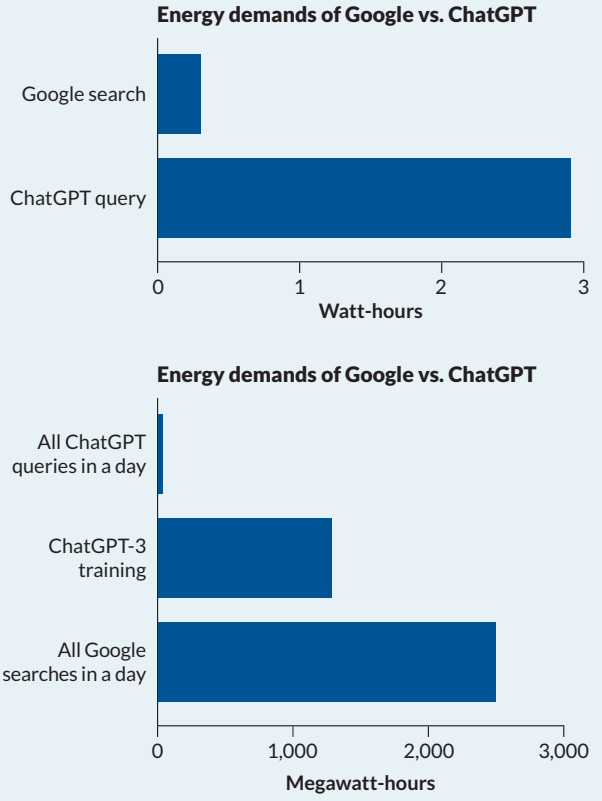
And that's just electricity. Ten to 50 ChatGPT queries use half a liter of water, per a 2023 analysis by Ren and colleagues. That turned out to be a big underestimate too, he says, off by a factor of four.

Some engineers and AI experts dispute these numbers. "I don't understand what the science is behind these [estimates]," says David Patterson, an engineer at Google and professor emeritus at the University of California, Berkeley. "The only way I can imagine getting an [accurate] answer would be with close cooperation with a company like Google."

Before 2022, total energy demand in the United States had been stable for about 15 years. Now it's rising.

Right now, that's impossible. Tech companies release limited information about their data centers and AI models, say de Vries and Ren. So it's hard to precisely assess the cradle-to-grave cost of AI or predict the future. In their estimates, both researchers relied on proxies, such as AI server production numbers from the tech company Nvidia or combining knowledge on data center locations with info from corporate sustainability reports.

Energy hog Answering a single ChatGPT query requires more electricity than a single Google search (top graph). Google search's total daily energy requirements currently surpass ChatGPT's (bottom graph) because it handles an estimated 8.5 billion searches daily compared with ChatGPT's 13 million daily queries. Training a generative AI model like ChatGPT is a huge energy suck, but individual usage over time adds up. SOURCES: IEA, J.G. MEYER *ET AL*/*BIODATA MINING* 2023



Real-world trends, however, do point to AI's voracious energy appetite. For decades before the generative AI boom, efficiency gains have compensated for the growing energy demand that's come with expansions in data centers and computing, says Andrew Chien, a computer scientist at the University of Chicago. That's changed. By the end of 2020, data center expansion began to outpace efficiency improvements, he says. Both Google's and Microsoft's self-reported energy usage more than doubled between 2019 and 2023. ChatGPT's release at the end of 2022 kick-started a generative AI frenzy — exacerbating the issue, Chien says. Before 2022, total energy demand in the United States had been stable for about 15 years. Now it's rising.

"The easiest way to save energy is to not do anything," Patterson says. But "progress involves investment and costs." Generative AI is a very young technology, and stopping now would stymie its potential, he argues. "It's too early to know that [generative AI] won't more than compensate the investment."

A more sustainable path for AI

The decision need not be between shutting down generative AI development entirely or allowing it to continue

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unrestrained. Instead, most experts note there's a more responsible way to approach the technology, mitigating the risks and maximizing the rewards.

Policies requiring companies to disclose where and how they're using generative AI, as well as the corresponding energy consumption, would be a step in the right direction, says Lynn Kaack, a computer science and public policy expert at the Hertie School in Berlin. Regulating uses of the technology and access to it may prove difficult, but Kaack says that's key to minimizing environmental and social harm.

Perhaps not everyone, for instance, should be able to freely produce voice clones and photorealistic images with a single click. Should we pour the same amount of resources into supporting a generative meme machine as we do for running a hurricane forecasting model?

More research into the tech's limitations could also save lots of futile consumption. AI "is very powerful in certain kinds of applications, but completely useless in others," Kaack says.

Meanwhile, data centers and AI developers could take steps to lessen their carbon emissions and resource use, Chien says. Simple changes like training models only when there's ample carbon-free power on the grid (say, on sunny days when solar panels produce an excess of energy) or subtly reducing system performance at times of peak energy demand might make a measurable difference. Replacing water-intensive evaporative cooling with liquid-immersion cooling or other closed-loop strategies that allow for water recycling would also minimize demand.

Each of these choices involves trade-offs. More carbon-efficient systems generally use more water, Ren says. There is no one-size-fits-all solution. The alternative to exploring and incentivizing these options — even if they make it marginally harder for companies to develop ever-bigger AI models — is risking part of our collective environmental fate, he says.

"There's no reason to believe that technology is going to save us," Chien says — so why not hedge our bets? ■

Ancient history

Grizzly details about ancient child sacrifices, a map of a lost city in the Amazon and the answer to a Stonehenge mystery are some of this year's insights into human history **BY MARIA TEMMING**

Bygone brains

Discovering a human brain at an archaeological site is more common than you might think. A new archive catalogs some 4,400 ancient brains that have been found dried out, frozen or otherwise preserved (*SN: 4/20/24, p. 8*). Brains may owe such surprising sturdiness to their chemical makeup.

Egyptian ergonomics

Hunching over scrolls took a toll on ancient Egyptian scribes (*SN: 8/10/24, p. 15*). The skeletons of 30 scribes buried at the Abusir pyramid complex show signs of arthritis and other damage from poor posture.

Stonehenge's Scottish centerpiece

The mysterious Altar Stone at the heart of Stonehenge likely came from Scotland (*SN: 9/7/24 & 9/21/24, p. 10*). Previously thought to share the Welsh origins of other Stonehenge blocks, the stone closely matches the mineral makeup of the Orcadian Basin, a Scottish rock formation.

Pompeii's no good, very bad day

Pompeii's infamous apocalypse was worse than thought (*SN: 8/24/24, p. 15*). When Mount Vesuvius erupted in A.D. 79, it didn't just coat nearby cities with lethally hot gas, ash and rock — it also triggered deadly earthquakes, a study of collapsed buildings and crushed skeletons found.

A lost city no more

Laser scans unveiled the earliest and largest known urban complex in the Amazon (*SN: 2/10/24, p. 7*). Beneath the trees in Ecuador's Upano Valley lie thousands of mounds that were once homes and community spaces, along with remnants of roads and farms. Inhabited from roughly 500 B.C. to A.D. 1500, the city shows how sophisticated Amazonian civilizations were long before European conquest.

Maya sacrifices unmasked

Child sacrifices in a Maya burial chamber on the Yucatán Peninsula were all young boys, DNA shows, upending a theory that women were sacrificed there in fertility rituals (*SN: 7/13/24 & 7/27/24, p. 8*). The boys, sacrificed between A.D. 500 and 900, may have been killed to appease a rain god.

X marks the spot

In a rare case of productive social media scrolling, a researcher identified part of a lost civilization's alphabet in a photo of an engraved slate posted to X (*SN: 7/13/24 & 7/27/24, p. 9*). Found in Spain, the slate is from the Tartessos civilization, which vanished in the fifth century B.C. The writing system is linked to the Phoenician alphabet that shaped Latin, Spanish and English writing. ■

NATIONAL MUSEUM OF DENMARK

HERDER HERITAGE

Yamnaya herders arriving from southwest Asia rewrote Europe's genetic history starting about 5,000 years ago. That's according to DNA from the remains of more than 1,600 ancient people, including this skull with an arrow through the nose. Yamnaya ancestry may contribute to northern Europeans' tall stature, fair skin and vulnerability to multiple sclerosis. Eastern Europeans may have inherited a Yamnaya gene linked to Alzheimer's disease (*SN: 2/10/24, p. 14*).

Health checkup

In the United States, new medical rules took effect and overdose deaths appeared to be on the decline **BY AIMEE CUNNINGHAM**

U.S. drug overdose deaths trended lower

Drug overdose deaths dropped from 113,154 in June 2023 to 96,801 in June 2024, a decrease of 14.5 percent, according to provisional counts from the U.S. Centers for Disease Control and Prevention. It is the largest drop ever recorded for U.S. overdose deaths. Experts are still assessing what contributed to the drop.

COVID-19 is still with us

March marked four years since COVID-19 was declared a pandemic (*SN: 4/6/24, p. 14*). The CDC has loosened isolation guidelines and the virus continues to spread, making people sick. High levels of SARS-CoV-2 in wastewater this summer indicated a spike in infections. Cases are expected to spike again in winter. Updated vaccines are now available and the federal government restarted a program that mails free rapid tests to homes.

Long COVID got an official definition

With the input of patients, the National Academies of Sciences, Engineering and Medicine announced a definition for long COVID (*SN: 7/13/24 & 7/27/24, p. 13*). The condition persists for at least three months after infection, affects any organ or system in the body and can include over 200 symptoms. An official definition may help with diagnosis and treatment.

Nasal spray for severe allergic reactions gained approval

The first epinephrine nasal spray for adults and kids who weigh 30 kilograms or more got the nod from the U.S. Food and Drug Administration (*SN Online: 8/27/24*). The prescription spray, sold under the brand name Neffy, treats severe allergic reactions including anaphylaxis.

Sensitive exams require informed written consent

Hospitals must document a patient's informed consent to conduct breast, pelvic, prostate and rectal exams that aren't medically necessary (*SN Online: 4/24/24*). The new federal guidance came in response to ethical concerns over unauthorized exams done for training purposes on patients under anesthesia.

A new rule for mammograms

Mammography reports must now include whether the patient has dense breast tissue, according to the FDA. Having dense breasts modestly increases the risk of a cancer diagnosis but is just one component of overall risk (*SN Online: 3/10/23*). ■

VIRAL SURGES

Multiple infectious disease outbreaks flared up around the world

BY ERIN GARCIA DE JESÚS

Mpox sparked a global emergency

A surge of mpox cases across Central Africa reached a tipping point that prompted the World Health Organization to declare the outbreak a public health emergency of international concern in August (SN: 9/7/24 & 9/21/24, p. 6).

Mpox, which can cause fever, muscle aches and a hallmark rash with painful pus-filled lesions, has long been a problem in parts of Africa. The Democratic Republic of Congo, where the first case was reported in 1970, is the center of the current outbreak. This year, the virus that causes mpox spread to previously unaffected countries including Burundi, Kenya, Rwanda and Uganda.

As of November 17, there have been more than 50,000 confirmed and suspected cases in 20 countries and 54 deaths in 2024. Children have been particularly hard hit.

Since late August, more than 170,000 vaccine doses have been distributed to Nigeria, Congo and Rwanda. On November 19, the United Nations authorized the first mpox vaccine for children age 1 and older.

The Africa Centres for Disease Control and Prevention estimates that around 10 million vaccine doses are needed to bring the outbreaks under control.

FROM TOP: ANDRESSA ANHOLETE/GETTY IMAGES; JOSEPH PREZIOSO/AFP/GETTY IMAGES; ARS PHARMACEUTICALS INC.

A health worker in Brazil sprays insecticide at a mall to kill dengue-carrying mosquitoes. Of more than 12 million cases globally this year, most occurred in the Americas.

Bird flu made the jump to cows

The H5N1 outbreak that began spreading globally in 2021 continued to infect myriad wild birds, poultry and mammals this year (SN: 2/24/24, *p.* 14). And in late March, the virus jumped to an unexpected new animal: dairy cows.

The ongoing outbreak in U.S. dairy cows has hit more than 400 herds in 14 states, with infections causing symptoms such as reduced milk production and lack of appetite. The virus infects cows' mammary glands, and studies suggest that contaminated milking equipment helps spread H5N1 from cow to cow (SN: 8/24/24, *p.* 9). High temperatures kill the virus, so pasteurized milk and cooked beef are safe to eat.

As of November 20, 52 farm workers have tested positive for the virus after exposure to infected livestock. In August, one person in Missouri contracted the virus despite having no contact with cows or poultry. Another person living in the same household showed signs of a past infection, the U.S. Centers for Disease Control and Prevention announced in October. The finding hints that the virus can sometimes, but rarely, spread person-to-person through very close contact. Researchers are keeping a close eye on whether new mutations arise that could help the virus spread easily among people.

Dengue cases soared

It was a record year for dengue fever, a disease transmitted by mosquitoes. The Americas have amassed about 12 million cases as of October 29. That's roughly 94 percent of the 12.7 million cases recorded around the world. Cases in the Americas alone are also more than double the previous global record of 5.3 million cases reported by the WHO just last year.

Climate change, El Niño and urbanization may have played a part in the massive outbreak, according to the WHO.

Rising temperatures may have boosted dengue transmission by around 18 percent in the Americas and Asia compared with what levels would have been in a world without warming, scientists reported in a paper posted this year at medRxiv.org. Depending on how high the average global temperature gets by 2050, transmission could become 40 to 57 percent higher on average than expected without climate change.

Triple E hit the East Coast

Health officials recorded 16 cases of eastern equine encephalitis, or Triple E, across eight states along the U.S. East Coast. This mosquito-borne viral infection pops up every year in eastern and Gulf Coast states. The virus normally circulates in waterfowl, and occasionally makes the jump to horses and people. Most human cases go undetected because most people don't develop symptoms. Those who do might have fever, body aches and joint pain. But in about 5 percent of cases, the virus invades the central nervous system, causing headaches, seizures or behavioral changes. About a third of people with severe disease die. All reported cases in 2024 were neuroinvasive, and three people died.

Oropouche fever became deadly

The Pan American Health Organization issued a health alert in August after an increase of confirmed cases of Oropouche fever. The virus that causes the disease — which is spread via insect bites and typically presents flulike symptoms — hit new parts of South America and the Caribbean. Guyana, the Dominican Republic and Cuba all reported their first-ever cases, as did some Brazilian states. It also became deadly for the first time, causing two fatalities and a stillbirth in Brazil this summer (SN: 11/30/24, *p.* 15). ■

A health care worker gives a child in Gaza an oral vaccine for polio in October during a World Health Organization campaign.

WHO

POLIO REARED ITS HEAD IN GAZA

In September, the WHO launched a massive polio vaccination campaign across Gaza after wastewater samples tested positive for poliovirus and an infected 10-month-old boy developed paralysis in his left leg. Because paralysis from polio is rare, a single case suggests hundreds of other infections. Israel's military offensive against Hamas has destroyed much of Gaza's health care and water treatment infrastructure, which has likely helped the virus to spread. Overall, 556,774 kids were fully vaccinated, a coverage rate of 94 percent, the WHO reported in November. Intense bombardment and mass displacement in northern Gaza cut off access to many areas, leaving up to 10,000 children there not fully vaccinated.

Europa Clipper (illustrated), which launched in October, will probe one of Jupiter's moons for signs of habitability.

SPACING OUT

Spacefaring robots and humans had us on the edge of our seats this year. Here's the latest status of space missions that made headlines in 2024 **BY LISA GROSSMAN**

New lunar visitors

The moon has been a hot destination for space agencies and private companies in recent years, and 2024 was no exception.

In January, Japan's SLIM spacecraft made a successful but lopsided precision landing on a crater's rim, marking the country's first soft landing on the moon. The solar-powered Smart Lander for Investigating the Moon was designed to collect data for one lunar day, or about two weeks on Earth, before night fell and it got too dark and cold to survive. But SLIM surprised everyone by sending signals to Earth for three months.

SLIM was joined by another sideways lander in February. Odysseus, built by Houston-based Intuitive Machines, touched down and toppled over near the lunar south pole. During its six-day mission, the probe sent back data that may be instructive for NASA's Artemis mission, which aims to land humans on the moon in 2026 (SN: 3/23/24, *p.* 16).

Finally, China's Chang'e 6 spacecraft grabbed the first samples from the farside of the moon in June (SN: 6/29/24, *p.* 12). The first look at the samples revealed soil that's fluffier than soil from the nearside. A chemical analysis of the samples, reported in *Nature*, suggests the farside was volcanically active some 2.8 billion years ago (SN *Online*: 11/15/24).

Private spaceflight highs and lows

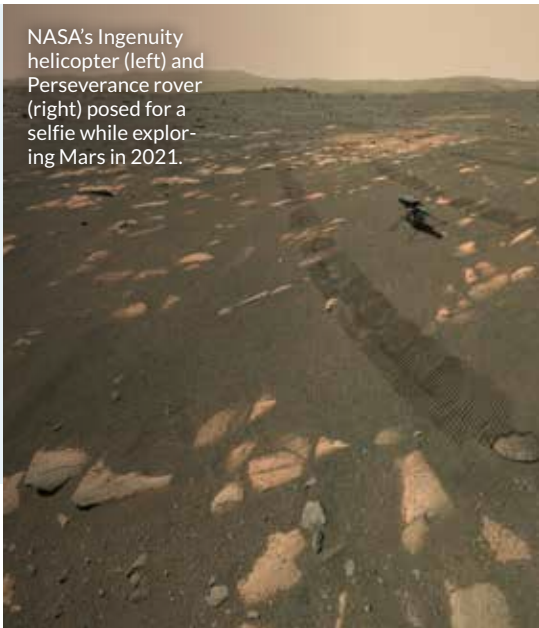
Four years after SpaceX became the first private company to launch astronauts to the International Space Station, the company supported another commercial milestone: the first all-civilian spacewalk. The Polaris Dawn mission launched four astronauts to the space station in September. The crew tested new SpaceX spacesuits and collected data on radiation and the astronauts' physiology.

Another company had a rougher time of it. Boeing's Starliner spacecraft launched astronauts Sunita Williams and Butch Wilmore to the space station in June for an eight-day mission, but problems with the spacecraft's thrusters delayed their return. Starliner returned to Earth in September without its crew. The pair will remain on the space station until February, when a SpaceX Dragon spacecraft will bring them home.

MOMENTS ON MARS

2024 opened with a farewell to a beloved Mars explorer. NASA's Ingenuity was the first helicopter to operate on the Red Planet. The craft was supposed to fly a few times over the course of 30 days; instead, it took 72 flights over almost three years. The airborne explorer was finally grounded in January after its rotor blades were damaged.

Ingenuity's companion, the Perseverance rover, made perhaps its most important discovery yet in July: a rock containing hints of ancient microbes (see Page 30). But the discovery came against a backdrop of uncertainty. The budget for NASA's planned Mars Sample Return mission is in jeopardy (*SN: 6/15/24, p. 12*), which means the rock might not make it to Earth for further study.



NASA's Ingenuity helicopter (left) and Perseverance rover (right) posed for a selfie while exploring Mars in 2021.

FROM TOP: JPL-CALTECH/NASA; JPL-CALTECH/NASA, MSSS

End of an asteroid-hunting era

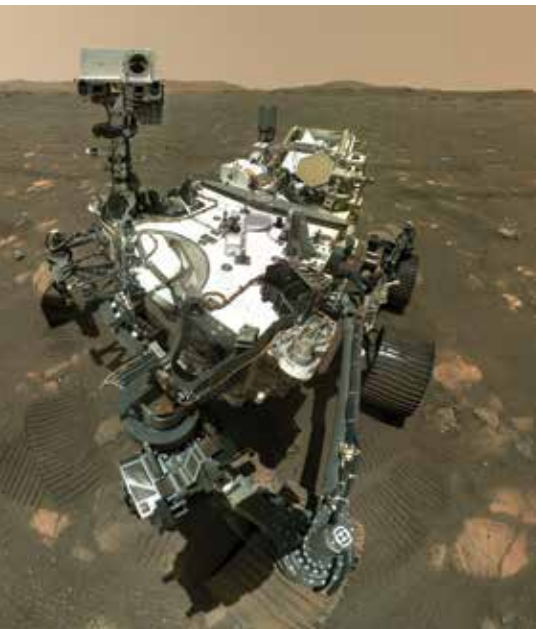
Earth lost a planetary protector this year. In August, NASA said goodnight to the NEOWISE probe after it spent more than a decade scanning the sky for threatening asteroids. Over its lifetime, NEOWISE observed thousands of asteroids and hundreds of comets, giving scientists a more precise sense of the dangers these space rocks pose to Earth. The telescope's loss leaves us somewhat in the dark, but not for too long. Another asteroid hunter, NEO Surveyor, is slated to launch no earlier than 2027.

New views of Mercury

The BepiColombo spacecraft made a close flyby of Mercury on September 4, getting its first view of the planet's south pole. Another flyby this year gave the joint European and Japanese probe views of Mercury it won't have once it enters the planet's orbit in 2026. BepiColombo approached from Mercury's night side, so crater rims cast deep shadows that could reveal new details about their topography. The next flyby will be on January 8.

Europa, ahoy!

NASA's Europa Clipper spacecraft launched on October 14, bound for an icy moon of Jupiter that may have the conditions for life to exist (SN: 11/2/24, p. 4). Once Clipper arrives at Jupiter in 2030, the spacecraft will make nearly 50 flybys of the moon to study its subsurface ocean. Due to intense radiation around Europa, Clipper will take data and then back off to recover before getting close again. ■



WHALE: PAUL SOUDERS/CORBIS/GETTY IMAGES

Astounding animals

Dispatches from the animal kingdom that drove us wild in 2024 include reports of theatrical snakes, acrobatic leeches, forehead-wobbling whales and more **BY DARREN INCORVAIA**

EXPRESSIVE WHALES You can learn a lot about a beluga (*Delphinapterus leucas*) by watching its forehead. During social interactions, belugas in captivity mold their melons — fat deposits on the head used for echolocation — into five distinct shapes (*SN: 6/1/24, p. 9*). Scientists suspect that the squishy shapes are purposeful communications.

Playful pets

Say the name of your dog's favorite toy, and she might be perplexed if you produce another plaything instead. When shown an unexpected toy, dogs' brains generate a signal that in humans indicates surprise. The finding suggests canines form mental images of objects (*SN: 4/20/24, p. 11*). Dogs aren't the only pets who love a good time. Many felines play fetch, but only when they feel like it, a survey found (*SN: 2/10/24, p. 5*).

Feathered flourish

Japanese tits (*Parus minor*) flutter their wings to tell mates to enter the nest first, a gestural communication never-before-seen in birds (*SN: 4/20/24, p. 10*).

Solving a mammoth mystery

The last woolly mammoths died out 4,000 years ago on Wrangel Island, off the coast of Siberia. Inbreeding has been blamed for their demise, but an analysis of 21 mammoth genomes suggests the population was robust and probably died from a natural disaster (*SN: 8/10/24, p. 9*).

Leaping leeches

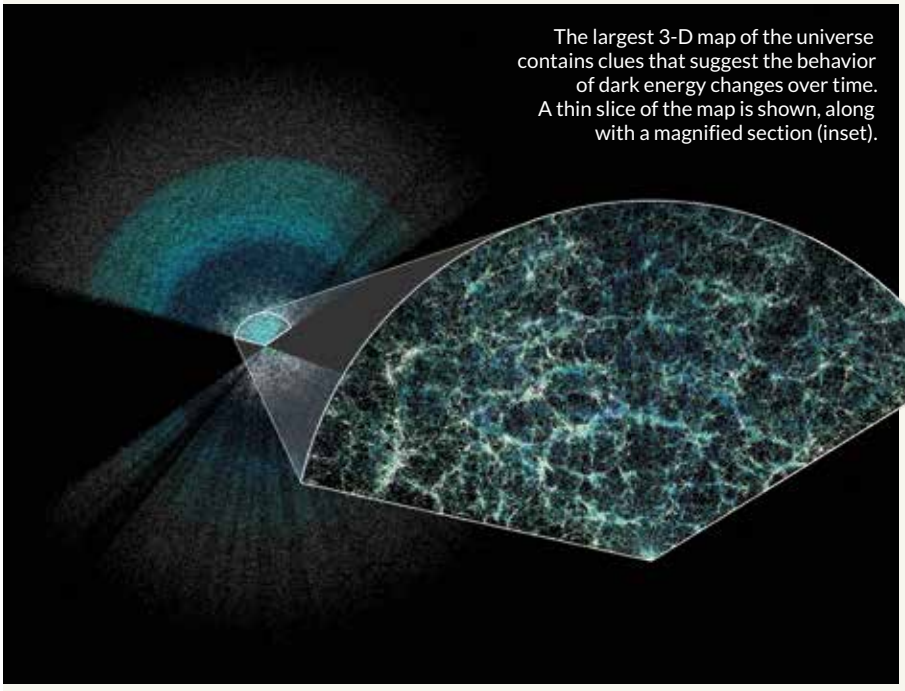
Can leeches leap? A 2017 cell phone video by a researcher may provide the answer. The video captures a leech in Madagascar coiling up and launching itself off of a leaf and onto the ground (*SN: 7/13/24 & 7/27/24, p. 11*).

Fake it 'til you make it

For the dice snake (*Natrix tessellata*), overacting pays off. When caught by a predator, the reptile feigns death by thrashing, pooping, sticking out its tongue and filling its mouth with blood. Using all of these tricks rather than just one or two seems to decrease the time needed to play dead before a predator moves on (*SN: 6/15/24, p. 11*).

Got milk?

Mammals have cornered the market on milk, but a wormlike amphibian has its own twist on the drink. Ringed caecilians (*Siphonops annulatus*) feed their offspring a milklike liquid that's made in the reproductive tract (*SN: 4/6/24, p. 10*). Mothers also offer up their own skin as a snack. Milk and cookies, anyone? ■



The largest 3-D map of the universe contains clues that suggest the behavior of dark energy changes over time. A thin slice of the map is shown, along with a magnified section (inset).

Only time will tell

Scientists turned up a slew of findings this year that could be a big deal — if they're the real deal **BY MARIA TEMMING**

Martian microbes, maybe

Alien microbes may have once made their home on Mars (*SN: 8/24/24, p. 6*). In July, NASA's Perseverance rover uncovered a rock on the Red Planet that sports white spots with black rings laced with iron phosphate (see Page 28). On Earth, such specks have been linked to ancient microbial life. But they're not surefire signs of microbes. The only way to know for certain is to bring the rock back to Earth for closer inspection.

Sparking superconductivity

Light may be the secret ingredient for making superconductors that don't require frigid conditions. In an experiment, blasting a copper and oxygen compound with a laser caused the material to throw off magnetic fields. That magnetism, the scientists say, is a smoking gun for superconductivity — the ability to ferry electricity with no resistance (*SN: 8/10/24, p. 6*). But skeptics contend that those magnetic fields might have arisen from some other, unknown physics.

Ancient engineering

Builders used a water-powered elevator to construct Egypt's first pyramid nearly 4,700 years ago, researchers propose (*SN: 9/7/24 & 9/21/24, p. 11*). That controversial idea is based on a computer model of structures in and around the Step Pyramid of Djoser. Controlling the flow of floodwater in and out of a shaft inside the pyramid could have lifted and lowered a block-hoisting platform, the model shows. But critics argue that occasional rains wouldn't have supplied enough water to sustain such a system.

Shedding light on dark energy

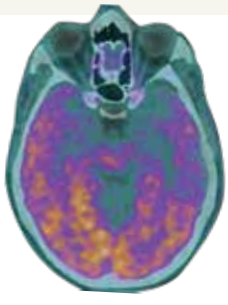
Dark energy may have gotten even more mysterious. The enigmatic stuff, which makes up the bulk of the cosmos, is generally thought to maintain a constant density. But new observations of 6.4 million galaxies and quasars from the Dark Energy Spectroscopic Instrument, or DESI, paired with data on exploding stars, cast doubt on that idea. These data more closely fit a model of the universe in which the relationship between dark energy's density and its pressure changes over time (*SN: 5/4/24 & 5/18/24, p. 6*). If confirmed, this finding would rewrite the history of the universe. Experts are withholding judgment until DESI completes its survey of over 30 million other galaxies (see Page 7).

Tectonic shake-up

Plate tectonics got off to an early start in Earth's history, a rock in South Africa suggests. Layers in the rock bear scars of 3-billion-year-old landslides that may have been caused by an earthquake (*SN: 4/6/24, p. 6*). That quake, scientists say, could have been triggered by slabs of crust colliding. The finding lends support to the contested idea that plate tectonics dates back more than 2.8 billion years. But other geologists are not convinced that this quake marks the start of global plate tectonics.

Medium size, maximum hype

For the first time, astronomers may have spotted a midsize black hole in our galaxy (*SN: 8/10/24, p. 7*). Telescope data suggest that a black hole at least 8,200 times as massive as the sun lurks in the star cluster Omega Centauri. But another study disputes the claim. Instead, the star cluster could harbor a horde of smaller black holes (*SN Online: 8/20/24*). ■



SPREADING ALZHEIMER'S?

Alzheimer's disease may spread from one person to another under extremely rare conditions (*SN: 2/24/24, p. 6*). Five people who received contaminated growth hormone injections as kids later developed early-onset Alzheimer's — most likely because the hormones were tainted with amyloid-beta, a protein whose buildup (purple in the bran scan above) is linked to the disease. But it's possible the health issues the hormones were meant to treat led the patients to develop Alzheimer's.

FROM TOP: CLAIRE LAMMAN/DESI COLLABORATION, CUSTOM COLORMAP PACKAGE BY CMASTRO; G. BANERJEE *ET AL*/*NATURE MEDICINE* 2024

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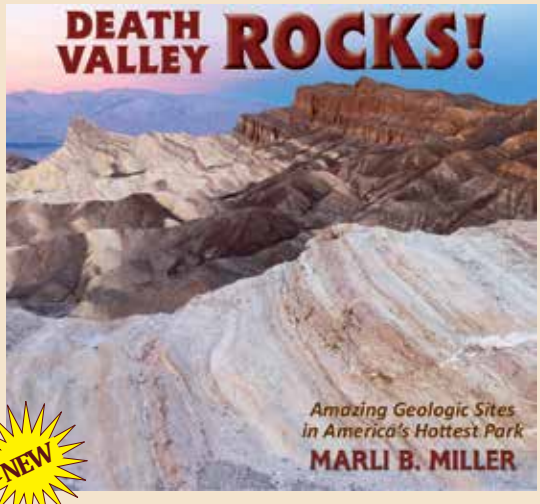

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MARLI B. MILLER

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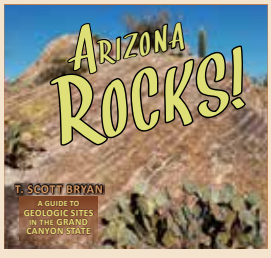

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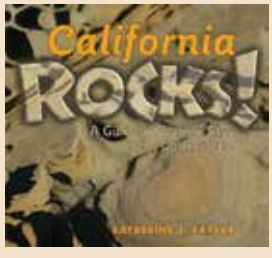

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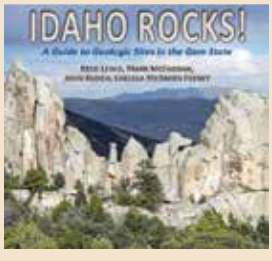

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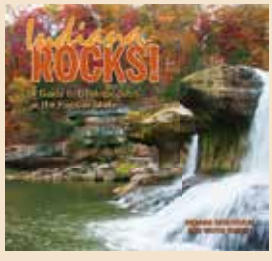

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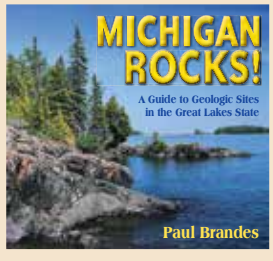

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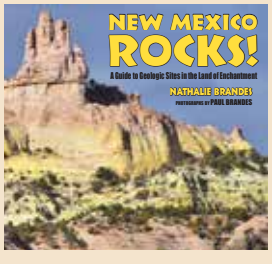

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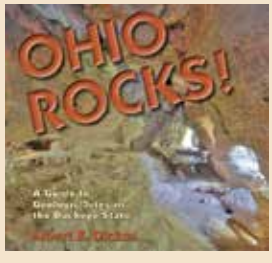

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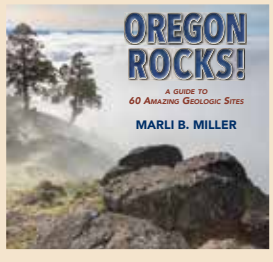

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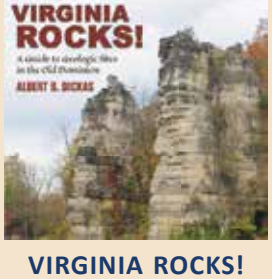

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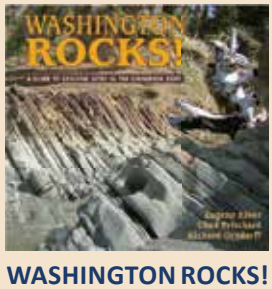

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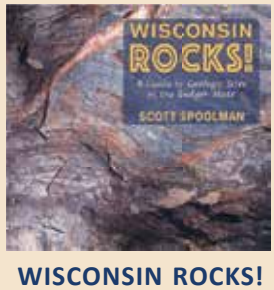

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TOP MOMENTS

2024 was another extraordinary year for Society for Science, publisher of Science News. We honored many of the top young STEM innovators in our country, reported breakthrough research and supported educators. Here are some of our favorite moments.

Connecting with the International Space Station
NASA astronaut Jeanette Epps took time away from her mission to speak virtually with attendees at Regeneron International Science and Engineering Fair.

Reporting on the Great American Eclipse
Science News, Science News Explores and Science News Learning covered every facet of the eclipse, from tips for safe viewing to explaining why this eclipse was so special to citizen science efforts.

Supporting Middle School Scientists
Tina Jin, 13, from San Jose, Calif., won the $25,000 top award in the Thermo Fisher Scientific Junior Innovators Challenge for her water filtration system using animal bone waste, as well as her leadership, collaboration and critical thinking skills.

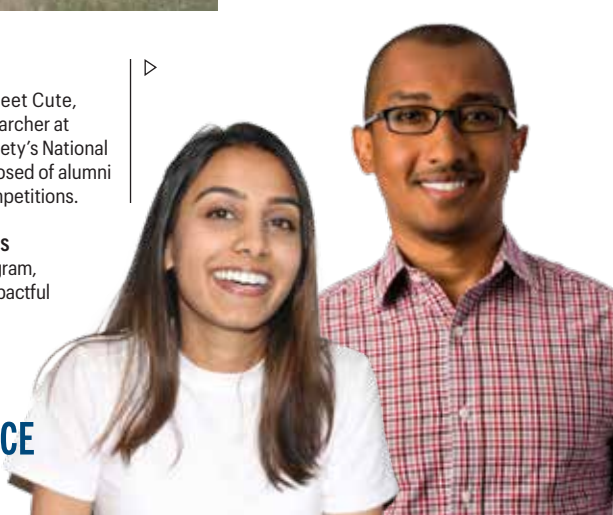
Earning Prestigious Awards
The Science News special project Electricity Saved My Brain was honored twice by the prestigious Online News Association Awards in the Features Category and the Sports, Health and Wellness Category for Small/Medium Newsrooms.

Identifying Tomorrow's STEM Leaders
Achyuta Rajaram, 17, of Exeter, N.H., won first place in the Regeneron Science Talent Search for developing an automatic method to discover which parts of a computer model are involved in decision making.

Celebrating 10 Years of the Advocate Program
The Society selected 100 educators for the Advocate Program, which seeks to expand access and opportunities for STEM students. Over the last decade, 398 educators have participated in the program, supporting more than 7,000 students.

Welcoming New Leaders
Naomi Shah, founder and CEO of Meet Cute, and Lester Mackey, a principal researcher at Microsoft Research, joined the Society's National Leadership Council, which is composed of alumni of the Society's STEM research competitions.

Promoting STEM Opportunities
Through the STEM Action Grant program, the Society gave $320,500 to 66 impactful nonprofit organizations that will expand opportunities for historically underrepresented groups in STEM.



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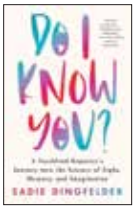
BOOKSHELF

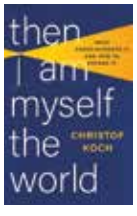
Our favorite books of 2024

Books contemplating the human experience and some of humankind's greatest challenges were among the *Science News* staff's favorite reads this year. What were your favorites? Let us know at feedback@sciencenews.org.

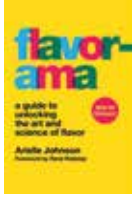
Night Magic
Leigh Ann Henion
As artificial light increasingly illuminates nighttime, a writer makes the case to preserve natural darkness and the ecosystems and life-forms it nurtures, from spotted salamanders to glowworms and bioluminescent fungi (*SN: 10/5/24, p. 28*). *Algonquin Books, $30*



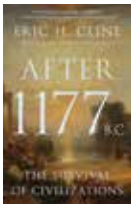
Do I Know You?
Sadie Dingfelder
A science journalist who can't recognize faces, perceive depth or visualize images in her mind takes readers along on her journey to understand her quirky brain. The hilarious and philosophical memoir is a reminder that our ways of perceiving the world are not uniform (*SN: 6/29/24, p. 28*). *Little, Brown Spark, $32*



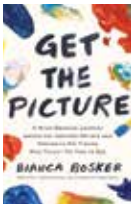
Then I Am Myself the World
Christof Koch
A neuroscientist argues that information integration in the brain is what makes humans conscious. The idea provocatively suggests that any system that integrates information, including computers, has the potential for some level of consciousness (*SN: 8/10/24, p. 28*). *Basic Books, $30*



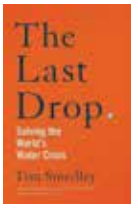
Flavorama
Arielle Johnson
Complete with colorful illustrations and fun recipes, this delicious tome digs into the science behind flavor. Reading it just might transform your skills in the kitchen (*SN: 4/20/24, p. 29*). *Harvest, $40*



After 1177 B.C.
Eric H. Cline
An archaeologist describes how the Late Bronze Age collapse transformed societies across the Eastern Mediterranean and Near East, with some experiencing hardship and decline while others flourished amid the chaos (*SN: 6/15/24, p. 29*). *Princeton Univ., $32*



Get the Picture
Bianca Bosker
Wielding science as a tool, a journalist sets out to understand humankind's primal desire for art, as well as art's expanding utility in the modern world. Along the way, she immerses herself in the exclusive and bizarre art world (*SN: 4/6/24, p. 29*). *Viking, $29*



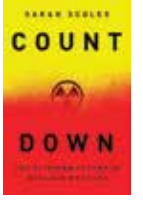
The Last Drop
Tim Smedley
Human mismanagement and climate change are fueling water crises around the globe. This book offers potential solutions, from agricultural and at-home remedies to policy changes, as well as a reminder to value every last drop of water as precious (*SN: 7/13/24 & 7/27/24, p. 33*). *Picador, $29.99*

The High Seas
Olive Heffernan
People are increasingly staking claims to international waters to exploit resources. A science journalist sounds the alarm for sustainable practices and the preservation of the ocean's rich ecosystems (*SN: 5/4/24 & 5/18/24, p. 40*). *Greystone Books, $32.95*

Turning to Stone
Marcia Bjornerud
A seasoned structural geologist reflects on her life story and the rich wisdom of Earth's rocks in this book that is part memoir, part geology explainer, part meditation on science and society (*SN: 8/24/24, p. 28*). *Flatiron Books, $29.99*

How to Kill an Asteroid
Robin George Andrews
What will it take to protect Earth from a destructive asteroid? A science journalist takes stock of the tools humankind already has in its asteroid preparedness arsenal, including the defensive strategy demonstrated by NASA's successful DART mission, and what else is still needed (*SN: 11/30/24, p. 26*). *Random House, $29.99*

Our Moon
Rebecca Boyle
This veneration of our celestial companion lays out how the moon has shaped life on Earth and molded the planet into a hospitable home. The moon's influence on human societies, both culturally and spiritually, as well as the threats humankind's material ambitions pose for the moon's well-being, also take center stage (*SN: 2/10/24, p. 28*). *Random House, $28.99*



Countdown
Sarah Scoles
Interviews with physicists tasked to maintain and modernize the United States' aging nuclear stockpile, as well as with other researchers and activists in that orbit, reveal the intense and often heavy feelings of those in the nuclear weapon industry. These conversations ponder the industry's contradictory existence to promote peace through destructive weapons and the future of nuclear research (*SN: 3/9/24, p. 28*). *Bold Type Books, $30*

Online favorites of 2024

Science News drew millions of visitors to our website this year. Here's a look back at the most-read and most-watched online news stories of 2024.

SOCIAL MEDIA

Top TikTok

Not only was news about the psychedelic drug psilocybin among our most-read stories of the year, it also topped TikTok. In our most popular video, *Science News Explores* assistant managing editor Maria Temming explains that a high dose of the drug can temporarily scramble a person's unique default brain activity. Watch the video at bit.ly/SN_TikTok24

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Top news stories

1 DNA from old hair helps confirm the macabre diet of two 19th century lions

Genetic analysis of old hair stuck in the maws of two famed lions reveal the beasts' diet. Dubbed the "man-eaters of Tsavo," the lions roamed Kenya more than a century ago, snacking on giraffe, oryx, zebra, waterbuck, wildebeest and, yes, humans. The method of analysis could help scientists re-create the dining habits of other long-dead predators (*SN Online: 10/11/24*).

2 Geoscientists found the most dangerous part of a famous West Coast fault

Seismic data reveal that the Cascadia megathrust, a massive fault in the Pacific Northwest, is not a single, continuous fracture, but rather composed of at least four segments. The most dangerous segment appears to stretch from off the coast of southern Vancouver Island through the state of Washington (*SN: 7/13/24 & 7/27/24, p. 6*).

3 Why the 2024 total solar eclipse will be such a big deal

The April 8 solar eclipse visible over North America was extraordinary, even by solar eclipse standards. The moon was at a point in its orbit that brought it quite close to Earth. The sun was also close to its peak activity, known as solar maximum. This confluence of factors gave spectators an especially dark and long eclipse and scientists an exciting opportunity to study the sun (*SN: 3/9/24, p. 24*).

4 Social media harms teens' mental health, mounting evidence shows. What now?

While evidence grows for the harmful effects of social media on adolescent mental health, more rigorous research is needed to examine the mechanisms behind this potential causal link and why certain groups are more at risk of harm. Only then can policy makers, health professionals, parents and other adults help safeguard young people online (*SN: 3/9/24, p. 14*).

5 Psilocybin temporarily dissolves brain networks

The psychedelic drug psilocybin briefly erases people's neural fingerprints, the baseline brain activity unique to an individual. Some of the biggest changes occur in an area called the default mode network, which may play a role in creating a sense of self. Most of the drug's effects typically go away within a day. A better understanding of psilocybin could lead to better mental health treatments (*SN: 8/10/24, p. 12*).

PEDRO MIGUEL ARAUJO

How parrot plumage gets its vibrant colors

One enzyme has a key role in determining whether parrots' rainbow plumage emerges in vibrant reds, yellows or greens, a new study reports.

Parrot feathers, such as those of a scarlet macaw (*Ara macao*) shown above, flaunt an array of colors. Yellow, red and orange hues are made possible by pigments called psittacofulvins, found only in parrots. Blue tones come from nanostructures on feathers — which can appear green when combined with yellow psittacofulvins — and melanin controls black, gray and brown colors (*SN: 3/9/24, p. 5*).

Until now, it's been unclear how psittacofulvin pigments shift a feather's shades as it develops. Previous research has shown that an enzyme called PKS makes red aldehyde-based psittacofulvins, says Joseph Corbo, a biologist at Washington University School of Medicine in St. Louis. Turns out, a second enzyme comes in as a second step, switching reds to yellows.

The enzyme ALDH3A2 alters the chemical composition of the pigments, which are molecules made primarily of carbon and hydrogen atoms, to control color in developing feathers, Corbo and colleagues report in the Nov. 1 *Science*. Through a chemical process called oxidation, the enzyme turns red aldehyde molecules into yellow carboxylic acids.

To crack the color code, the researchers turned to the dusky lory (*Pseudeos fuscata*), a parrot species that comes in red and yellow varieties, and rosy-faced lovebirds (*Agapornis roseicollis*), which have both red and green feathers.

Chemical and genetic analyses of the parrots revealed that ALDH3A2 is more active in yellow and green feathers than in red ones, suggesting that the enzyme helps developing feathers swap colors. What's more, the ratio of aldehyde- to carboxylic acid–containing molecules can create a sliding scale of colors, the team found. For instance, equal ratios of red and yellow molecules should produce orange feathers, Corbo says.

Yellow feathers topped with blue nanostructures make rosy-faced lovebirds' feathers green, while blue with red psittacofulvins could create purple, Corbo says. When factoring in melanin, parrot feathers have "many different ways of mixing and matching these different types of pigments to achieve sometimes unusual colors."

Parrot psittacofulvins are chemically very similar to carotenoids, pigments that other birds, including bright red cardinals, get from their diet. It raises the question of why parrots evolved to use psittacofulvins, Corbo says. "Are these molecules better than carotenoids in some way?"

One hypothesis is that psittacofulvins create feather colors that are more durable than do pigments that need to be replenished through diet, meaning brilliant parrot plumage doesn't easily fade. — *Erin Garcia de Jesús*

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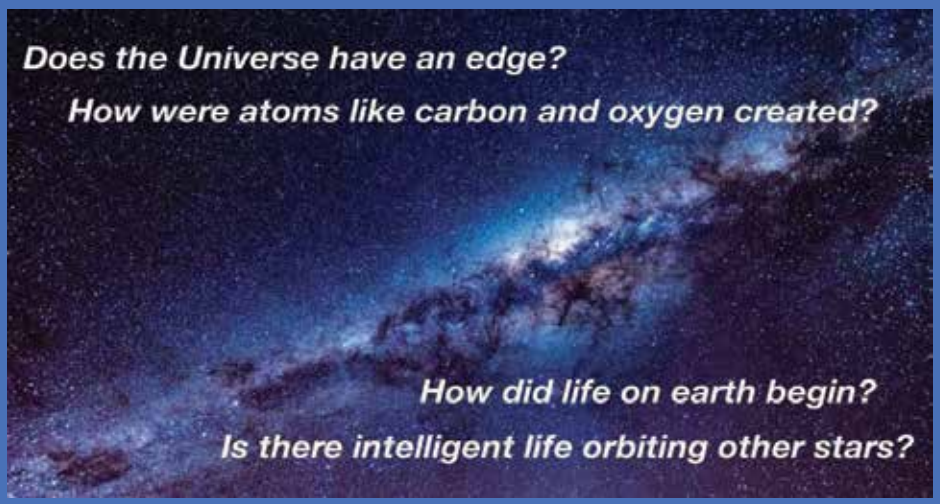

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