Chatbots Blunt Conspiracy Beliefs | Bat Toes Glow in the Dark

ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ OCTOBER 19, 2024

Democracy in Decline?

How political scientists measure the health of a republic

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

CONGRATULATIONS to the 2024 Finalists!

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

Maedot Tinsae Ayalew
Arlington, Virginia

Carina Andreea Bobulescu
New York, New York

Oliver Nicolas Cottrell
La Jolla, California

Zealand Murphy Dobrowski
Missoula, Montana

Giselle Drewett
Palo Alto, California

Parker Flynn
Charlottesville, Virginia

Alexander Godsey
Honolulu, Hawaii

Dalia Habib
Salt Lake City, Utah

Arya Gowri Hirsave
Austin, Texas

Sophia Hou
Livingston, New Jersey

Olivia Huang
Englewood Cliffs, New Jersey

Brody Jaworski
Keller, Texas

Tina Jin
San Jose, California

Mikah Elizabeth Kaalund
Greenwich, Connecticut

Samvith Mahadevan
Austin, Texas

Tyler Malkin
Greenwich, Connecticut

Jocelyn Mathew
Anaheim, California

Yash Mehta
Durham, North Carolina

Gary Allen Montelongo
La Joya, Texas

Samhita Paranthaman
Mason, Ohio

Anushka Sable
Decatur, Georgia

Leif Speer
Terre Haute, Indiana

Rhea Sreedhar
Anaheim, California

Jairam Susarla
Sugar Land, Texas

Sophie Tong
Palo Alto, California

Hiruni Wansapura
Plano, Texas

Ezekiel Wheeler
Portland, Oregon

Mackensey McNeal Wilson
Riverside, Connecticut

Aiden Yun
Hillsborough, California

Sophia Yuxin Zhang
Salt Lake City,Utah

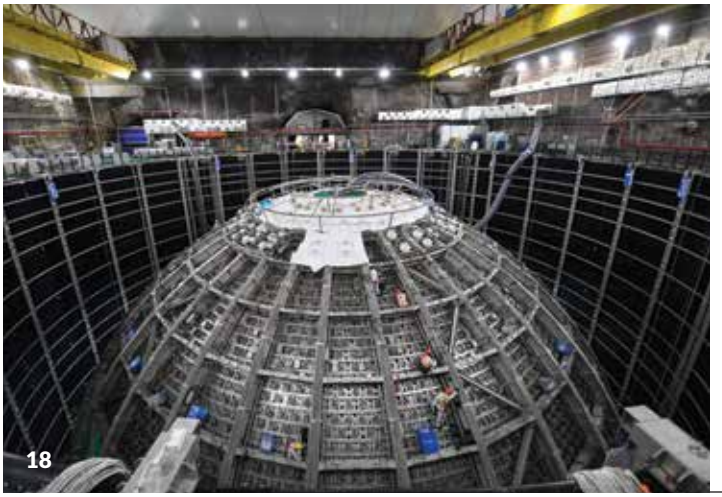
About Thermo Fisher Scientific Junior Innovators Challenge

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

www.societyforscience.org/jic | www.thermofisher.com/csr
Instagram: @thermofisherscientific/@Societyforscience | X: @thermofisher/@societyforscience

VOL. 206 | NO. 6

ScienceNews


18

Features

News


10


4

Departments

COVER Free and fair elections are a hallmark of democracy. Here, a voter casts their ballot in the New Hampshire primary. *Brandon Bell/Getty Images*

FROM TOP: DENG HUA/IMAGO/ALAMY STOCK PHOTO; F. GUAL-SUÁREZ; IMAGINECHINA LIMITED/ALAMY STOCK PHOTO

Taking the temperature of democracy

Concern about the health of democratic governments has been rising worldwide, and one of the key metrics researchers use to measure the robustness of a democracy is its ability to conduct free and fair elections.

With the United States in the midst of a polarized presidential election, we here at *Science News* have taken a close look at the science of studying democracies and what characteristics make them strong—or can destabilize them (Page 24).

It turns out that how best to measure democracy is itself contentious. Some researchers argue it should be binary—there's either a peaceful transfer of power from an incumbent who lost at the polls, or there's not. Others think the calculus is much more nuanced. Political scientists who favor the second approach note that some countries are democratic-ish—they do better or worse on individual metrics including executive respect for the constitution or a free press. Researchers can use those indices to plot governments along a continuum, from least to most democratic.

I was surprised to learn that a key research effort, Varieties of Democracy, or V-Dem, has calculated values on the status of liberal democracies all the way back to 1900. That's the year when Republican President William McKinley won re-election, fending off a challenge from Democratic Rep. William Jennings Bryan of Nebraska. McKinley pushed an imperialist foreign policy, having just won the Spanish-American War that gained independence for Cuba and wrested Puerto Rico, Guam and the Philippines from Spain. Bryan argued against the pursuit of empire and for an economic policy based on free trade and "bimetallism," backing U.S. currency not just with gold but also with silver.

The United States' liberal democracy score has risen steadily since the McKinley-Bryan election, with some ups and downs along the way. The score has dipped in the last decade, and political scientists say even a small decline is concerning. People seem to agree. A recent poll found that more than 60 percent of U.S. respondents think democracy is at risk depending on who wins this year's presidential election. But the United States also has factors that make a democratic system more resilient, political scientists say, including independent media and civic organizations, intense competition between political parties and public engagement in the electoral process.

Should you wish to take a breather from the election, we offer an exploration of another quandary in measurement—the masses of neutrinos. Researchers have not yet been able to pin down that key attribute of these subatomic particles, with particle physicists and cosmologists using different approaches to measure them and coming up with contradicting answers, senior physics writer Emily Conover reports (Page 18). Neutrinos and their masses influence the configuration of the cosmos, so both sides really want to get this thing figured out. Recent results from the DESI experiment can be explained by positing neutrinos with negative mass, which has physicists thinking that the cosmos might be weirder than they imagined. As one cosmologist tells Conover, if you take the results at face value, "then clearly we need new physics." —*Nancy Shute, Editor in Chief*

Science News
1719 N Street NW, Washington, DC 20036
(202) 785-2255
Subscriber services:
Email subscriptions@sciencenews.org
Phone (800) 552-4412 in the U.S. or
(937) 610-0240 outside of the U.S.
Web www.sciencenews.org/subscribe
For renewals, www.sciencenews.org/renew
Mail Science News, PO Box 292255, Kettering, OH 45429
Editorial/Letters: feedback@sciencenews.org
Science News Learning: snlearning@societyforscience.org
Advertising/Sponsor content: ads@societyforscience.org
Science News (ISSN 0036-8423) is published 22 times per year, bi-weekly except in May, July, October and December by the Society for Science & the Public, 1719 N Street, NW, Washington, DC 20036.
Subscribe to Science News: Subscriptions include 22 issues of *Science News* and full access to www.sciencenews.org and cost $59 for one year (international rate of $77 includes extra shipping charges).
Subscribe www.sciencenews.org/subscription
Single copies are $4.99 plus shipping and handling ($1.01 domestic, $5.01 international). Preferred periodicals postage paid at Washington, D.C., and an additional mailing office.
Postmaster: Send address changes to Science News, PO Box 292255, Kettering, OH 45429-0255. Two to six weeks' notice is required. Old and new addresses, including zip codes, must be provided.

Alliance for Audited Media

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!

A NEARLY $400 VALUE FOR JUST $29!

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!**

Act fast! The first time we ran this jewelry in our catalog, it sold out in a matter of days. Get this collection now before this offer goes extinct!

Jewelry Specifications:
- Enamel with Austrian crystal. Yellow gold finish
- Pendant: 1 ½" W x 1 ¼" H.
  Chain: 18" + 2", lobster clasp.
  Earrings: 1 ¼" L, french wire

Dragonfly Nouvelle Collection
A. Necklace ~~$199~~ $29* + S&P *Save $170*
B. Earrings ~~$199~~ **FREE** with purchase of Dragonfly Nouvelle Necklace

**Special price only for customers using the offer code.*

1-800-333-2045

Your Insider Offer Code: DFC268-01

Stauer, 14091 Southcross Drive W., Dept. DFC268-01, Burnsville, MN 55337 | www.stauer.com

Stauer® | AFFORD THE EXTRAORDINARY®

Excerpt from the October 26, 1974 issue of *Science News*

50 YEARS AGO

Science and the sources of pain

Chronic pain is no small problem for thousands of Americans. They take analgesics, sedatives or tranquilizers. They seek out chiropractors, acupuncturists or even miracle workers. Often they are not helped, at least over the long run…. The reason that so many people aren't getting relief from pain is that clinicians still aren't sure what pain is and how to treat it.

UPDATE: Chronic pain still puzzles scientists, but they now know that the mechanisms involve a complex confluence of factors. The nervous and immune systems, emotions, age and sex all play a role. That understanding has propelled research into better diagnostics and treatments. Scientists recently identified a potential biomarker for chronic pain — activity in a brain region called the orbitofrontal cortex (*SN: 6/17/23, p. 10*). The finding suggests it's possible to track pain in the brain. And a drug called suzetrigine, which curbs pain by blocking a sodium ion channel on pain-sensing cells, is currently under review by the U.S. Food and Drug Administration (*SN: 9/7/24 & 9/21/24, p. 18*).

FIRST

Mexican free-tailed bats' toes glow in the dark

You've heard of jazz hands? Well, these bats have glow toes.

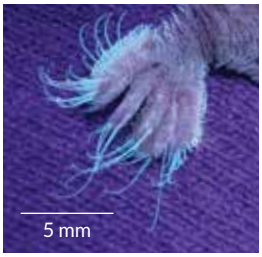
In the dark, when ultraviolet light shines on the Mexican free-tailed bat's extraordinarily hairy toes, they light up like a Christmas tree. That's because the animals have bristly structures that are capable of UV-induced photoluminescence, scientists report August 8 in *Mammalian Biology*. The finding marks the first time photoluminescent structures have been reported in live bats, and places the Mexican free-tailed bat (*Tadarida brasiliensis*) on an ever-growing list of creatures that can absorb UV light and reemit it at a different wavelength.

Biologist Fernando Gual-Suárez says he will always remember the moment he heard a colleague utter, "Is that normal? Do the feet usually look like that?"

It was January 2021, and his team had been catching Mexican free-tailed bats outside of a well-known roost in southern Mexico City. The night before, the researchers had caught bats farther north and dusted them with a powder that shines under UV light. The hope was to later detect that powder on bats in the south, proving that the animals were moving between the locations.

"We failed at that," says Gual-Suárez, of the National Autonomous University of Mexico in Mexico City. However, while searching for signs of the powder with their UV flashlights, the team stumbled upon something even cooler on the powderless bats: glow-in-the-dark toes.

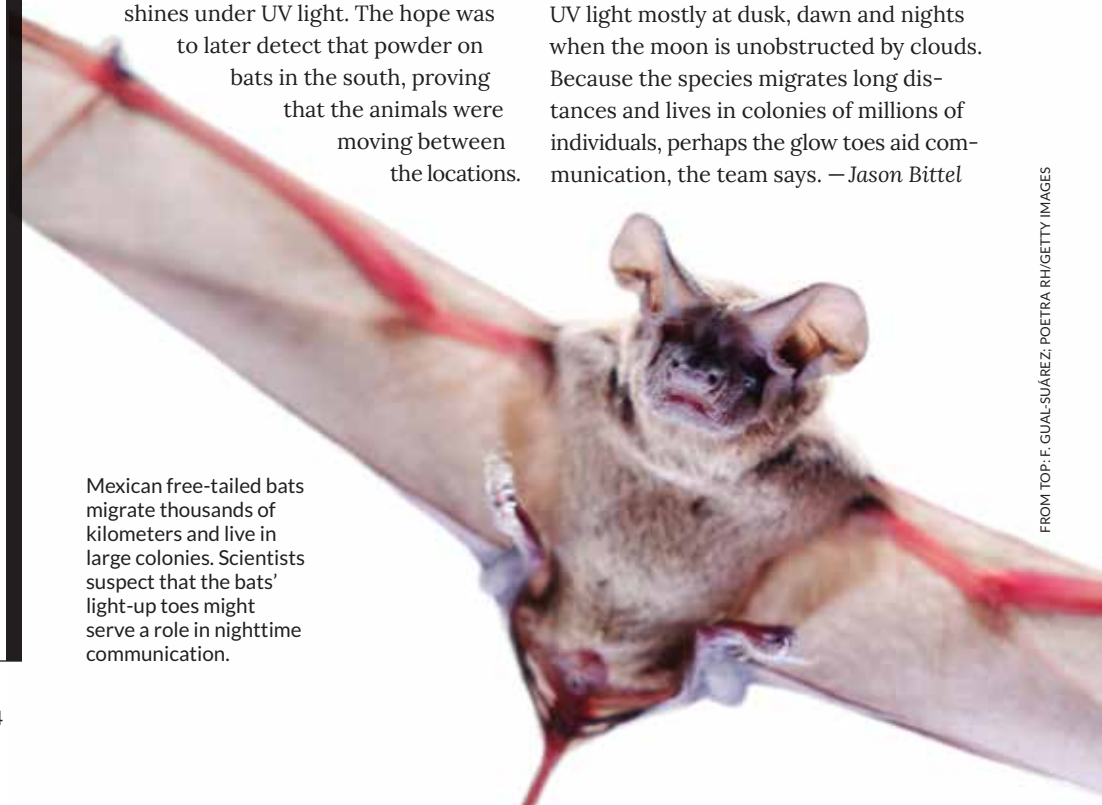
In visible light, a Mexican free-tailed bat looks like a fluff of dark fur. To be sure the photoluminescent footsies weren't a result of powder residue or a local aberration, the researchers looked for and found similarly bright toes on 25 live bats at both sites, as well as on one bat captured more than 700 kilometers to the north.



Under an ultraviolet light, the toe structures on this Mexican free-tailed bat glow a brilliant cyan.

Scientists have found UV photoluminescence in platypuses, tardigrades and other creatures. While many of these animals glow essentially from head to toe, in the bats, it's just the toes.

What purpose the glowing toes serve is unclear. It's not yet known whether the bats can perceive the light wavelengths that appear as a brilliant cyan to the human eye. As nocturnal creatures, Mexican free-tailed bats would encounter UV light mostly at dusk, dawn and nights when the moon is unobstructed by clouds. Because the species migrates long distances and lives in colonies of millions of individuals, perhaps the glow toes aid communication, the team says. —*Jason Bittel*



Mexican free-tailed bats migrate thousands of kilometers and live in large colonies. Scientists suspect that the bats' light-up toes might serve a role in nighttime communication.

FROM TOP: F. GUAL-SUÁREZ; POETRA RH/GETTY IMAGES

THE –EST

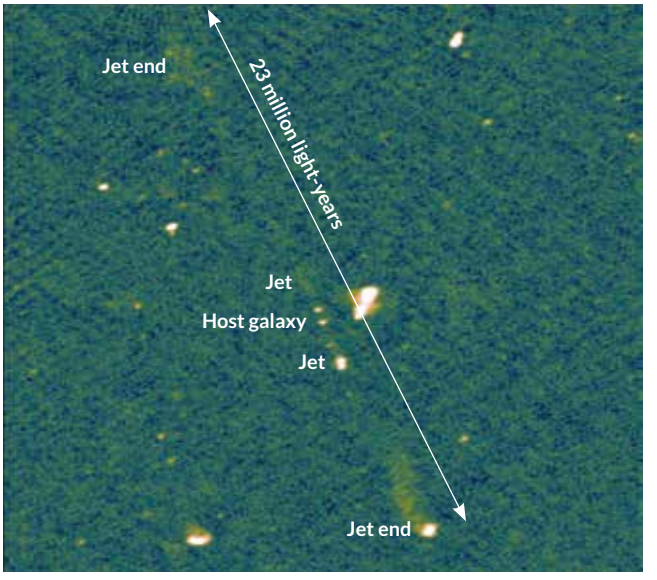
Two black hole jets stretch superfar

Opposing plasma fountains spanning 23 million light-years are the longest pair of black hole jets ever seen. They're long enough to influence the evolution of the universe on cosmic scales, astronomers report in the Sept. 19 *Nature*.

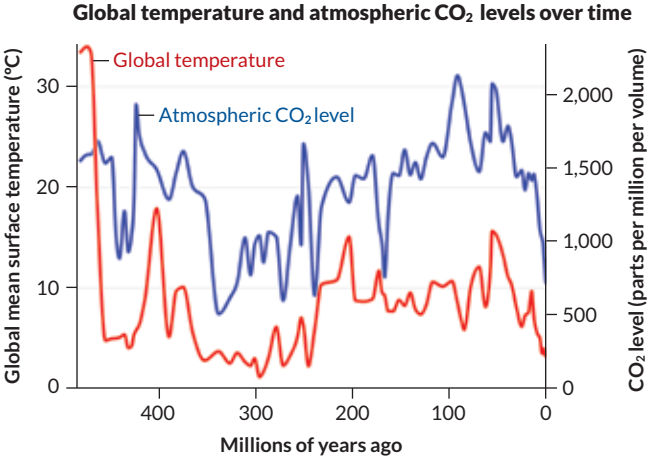
"Traditionally, astronomers believed all jets remain within, or at least very close to, their host galaxy," astrophysicist Martijn Oei of Caltech said September 16 in a news conference. "We present evidence that supermassive black holes don't only hold sway over the galaxy, but also of the cosmic web that surrounds them."

Massive galaxies are thought to each host a gargantuan black hole at their centers, and some of those black holes shoot high-energy plasma jets into space. Those jets influence the structure and evolution of their home galaxy, slowing down or even shutting off star formation.

The newly discovered pair, dubbed Porphyrion after a giant in Greek mythology, was spotted by LOFAR, a network of radio wave detectors in Europe. Porphyrion's prodigious size (it outstretches the previous record holder by about 7 million light-years) hints that its influence could outstrip the bounds of galaxies. Additional observations suggest that Porphyrion's home galaxy is embedded in a filament of the cosmic web, the tangled skein of gas and galaxies where most of the universe's ordinary matter resides (SN: 3/25/23, p. 14). Oei and colleagues calculate that the jets could span two-thirds of the way across the voids between filaments. —*Lisa Grossman*



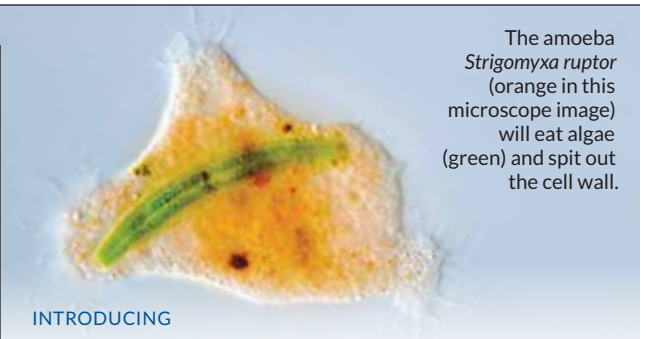
The longest black hole jets ever observed appear as faint lines extending diagonally across this image from the LOFAR telescope array.



SCIENCE STAT

Earth's temperature highs and lows

A new timeline of Earth's average temperature (shown above) over the last 485 million years reveals the ebbs and flows largely driven by shifts in the concentration of atmospheric carbon dioxide. The average dropped as low as 11° Celsius and shot up as high as 36° C, paleoclimatologist Emily Judd and colleagues report in the Sept. 20 *Science*. The current average—15° C—is on the cool side, but global warming is still a threat: Life can't adapt as fast as the climate is changing, says Judd, of the University of Arizona in Tucson. —*Carolyn Gramling*



The amoeba *Strigomyxa ruptor* (orange in this microscope image) will eat algae (green) and spit out the cell wall.

INTRODUCING

This amoeba eats prey like owls do

A newfound amoeba eats its prey like no other protist, by enveloping the victim and leaving just the husk behind, scientists report in the August *Ecology and Evolution*.

Protozoologists Andreas Suthaus and Sebastian Hess of the University of Cologne in Germany noticed reddish round blobs in pond water samples. The blobs resembled vampyrellid amoebas after they've sucked out the insides of algae. Oddly, nearby algae lacked telltale feeding holes.

Photos taken in the lab confirmed the amoebas were vampyrellids, and experiments revealed how these vampires feed. An amoeba engulfs an alga and keeps it in an internal chamber. Enzymes dissolve part of the prey's cell wall and as the chamber expands, the alga splits open. The amoeba scoops up its meal and spits out the shell. This owl-like regurgitation earned this amoeba the name *Strigomyxa ruptor*, from the Greek words for owl and slime. —*Jake Buehler*

CLOCKWISE FROM TOP: LOFAR COLLABORATION, M. OEI/CALTECH; A. SUTHAUS; E.J. JUDD *ET AL*/*SCIENCE* 2024, ADAPTED BY C. CROCKETT

HEALTH & MEDICINE

Semaglutide may curb opioid overdoses

The key ingredient in Ozempic shows promise against addiction

BY MEGHAN ROSEN

A wildly popular diabetes and weight-loss drug may also protect people from overdosing on opioids.

That's the implication of a new study that examined health records of people with type 2 diabetes and opioid use disorder in the United States. People prescribed semaglutide, which is sold under the brand names Ozempic and Wegovy, were roughly one-third to one-half as likely to overdose on opioids during a one-year follow-up as people prescribed different diabetes drugs, scientists report September 25 in *JAMA Network Open*.

"It's a big decrease," says study coauthor Rong Xu, a biomedical researcher at Case Western Reserve University in Cleveland.

More than 80,000 people in the United States died of opioid overdoses in 2023, so a new preventive strategy could save lives. But Xu is careful to point out that the study does not prove that the medication curbs opioid overdoses. "We can only say semaglutide is associated with reduced risk," she says.

The findings set the stage for clinical trials that directly test semaglutide's effects, Xu adds.

The new work is the first to suggest that this type of drug could have such a protective effect in people, says behavioral neuroscientist Patricia "Sue" Grigson of Penn State College of Medicine in Hershey. "And that is a pretty remarkable finding."

> The new work is the first to suggest that this type of drug could have such a protective effect in people.

Semaglutide belongs to a family of drugs that mimic the gut hormone GLP-1 (*SN: 9/23/23, p. 8*). Originally approved for diabetes, semaglutide and its relatives have gained fame and notoriety in recent years as weight-loss medications (*SN: 12/16/23 & 12/30/23, p. 26*). But evidence is stacking up that the drugs may do more than help people with diabetes and obesity—the drugs appear to be a kind of medicinal Swiss Army knife.

Studies in rats and mice have suggested that semaglutide can curb addictive behaviors. Early results from Grigson and colleagues suggest that a related drug, liraglutide, reduces opioid cravings in people with opioid use disorder (*SN: 3/23/24, p. 16*). And a handful of studies from Xu and colleagues this year suggest that semaglutide may offer some benefits to people addicted to alcohol, tobacco and cannabis.

For the latest study, Xu's team analyzed electronic health records of more than 33,000 people prescribed semaglutide or a handful of other diabetes medications and counted opioid overdoses over the next year. Though overall numbers were low, people prescribed semaglutide were less likely to overdose than people prescribed other medications. The scientists logged 35 overdoses across 2,605 people on semaglutide, for example, compared with 76 out of 2,605 people on metformin.

Scientists don't know why semaglutide may have this protective effect. It's possible people on the medication crave opioids less and thus don't use as much of the drugs, making overdoses less likely, Grigson says.

In November, Grigson's team will begin enrolling people with opioid use disorder in a new clinical trial. Participants will take semaglutide along with one of two standard treatments for the disorder, and researchers will track whether the drug combinations affect people's opioid usage.

Xu's team has now set its sights on stimulants: Perhaps semaglutide could help people who use methamphetamines and cocaine. She thinks the medication may tinker with some underlying biological mechanism that drives drug cravings in general.

Pharmacoepidemiologist Serena Jingchuan Guo of the University of Florida in Gainesville wonders if the drug could one day be used before addiction sets in, for instance as part of a pain management plan for patients prescribed opioids for pain relief after surgery. Perhaps taking semaglutide at the same time could prevent people from getting hooked on opioids in the first place, Guo suggests.

But she cautions that many questions about semaglutide and its relatives remain, like what molecular buttons the drugs are pushing in the body to trigger their varied effects. People think of these as a "miracle drug," she says, but "there are so many unknowns." ■

More than 80,000 people died from opioid overdoses in the United States in 2023. A study of 33,000 people with opioid use disorder and type 2 diabetes suggests that GLP-1 drugs might help prevent some opioid overdoses.

AH_DESIGNS/GETTY IMAGES

A primordial black hole (left, illustrated) in the solar system would jostle planetary orbits.

ASTRONOMY

Black holes may dot the solar system

The tiny, hypothetical objects would tug on satellites and planets

BY EMILY CONOVER

Black holes about the size of a hydrogen atom could be careening through the solar system unnoticed. But their days of stealth may be numbered.

Two teams of researchers propose methods to search for these tiny, hypothetical objects, which would have the mass of an asteroid. Because the black holes would have formed in the universe's infancy, they are known as primordial black holes.

If they exist, primordial black holes in this mass range could explain some or all of the universe's dark matter. That unknown invisible source of mass exerts gravitational influence on galaxies and, perplexingly, seems to outweigh normal matter by about 6-to-1. Extensive searches for subatomic particles that could explain dark matter have come up empty, putting new focus on primordial black holes (SN: 10/5/24, p. 13).

Black holes typically form when a dying star collapses, resulting in a black hole with at least several times the mass of the sun. Some scientists think smaller black holes might have formed in the early universe, perhaps from quantum fluctuations that caused portions of space to collapse directly.

If such a primordial black hole passed close to a planet, it would produce noticeable effects despite its tiny size, researchers report in the Sept. 15 *Physical Review D*. "The incredibly strong gravitational pull of this primordial black hole will have the effect of making Mars wobble in its orbit around the sun," says cosmologist Sarah Geller of the University of California, Santa Cruz. In the future, Geller and colleagues plan to partner with researchers who are skilled in doing detailed simulations of the solar system to dig through the data for wobbles.

Likewise, a primordial black hole flyby could jostle GPS satellites and similar satellite networks, cosmologist Sébastien Clesse and colleagues report in the same issue of *Physical Review D*. If a primordial black hole with the mass of an asteroid buzzed Earth within thousands or hundreds of thousands of kilometers, satellites could change altitude by a small but detectable amount. "That's very exciting to know that we have some probes that could be used to really detect baby black holes in the solar system," says Clesse, of Université Libre de Bruxelles in Belgium.

Asteroid-mass primordial black holes might whiz through the inner solar system just once a decade. Luckily, scientists have decades of data on satellites' trajectories. The same goes for Mars' orbit, thanks to rovers and satellites around the planet.

The satellite search would be sensitive to primordial black holes of smaller masses than the planetary wobble technique could detect. "It is very complimentary," says astrophysicist and metrologist Bruno Bertrand of the Royal Observatory of Belgium in Uccle, who coauthored the satellite paper.

Run-of-the-mill asteroids could mimic the signature of the primordial black holes. But the black holes would have speeds of about 720,000 kilometers per hour and come from outside the solar system. That's rare for space rocks. "We have never seen an object pass through the solar system that would have the characteristics we would associate with a black hole transit," says MIT physicist Ben Lehmann, who is a coauthor of the paper on the planetary method. To clinch the case, though, ideally scientists would detect a wobble in real time and check for any space rocks that could explain it.

Other effects that could tweak planetary orbits would also need to be accounted for, such as the solar wind of charged particles that streams out from the sun, says astrophysicist Andreas Burkert of Ludwig-Maximilians-Universität München in Germany, who was not involved with either study. And the satellite technique could be especially challenging, he says, arguing that a primordial black hole passing close enough to Earth to detect could be an extremely rare event.

At the moment, Burkert says of detecting these black holes, "I don't think it's realistic." But "I'm optimistic that it might be possible at some point." ■

CLIMATE

Extinction linked to mega El Niños

Climate swings may have contributed to the Great Dying

BY JAKE BUEHLER

Intense, wild swings in climate conditions may have fueled the Great Dying, the largest mass extinction in Earth's history. A reconstruction of how ancient sea surface temperatures, ocean and atmosphere circulation, and landmasses interacted more than 250 million years ago revealed nearly decade-long stints of droughts, wildfires and flooding.

A spike in global temperatures, triggered by carbon dioxide emissions from enormous volcanic eruptions lasting millions of years, probably kicked off the mass extinction some 252 million years ago. But it was the resulting mega El Niños that whiplashed ecosystems, ultimately wiping out some 90 percent of all ocean species and 75 percent of those on land, researchers report in the Sept. 13 *Science*.

The findings suggest that the Great Dying was "a bit more nuanced" than scientists thought, says Erik Gulbranson, a sedimentary geochemist at Gustavus Adolphus College in St. Peter, Minn.

Scientists have wondered why the Great Dying, which played out at the border of the Permian and Triassic periods, was so brutal. "We have other episodes of global warming in the geological record that don't do anything nearly as bad to ecosystems as this," says paleontologist David Bond of the University of Hull in England.

A sharp increase in sea surface temperature plus the resulting collapse in the ocean's ability to hold dissolved oxygen would have been abysmal for ocean organisms, but it wasn't clear what drove the extinction of terrestrial life or why organisms couldn't just move to the cooler poles.

Part of the answer may lie in short-term oscillations in paleoclimate. Such variations include climate wobbles on the scale of years. For instance, today's El Niño-Southern Oscillation lasts roughly a year. This periodic warming of the tropical Pacific Ocean brings heat and aridity to northern North America and induces droughts and floods globally.

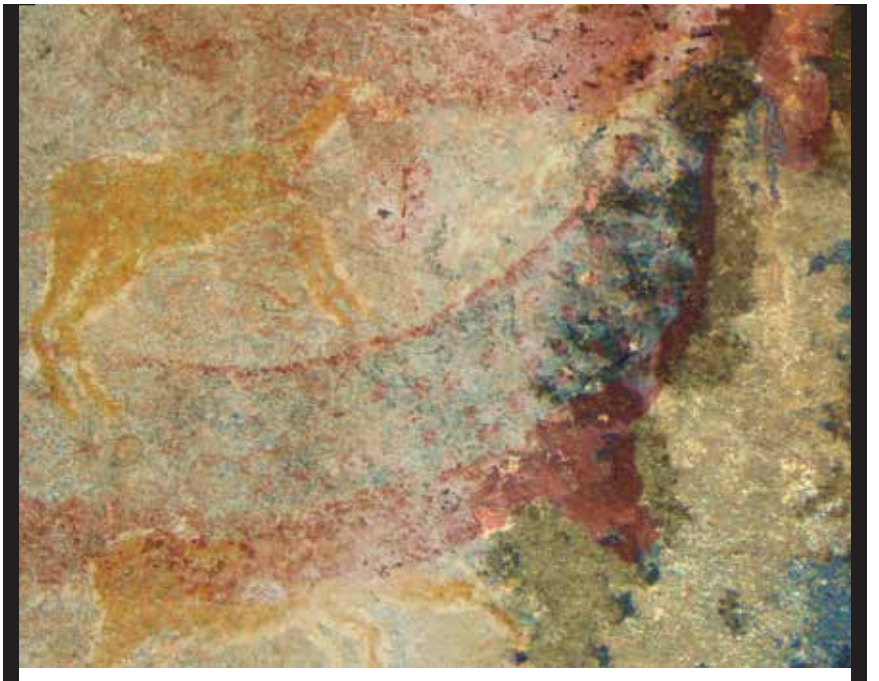
Bond and colleagues reconstructed what ancient Earth's climate patterns looked like. The team calculated seawater temperatures using ratios of different forms of oxygen in the fossilized teeth of ancient fishlike animals. With this data plus computer simulations of atmospheric and ocean circulation patterns, the researchers produced a more cohesive picture of climate during the Great Dying.

When CO_2 levels doubled from about 410 to 860 parts per million and global temperatures rose, El Niño–like spells over one of the late Permian's two giant oceans intensified, the team found. Over time, the swings lengthened to nearly a decade.

The effects of these mega El Niños would have been too much for land organisms to bear. As forests baked and died, fewer greenhouse gases were pulled out of the atmosphere, creating a feedback loop as volcanoes continued pumping out warming gases, says study coauthor Alexander Farnsworth, a paleoclimate modeler at the University of Bristol in England. "You get more warming, more vegetation die-off, stronger El Niños, higher temperatures globally, higher weather extremes again, leading to more die-off," he says.

The heat eventually invaded higher latitudes, which meant species "couldn't simply migrate north and south," Bond says. In the end, many species couldn't adapt.

Ancient cave stalactites and tree rings might show evidence of the mega El Niños, Gulbranson says. "We need to track down these signals in the fossil record." ■



J. BENOIT (CC BY 4.0)

ARCHAEOLOGY

Rock art resembles an ancient dicynodont

South African rock art of a mythical creature may mirror dicynodonts, mammal relatives that lived from about 270 million to 200 million years ago. An animal (red and blue figure, above) painted by San hunter-gatherers in a rock-shelter has tusks that curve down and back, similar to those of exposed dicynodont fossils in the area, paleontologist Julien Benoit of Wits University in Johannesburg reports September 18 in *PLOS ONE*. If such fossils inspired the painting — made sometime between 1821 and 1835 — then the portrayal preceded the first scientific description of dicynodonts in 1845. — *Bruce Bower*

ANIMALS

How big were extinct giant creatures?

Scientists call for more caution as size estimates get revised

BY CAROLYN GRAMLING

Body size estimates of some of Earth's larger-than-life species may have been just that: a little bit too large for real life.

Take *Dunkleosteus*, an armored fish that lived around 360 million years ago. It had long been thought to be as much as 10 meters long, based on the fossilized remains of its massive bony head. But the head-to-body ratio used in that calculation might not have been correct. Instead, the fish was probably about half as long and much stouter, earning it the nickname "Chunkleosteus" from some researchers.

Size estimates of many extinct giants have been called into question in the last decade as new data and analytical techniques have emerged, researchers report in the September *Ecology and Evolution*.

To some extent, that's how science works, say evolutionary biologist Joel Gayford and colleagues. But the scale of the size dispute in some cases calls for much more caution in making those initial estimates, the researchers say.

"There's an ongoing trend of… high-profile papers publishing 'world's largest,' 'world's heaviest' something," says Gayford, now at James Cook University in Brisbane, Australia. "Before long, there's another paper in a lower-profile journal saying, 'Hold on, it wasn't actually that long.'"

When it comes to estimating body size, there isn't always a lot to go on. Megalodon (formally *Otodus megalodon*), the largest shark to ever live, left mostly teeth behind; the ancient whale *Perucetus*, initially estimated to be heavier than the modern blue whale, left just a few vertebrae, ribs and a single individual's pelvis (SN: 9/9/23, p. 5). To extrapolate from these pieces to a whole animal, scientists may compare the fossils with living or extinct relatives, or plug the data into computer analyses of evolutionary trees.

But those extrapolations come with assumptions that can lead researchers astray.

Megalodon is one of several examples that Gayford's team zeroes in on. Once thought to be a close relative of modern great white sharks, scientists assumed megalodon's body was proportionally broad to match its perhaps 11 meters in length. But a recent study suggested that megalodon may have been longer but also more slender (SN: 3/9/24, p. 4).

Similarly, the initial size estimate of the whale *Perucetus* was called into question in February in *PeerJ*. Using different calculation methods, researchers downgraded the whale's weight from up to 340 metric tons to about 100 — still a big whale, just not quite in the same weight class as the blue whale, which can weigh up to 245 tons.

Spurious size estimates create lasting bias when it comes to perceptions of how big it's possible to get, Gayford says. Maximum size estimates matter because larger-than-most species can have an outsize impact on ecology, such as food resources and predator-prey relationships. And changes to the environment (loss of those food sources, for example) can in turn have an outsize impact on the giants.

The review correctly points out that "we need to be cautious and acknowledge wide margins of error when reconstructing any extinct taxon," says vertebrate paleontologist Jack Cooper of Swansea University in Wales. But the team did not analyze every case study equally rigorously, he says. For example, there is still a lot of debate about how best to estimate megalodon's size.

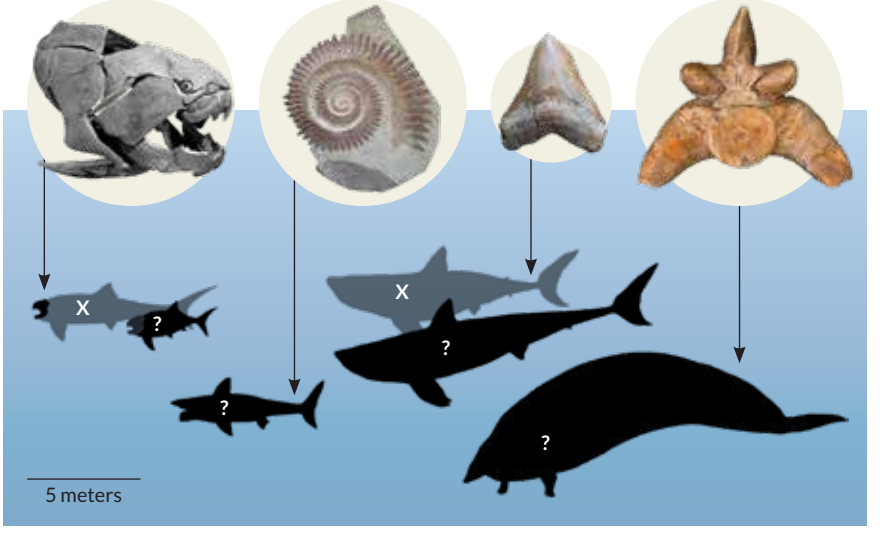
The review, Cooper says, inaccurately claims his own work on the giant shark, based on a rare vertebral fossil, is unreplicable. He's concerned about "what else has been incorrectly reported [in the paper]."

Gaylord says the team was referring to the rarity of the fossil, not criticizing Cooper's work. The intent was to highlight the inherent challenges of estimating sizes from the scant fossil record, he adds.

Research journals bear some of the burden for outsize claims, Gayford says. "They are less likely to publish detailed, methodologically sound but not particularly amazing conclusions. And that has a knock-on effect for what people might focus their research on."

Downplaying size is one way to address the problem, Gayford suggests. "The point is for people to understand that it's not the size or the weight of an animal that makes it interesting," he says. It's still an "awesome animal that we can learn a lot about." ■

Sizing up extinct animals Four famous ocean dwellers, known from just a few scant fossils, may each have been less hefty than first thought. At top from left are the skull of the armored fish *Dunkleosteus terrelli*, the tooth whorl of the fish *Helicoprion*, a tooth from the giant shark *Otodus megalodon* and vertebra from the whale *Perucetus colossus*. Past reconstructions of some of these creatures are in gray. Black silhouettes represent new or revised reconstructions — though these, too, are still uncertain.



J.H. GAYFORD ET AL/ECOLOGY AND EVOLUTION 2024 (CC BY-SA 4.0), ADAPTED BY B. PRICE

PLANTS

This flower launches missiles of pollen

The projectiles knock off competitors' pollen from bird beaks

BY NALA ROGERS

For certain Brazilian red flowers, pollinators may act as sexual battlegrounds.

Hypenia macrantha flowers use projectile blasts of pollen to knock off rival flowers' pollen from hummingbirds' beaks and replace it with their own, researchers report in a study to appear in the *American Naturalist*. The tactic may increase a male flower's chances of siring seeds in the next female flower the bird visits.

H. macrantha flowers have both male and female reproductive organs. To avoid self-pollination, a flower goes through a male phase and then a female phase. Hummingbirds transfer pollen between flowers. When visiting a male flower, a hummingbird's beak triggers a catapult-like mechanism that flings all of the flower's pollen in a single burst. Afterward, the flower becomes female.

To see if projectile pollen blows away the competition, evolutionary ecologist Bruce Anderson of Stellenbosch University in South Africa and colleagues simulated hummingbird visits by poking a hummingbird skull into flowers.

First, the researchers applied pollen marked with tiny fluorescent particles to the part of the beak where pollen tends to accumulate. Next, the team inserted the bird's beak with its load of fluorescent pollen into a set of male and female flowers containing unmarked pollen and tracked where the marked and unmarked pollen particles ended up.

The hummingbird beaks lost twice as much fluorescent pollen when inserted into an explosive flower versus an inert, already-exploded flower. And the more fluorescent pollen an explosion removed, the more successful that explosion was at depositing the flower's own pollen onto the beak.

High-speed video showed that pollen grains from exploding flowers functioned like missiles that knock existing pollen away.

"It's almost like there's a division of labor for pollen. Some of it is meant for mating, and some of it's meant for fighting," Anderson says.

More research is needed, he adds, to determine whether the pollen blasts result in more offspring for *H. macrantha*.

The animal world is full of males trying to get rid of rivals' sperm and replace it with their own. For example, many animal penises have elaborate shapes for scooping sperm out of the female reproductive tract. Even the capped shape of the human penis may function to remove other men's sperm, research from evolutionary psychologist Rebecca Burch and colleagues suggests.

This is the first experimental evidence for a similar sperm cell–removal strategy in plants.

"Plants are not just stationary objects," says Burch, of the State University of New York at Oswego. "They engage in communication, competition and now active reproductive sabotage of other plants." ■

To see if *Hypenia macrantha* flowers blow competitors' pollen from hummingbird beaks, researchers poked skulls of the birds laden with fluorescent pollen into flowers (as shown) and tracked how much remained.

B. ANDERSON

ANIMALS

Stem cell feat could help pandas

The advance could aid breeding and conservation efforts

BY JASON BITTEL

With roughly 2,000 giant pandas remaining in the wild, scientists have spent the last several decades looking for new ways to help the iconic black-and-white bears stave off extinction. And now, it seems there may be more hope than ever before.

For the first time, scientists have transformed ordinary skin cells from pandas in a zoo into induced pluripotent stem cells, the team reports in the Sept. 20 *Science Advances*. Having this type of stem cell, which can be nudged into becoming any kind of cell in the body, could help researchers breed more giant pandas (*Ailuropoda melanoleuca*) and develop treatments for their diseases.

This result "is really a great breakthrough in the field of giant panda conservation," says Thomas Hildebrandt, a veterinarian who specializes in wildlife reproduction at the Free University of Berlin. It "opens up a complete new avenue [to rescue] this magnificent species" and may suggest strategies for generating stem cells for other endangered species.

Researchers have already turned both mouse and human skin cells, called fibroblasts, into pluripotent stem cells. These stem cells "have unlimited proliferation potential and can form any kind of cell, tissue or organ in the body under certain conditions," says Liu Jing, a stem cell researcher at the Chinese Academy of Sciences' Guangzhou Institutes of Biomedicine and Health. The catch is that the process for creating such cells must be tailored to each species.

To reprogram panda fibroblasts into pluripotent stem cells, Jing and colleagues first inserted genes known to reprogram adult cells into panda skin cells along with small RNA molecules known to enhance the transformation into stem cells. The researchers also had to identify the specific proteins and growth factors that

would help turn the panda skin cells into stem cells, as well as ones that would keep them in the pluripotent state.

Having pluripotent cells on demand could allow scientists to create giant panda primordial germ cells, precursors to sperm and egg cells, a feat that's been done in mice and northern white rhinos.

Obtaining panda sex cells has been difficult because the majority of the remaining pandas in the wild are under strict protections that forbid typical egg extraction techniques. There are also too few pandas remaining to reliably harvest eggs from animals as they die from natural causes.

If scientists could generate sperm and egg cells from pandas in a noninvasive manner, such as turning skin cells into stem cells and then germ cells, and use those cells to make new pandas, scientists might be able to add genetic diversity to different panda populations. Currently, there are 33 isolated populations, 15 of which are very close to extinction.

Xing Rong (shown) and another giant panda had some of their skin cells turned into a kind of stem cell that can potentially become any kind of cell in the body, including the precursors of eggs and sperm.

Creating primordial germ cells from the stem cells is the team's next step. But assisting pandas reproduction is not the only goal. Pluripotent stem cells can help in disease diagnosis and treatment. Ultimately, Jing says, the hope is to both expand the giant panda population and improve the population's health.

The findings may also hold potential for achieving the stem cell transformation in other endangered species. "It's like a library you use," says Hildebrandt, who has been instrumental in similar efforts to prevent northern white rhinos from going extinct (SN: 8/4/18, p. 8). "You know, there are a lot of books which describe a similar thing but describe it from a different angle."

Scientists have also created pluripotent stem cells for Tasmanian devils (*Sarcophilus harrisii*), Grevy's zebras (*Equus grevyi*), Sumatran rhinos (*Dicerorhinus sumatrensis*) and drills (*Mandrillus leucophaeus*). With another book added to the library, who knows which species scientists will be able to apply the stem cell technology to next. ■

ANIMALS

Ants renovate nests to stop pathogens

Structural and behavioral changes might reduce disease spread

BY RICHARD KEMENY

If an infection takes hold in an ant nest, it could spell disaster for the whole colony. But some worker ants appear to have a remedy. When exposed to a pathogen, black garden ants (*Lasius niger*) tinker with their nest layout in ways that could slow the spread of disease.

Several animals are known to alter their behavior to avoid infections. But the ants' behavior, reported September 2 in a paper posted at bioRxiv.org, is the first example of nonhuman animals actively altering their surroundings in an apparent response to infection.

Limiting social contact—through social distancing, for example—is thought to be an effective barrier to disease spread. Humans also alter what researchers call spatial networks by, for instance, using quarantine zones.

To see whether ants act similarly, behavioral ecologist Nathalie Stroeymeyt and her team at the University of Bristol in England let 20 groups of 180 black garden ants excavate nests in soil-filled jars. The day after digging started, the researchers added 20 more worker ants to each jar, with half of the jars receiving ants infected with a fungal pathogen.

Over the next six days, the team monitored the ants' behavior with video and used micro-CT scans to study the evolution of the nests.

Ant colonies exposed to the pathogen dug nests faster and initially made more tunnels than healthy colonies. After six days, the exposed colonies had made several structural modifications, including spacing entrances 0.62 centimeters farther apart on average. Those colonies had also placed chambers—which house resources such as queens and food—in less central locations. And infected ants had spent more time at the surface than their coworkers, perhaps a form of self-isolation.

Simulations of how disease might spread in the nest designs crafted by the exposed and unexposed colonies suggest that ant colonies in the redesigned nests would have a lower fungal load—and fewer lethal doses—than ant colonies in more typical nests.

The findings are fascinating, though not surprising, says Sebastian Stockmaier, a behavioral disease ecologist at the University of Tennessee, Knoxville. Social insects like ants, bees and termites have evolved a range of colony-level defenses to effectively manage diseases, he says, and large-scale outbreaks are rare.

Group living is generally thought to increase the risk of disease, and this threat is particularly pronounced in social insects because of their low genetic diversity and frequent social interactions, factors which help disease to spread. Therefore, when faced with disease, Stockmaier says, "their strategies are typically targeted at protecting the group as a whole, rather than focusing on the individual." ■

ARTIFICIAL INTELLIGENCE

AI chatbot weakens conspiracy beliefs

In a study, participants' conviction waned by about 20 percent

BY SUJATA GUPTA

Know someone convinced that the moon landings were faked or the COVID-19 pandemic was a hoax? Debating with a sympathetic chatbot may help pluck people who believe in those and other conspiracy theories out of the rabbit hole, researchers report in the Sept. 13 *Science*.

Experiments with thousands of people showed that talking with a chatbot weakened people's beliefs in a given conspiracy theory. Those conversations even curbed the strength of conviction for people who said the conspiratorial belief was central to their world view. When scientists checked in with a subset of participants two months later, those changes were still present.

Large language models like the one that powers ChatGPT are trained on the entire internet. So when the researchers asked ChatGPT to "very effectively persuade" conspiracy theorists out of their belief, it delivered a rapid and targeted rebuttal, says Thomas Costello, a cognitive psychologist at American University in Washington, D.C. That's more efficient than, say, a person trying to talk their hoax-loving uncle off the ledge at Thanksgiving. "You can't do off the cuff, [because then] you have to go back and send them this long email," Costello says.

Up to half of the U.S. population buys into conspiracy theories, evidence suggests. Rational arguments that rely on facts and counterevidence rarely change people's minds, Costello says. Prevailing psychological theories posit that such beliefs persist because they help believers fulfill unmet needs around feeling knowledgeable, secure or valued. If facts and evidence really can sway people, the team argues, then perhaps those prevailing psychological explanations need a rethink.

Though the study adds to evidence suggesting that chatting with bots can help people improve their reasoning, it doesn't call into question reigning psychological theories, says Robbie Sutton, a psychologist and conspiracy theory expert at the University of Kent in England.

The longings that drove people to adopt such beliefs in the first place remain entrenched, Sutton says. He likens conspiracy theories to junk food. "You eat it, but you're still hungry," he says. Even if conspiracy beliefs weakened, most participants still believed in the conspiracy.

Across two online experiments initially involving more than 3,000 participants in the United States, Costello and colleagues tested AI's ability to change beliefs on conspiracy theories. Participants in both experiments were tasked with writing down a conspiracy theory they believe in with supporting evidence. In the first experiment, participants were asked to describe a conspiracy theory that they found "credible and compelling." In the second experiment, the researchers softened the language, asking people to describe a belief in "alternative explanations for events than those that are widely accepted by the public."

The team then asked GPT-4 Turbo to summarize the person's belief in a single sentence. Participants rated their level of belief in the summarized theory on a scale from 0 for "definitely false" to 100 for "definitely true." Those steps eliminated roughly a third of potential participants who expressed no belief in a conspiracy theory or whose rating was below 50.

> After chatting with an AI, participants' skepticism in a conspiracy belief outweighed their conviction.

Roughly 60 percent of the remaining participants engaged in three rounds of conversation with GPT-4 about the conspiracy theory, with conversations lasting 8.4 minutes on average. The team directed the chatbot to talk the participant out of their belief. To facilitate that process, the AI opened the conversation with a person's initial rationale and supporting evidence.

Some 40 percent of participants, in the control group, chatted with the AI about the American medical system, their preference for cats or dogs, or their experience with firefighters.

After these interactions, participants again rated the strength of their conviction from 0 to 100. Averaged across both experiments, belief strength in the group the AI was trying to dissuade was around 66 points compared with around 80 points in the control group. In the first experiment, scores of the participants in the experimental group dropped almost 17 points more than in the control group. And scores dropped by more than 12 points more in the second experiment.

On average, participants who chatted with the AI about their theory experienced a 20 percent weakening of their conviction. And the scores of about a quarter of those participants tipped from above 50 to below. In other words, after chatting with the AI, their skepticism in the belief outweighed their conviction.

The AI conversations also weakened more general conspiratorial beliefs, beyond the single belief being debated. Before the first experiment, participants rated their belief in various conspiracy theories on the 0 to 100 scale. Chatting with AI led to small reductions in participants' overall scores.

A fact-checker vetted the chatbot's responses and determined that none were inaccurate or politically biased, and just 0.8 percent might have been misleading.

The findings may hold promise for counteracting fake news and conspiracy theories, which "constitute some of the greatest threats to our communication as a society," says media psychologist Jan-Philipp Stein of Chemnitz University of Technology in Germany. But getting people to converse with these bots might be difficult: Conspiracy theorists are unlikely to trust AI, Stein's research has shown.

As AI infiltrates society, there's reason for caution, Sutton says. "These very same technologies could be used to … convince people to believe in conspiracy theories." ■

Meet the Beauty in the Beast

Discover this spectacular 6½-carat green treasure from Mount St. Helens!

For almost a hundred years it lay dormant. Silently building strength. At 10,000 feet high, it was truly a sleeping giant. Until May 18, 1980, when the beast awoke with violent force and revealed its greatest secret. Mount St. Helens erupted, sending up a 80,000-foot column of ash and smoke. From that chaos, something beautiful emerged… our spectacular ***Helenite Necklace***.

EXCLUSIVE
FREE
Helenite Earrings
-a $149 value-
with purchase of Helenite Necklace

Helenite is produced from the heated volcanic rock of Mount St. Helens and the brilliant green creation has captured the eye of jewelry designers worldwide. Today you can wear this massive 6½-carat stunner for ***only $149***!

Make your emeralds jealous. Our *Helenite Necklace* puts the green stone center stage, with a faceted pear-cut set in .925 sterling silver finished in luxurious gold. The explosive origins of the stone are echoed in the flashes of light that radiate as the piece swings gracefully from its 18" luxurious gold-finished sterling silver chain. Today the volcano sits quiet, but this unique piece of American natural history continues to erupt with gorgeous green fire.

Your satisfaction is guaranteed. Bring home the *Helenite Necklace* and see for yourself. If you are not completely blown away by the rare beauty of this exceptional stone, simply return the necklace within 30 days for a full refund of your purchase price.

JEWELRY SPECS:
- 6 ½ ctw Helenite in gold-finished sterling silver setting
- 18" gold-finished sterling silver chain

Limited to the first 2200 orders from this ad only

Helenite Necklace (6 ½ ctw) .....Only $149 +S&P
Helenite Stud Earrings (1 ctw) .....$149 +S&P
Helenite Set ~~$298~~.....Call-in price only **$149** +S&P
(Set includes necklace and earrings)

Call now to take advantage of this extremely limited offer.

1-800-333-2045

Promotional Code HNN160-03
Please mention this code when you call.

BBB ACCREDITED BUSINESS
Rating of A+

Stauer® 14091 Southcross Drive W., Dept. HNN160-03, Burnsville, Minnesota 55337 **www.stauer.com**

Stauer… *Afford the Extraordinary.*®

Necklace enlarged to show luxurious color.

"My wife received more compliments on this stone on the first day she wore it than any other piece of jewelry I've ever given her."

- J. from Orlando, FL
Stauer Client

ENVIRONMENT

Great Salt Lake dust raises alarm

Small, metal-rich particles might harm human health

BY SKYLER WARE

Exposed swaths of the Great Salt Lake's bed contain metal-rich dust that is small enough to be inhaled and can generate molecules that may cause health problems.

Dust particles blowing from Utah's Great Salt Lake might pack an unwanted punch if inhaled — metals that can cause inflammation. Metals in the dust are more reactive than dust from nearby lake beds, scientists report in the Nov. 1 *Atmospheric Environment*.

Drought, overconsumption and climate change have steadily drained the Great Salt Lake, exposing nearly 2,000 square kilometers of lake bed (SN: 6/3/23, p. 18). Chemical engineer Kerry Kelly of the University of Utah in Salt Lake City and colleagues collected samples of exposed lake bed and isolated dust particles that were no wider than 10 micrometers — small enough to be inhaled.

A chemical analysis revealed that the particles had higher concentrations of manganese, copper, iron and lead than dust from other nearby playas. Lithium and arsenic were also present, at levels exceeding the U.S. Environmental Protection Agency's regional screening levels — a reference point for further risk evaluation.

The particles were also more likely to generate reactive oxygen species than dust from the other lake beds. These unstable molecules can interact with and sometimes damage living cells.

"If we get too much of these reactive particles or reactive species that enter our lungs, it can … lead to inflammation, and then inflammation leads to a number of adverse health effects," Kelly says.

Biomedical scientist David Lo advises against jumping to conclusions. "It's fine to look at environmental components and to look at their potential for having this or that effect," says Lo, of the University of California, Riverside. But linking this reactive dust exposure with public health outcomes will require more data, he says.

The study, Kelly says, "shows that the dust from the Great Salt Lake is potentially a significant health concern, so we need to do more work." ■

CHEMISTRY

Hydrogen saps energy from batteries

Wrangling the atoms may be key to longer-lasting lithium-ion cells

BY LAUREN LEFFER

Rechargeable lithium-ion batteries don't last forever. Over time, they hold on to less charge and eventually transform from power sources to bricks. A new study suggests one reason: leaky hydrogen.

Unwanted hydrogen protons fill molecular slots in the positive end of the battery, leaving less room for charged lithium atoms, or ions, that maintain reactivity and help conduct charge, researchers report in the Sept. 13 *Science*.

The study identifies a set of undesirable chemical reactions that unfold when the battery's electrolyte, which is supposed to transport lithium ions, inadvertently releases hydrogen into the positive end, or cathode. This "triggers all kinds of problems," reducing the capacity and life span of the battery, says materials physicist Gang Wan of Stanford University. "Even if you're not using the battery, it loses energy."

Explanations of energy loss in batteries typically focus on lithium ions. Some researchers have hypothesized that hydrogen atoms play a role, but it has been hard to observe because hydrogen is so small and ubiquitous. So Wan and colleagues swapped the hydrogen in the electrolyte of button-shaped batteries for deuterium, a heavier variant of hydrogen.

The researchers then tracked the deuterium's movement with high-powered X-ray imaging and mass spectrometry. Combining the results with theoretical calculations showed that hydrogen is the key player in cathode charge loss.

The study sheds light on the opaque chemistry unfolding inside batteries, says inorganic chemist Bart Bartlett of the University of Michigan in Ann Arbor. That's significant because it hints at ways to adjust the chemistry to avoid hydrogen reactions.

The work also highlights a problem in the push for increasingly high-voltage batteries, he says. Higher-voltage cathodes are more reactive and thus more likely to pull in hydrogen, so the higher the battery voltage, the more "hydrogenation" takes place. "It's a trade-off that I don't think we fully appreciated," Bartlett says.

It's unclear whether the findings apply to other types of lithium-ion batteries. If so, the results could help speed up innovations like longer-range electric vehicles, says Jacqueline Edge, a battery researcher at Imperial College London. Those new batteries might also decrease the need for mining battery minerals, which comes with negative environmental and social consequences. It would be a two-fold sustainability win, she says. ■

JUSTIN SULLIVAN/GETTY IMAGES NEWS

NEUROSCIENCE

Brain network size tied to depression

The difference exists even before symptoms arise, scans show

BY NORA BRADFORD

Symptoms of depression fluctuate over time, but many brain-imaging studies of the condition examine only one point in time. That has made it hard to connect networks of brain activity to various symptoms and mood changes. Now, a new study that used long-term brain imaging is helping to reveal one such connection.

The salience network, which is involved in guiding attention, was nearly two times as large in patients with depression as in people without the condition, scientists report in the Sept. 19 *Nature*. What's more, the network stayed large even as symptoms ebbed and flowed.

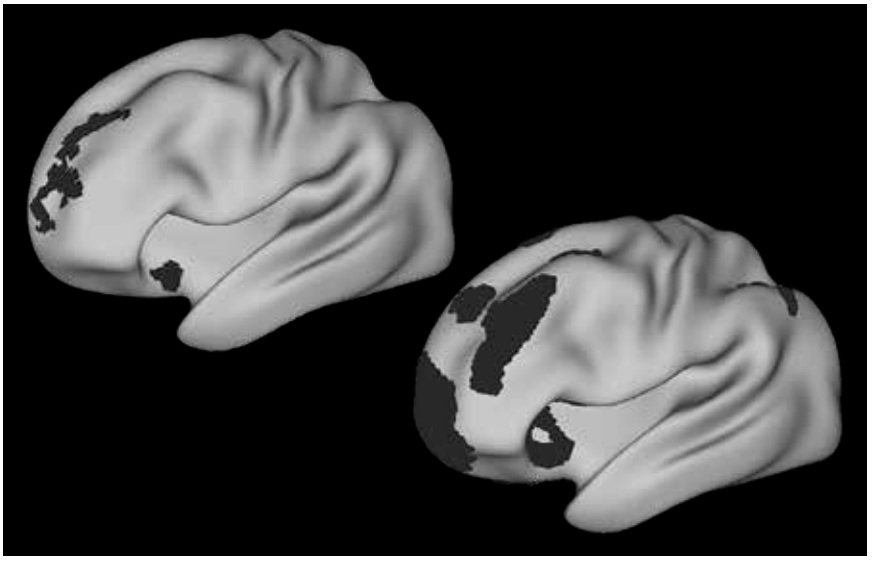
"Honestly, when we started this project, we weren't expecting necessarily to find stable, traitlike differences in brain [activity patterns] in people with depression," says neuroscientist Charles Lynch of Weill Cornell Medical College in New York City. "We were more interested in looking for things that would change over time as their symptoms fluctuate."

The researchers hoped to uncover the driving forces behind mood changes in depression by mapping brain networks over time. Existing functional MRI datasets allowed the team to look at the brain activity of more than 100 adults across multiple days. The datasets also included patients' ratings of their depression symptoms at the time of each scan.

The team identified the networks of brain areas with the most coordinated activity. The salience network, which also directs two other networks involved in self-focused thinking and working memory during goal-directed tasks, stood out. Compared with healthy people, the salience network in people with depression took up an average of 73 percent more surface area of the cerebral cortex.

Previous work hinted that the salience network may be involved in depression, but those findings were unclear. The new study shows that though the overall shape of the network is similar across people with and without depression, its borders extended farther outward in people with the condition.

Salience network boundaries remained stable over time and across various moods for both groups, but changes in connectivity between specific nodes in the network corresponded with worsening symptoms in people with depression.



C. LYNCH ET AL/*NATURE* 2024

Compared with the brain of a person who does not have depression (left reconstruction), the brain of someone who does (right) has a larger salience network (dark gray), on average.

An analysis of salience network changes in two patients who were scanned over many months revealed that connectivity between the nucleus accumbens, which is involved in reward-seeking, and the anterior cingulate, which plays a part in decision-making, weakened when the patients reported experiencing less joy.

Two individuals with bipolar II disorder, a mental health condition that causes extreme mood swings from depression to mania, also had expanded salience networks. But participants with autism or obsessive compulsive disorder did not.

"The specificity of salience network expansion to depression will thus be a very intriguing question to explore in future studies," says Lucina Uddin, a neuroscientist at UCLA who was not involved in the research.

Lynch's team also analyzed a neuroimaging dataset of adolescents over time. These 57 children did not have depressive symptoms when they were scanned between age 10 and 12 but developed symptoms within a couple years.

The findings were strikingly similar to the analysis of adult brains. The children had substantially larger salience networks than other adolescents who did not develop depression, and the size of the network remained stable over time in both groups. A larger salience network is not the result of depression, but instead precedes depression, the results suggest.

Lynch and colleagues think the enlarged network may even be related to early life stressors or genetics, but more research needs to be done before anyone can say for sure.

A better understanding of the neural components driving depression could lead to more precise therapeutic interventions, such as using electricity to stimulate specific brain regions (SN: 9/23/23, *p.* 16). That would be especially helpful given the unreliable effectiveness of current medications.

"We think there is an opportunity to incorporate information about how functional brain networks are organized spatially in individuals with depression to inform how we administer brain stimulation therapies," Lynch says. ■

PARTICLE PHYSICS

Rare particle decay confirmed

An experiment has clinched the case for a special type of decay of subatomic particles called kaons. Further study of the ultrarare decay could reveal a potential flaw in the standard model, physicists' stalwart theory of subatomic particles.

The decay, in which a kaon produces another particle called a pion alongside a neutrino and an antineutrino, is known as a golden channel. That's because its rate can be predicted to high precision by the standard model. The experiment, called NA62, aims to test that precise prediction.

The search involved smashing high-energy protons into a target to produce kaons and observing the particles they decayed into. Typically, kaon decays result in a neutrino and a muon. But about 13 in 100 billion times, kaons decayed via the golden channel, NA62 scientists reported September 24 at a seminar at the particle physics lab CERN near Geneva.

That's about 50 percent more often than the standard model prediction. But given the precision of the measurement, "that is still consistent with the standard model, at this moment," says NA62 member Cristina Lazzeroni, a particle physicist at the University of Birmingham in England.

NA62 will take more data and produce a more precise measurement, which should determine with more certainty whether the standard model is correct. — *Emily Conover*

QUANTUM PHYSICS

Large Hadron Collider exposes quarks' quantum entanglement

Quantum entanglement has made its way to the top. Scientists have measured the strange quantum phenomenon of entanglement in top quarks, the heaviest known fundamental subatomic particles. It's the first detection of entanglement between pairs of quarks — a class of subatomic particles that make up larger particles, including protons and neutrons.

Using data from proton collisions, scientists with the ATLAS experiment — a particle detector at the Large Hadron Collider near Geneva — studied smash-ups that formed a top quark and a top antiquark. The two particles were entangled via a quantum property called spin, which means that measuring the spin of one particle would immediately tell you the other.

To detect the entanglement, researchers observed the particles that the top quark and antiquark decayed into. The angles at which those particles were emitted revealed the entanglement, the team reports in the Sept. 19 *Nature*.

As quarks go, top quarks are special. Generally, when quarks are cut loose in high-speed collisions, pairs of quarks and antiquarks quickly materialize, glomming together into larger particles. This process of hadronization washes out any entanglement. But top quarks and antiquarks decay so fast that hadronization can't occur, so the particles that they decay into can carry the signature of their entanglement. That means, for demonstrating entanglement, top quarks have the upper hand. — *Emily Conover*

ASTRONOMY

A dying star evokes a lava lamp

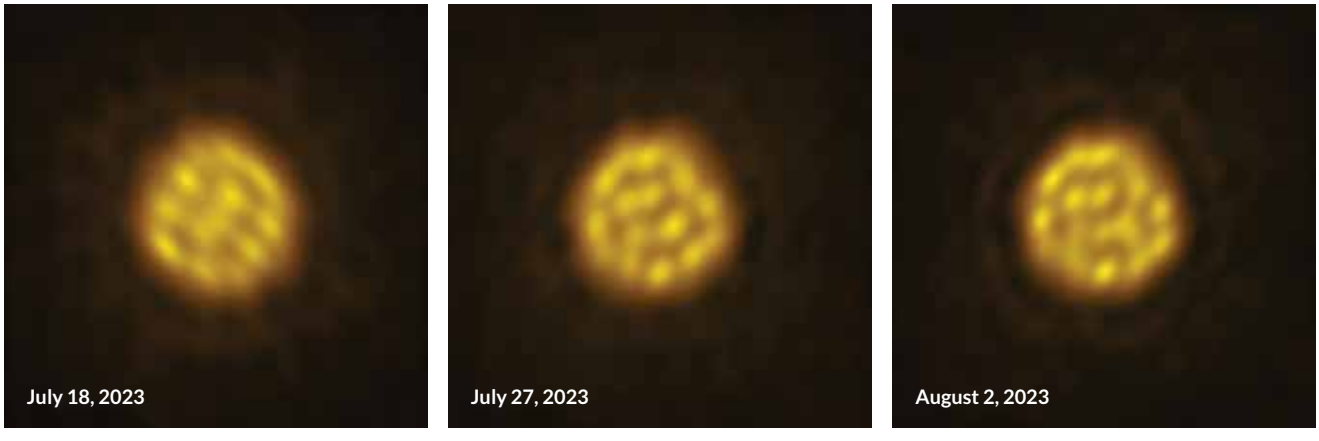
Astronomers have watched gas boil and bubble on the surface of a distant star.

R Doradus is a red giant that's about 180 light-years from Earth. Images of the star taken in July and August 2023 with the Atacama Large Millimeter/submillimeter Array in Chile show large gaseous cells rising and sinking at the surface, scientists reports in the Sept. 12 *Nature*.

Those bubbles are the hallmark of convection, which transports heat and energy around the insides of stars. "It's kind of the principle of a lava lamp or boiling water," says astronomer Wouter Vlemmings of the Chalmers University of Technology in Gothenburg, Sweden.

Similar bubbles have been observed on other giant stars. But this is the first time the bubbles' speeds and motions have been tracked in a star other than the sun.

R Doradus is about 350 times as wide as the sun but has about the same mass. The convective cells are correspondingly enormous — a single cell is 75 times as wide as the sun — and roil at about 20 kilometers per second. That's fast enough that a small fraction of the gas could escape into space. These observations and others like it could help illuminate the origins of the elements that make up stars, planets and people. — *Lisa Grossman*



A time series of telescope images of the star R Doradus shows bubbles of gas rising and sinking on the star's surface. The giant bubbles, each about 75 times as wide as the sun, appear as bright and dark spots and indicate convection inside the star.

ALMA/ESO, NAOJ AND NRAO, W. VLEMMINGS *ET AL*

CLIMATE

U.S. temperature-linked deaths could double by midcentury

Heat-related deaths in the United States are on the rise. But how bad will it be 20, 30 or 40 years from now? Scientists now have a clue.

Extreme temperatures, both hot and cold, contribute to over 8,000 deaths every year. Within the next few decades, that number could double or even triple as the climate changes due to greenhouse gas emissions, researchers report in the September *JAMA Network Open*.

Cardiologist Sameed Khatana of the University of Pennsylvania and colleagues estimated how many U.S. deaths are now associated with extreme temperatures by comparing the number of days with extreme temperatures and number of deaths from 2008 to 2019. Projections of temperatures and population sizes let the team estimate the number of deaths associated with extreme temperature for a future with a lower increase in greenhouse gas emissions and one with a higher increase. By 2036 to 2065, the annual number of deaths could double in a future with a lower increase in emissions, or triple in one with a higher increase. — *Andrea Tamayo*

Vertical farms grow crops indoors in stacks under artificial lights. A new computer program that adjusts the intensity of the lights based on electricity costs could help these farms save money.

AGRICULTURE

Smart lighting might make vertical farming more affordable

Fiddling with the dimmer switch might help some indoor farmers curb soaring electricity costs.

Growing crops in stacked rows indoors under fixed-intensity lights can produce more food per square meter while using less water than traditional outdoor farms. But this vertical farming technique is also energy intensive and expensive. Now, researchers have designed a computer program that controls lighting to optimize both photosynthesis and electric bills. Described September 24 in *Frontiers in Science*, the computer program adjusts the intensity of grow lights hourly based on the changing cost of electricity.

This smart lighting could cut vertical farms' electricity costs by 12 percent, says horticulturist Leo Marcelis of Wageningen University in the Netherlands, potentially saving some farms tens of thousands of dollars annually.

Experiments with leafy greens suggest that crops can grow under dynamic artificial lighting just as well as under fixed-intensity lights, Marcelis and colleagues found. Future research will test dynamic lighting on larger scales, Marcelis says. — *Sophie Hartley*

ANIMALS

Fish have bacteria on the brain

Members of the salmon family harbor active microbial communities inside their brains, evolutionary immunologist Irene Salinas of the University of New Mexico in Albuquerque and colleagues report in the Sept. 20 *Science Advances*.

Probing the brains of lab-raised and wild fish, including rainbow trout (*Oncorhynchus mykiss*), Atlantic salmon (*Salmo salar*), Chinook salmon (*O. tshawytscha*) and Gila trout (*O. gilae*), revealed that the fish had brain microbiomes. The bacteria may have hailed from different organs, crossed the blood-brain barrier and adapted to living in the brain, genetic analyses suggest.

Bacteria invading animals' brains is typically linked with disease. The finding hints that brain bacteria may not be bad news for fish, as the animals seemed healthy. Perhaps the bacteria help fish sense microbial cues in the environment, Salinas suggests. — *Erin Garcia de Jesús*

HEALTH & MEDICINE

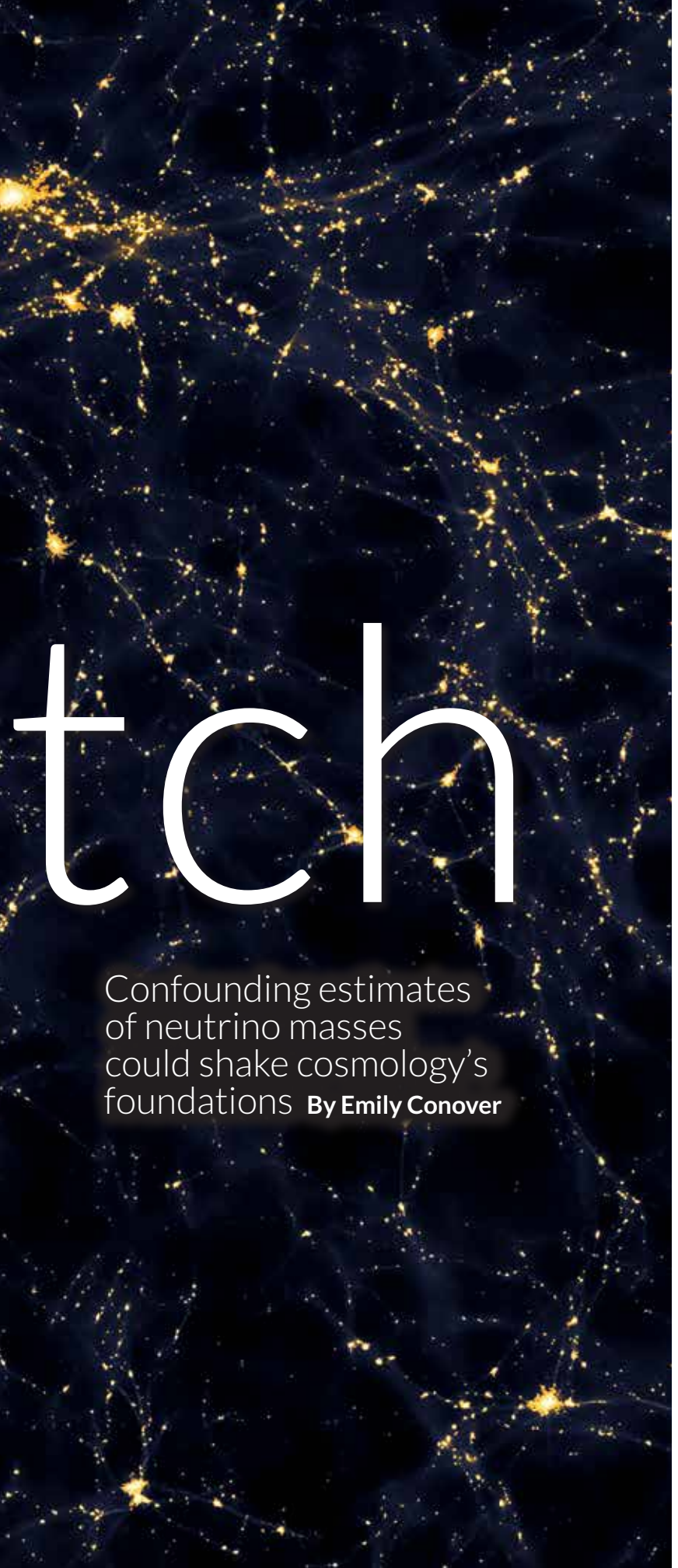
A study in mice hints at a new way to treat spinal cord injuries

After a spinal cord injury, some mouse nerve cells swell, stay that way longer than expected and begin dying. A drug that reduces swelling improved the mice's recovery, scientists report in the Sept. 25 *Science Translational Medicine*.

A team led by neuroscientist Bo Chen of the University of Texas Medical Branch at Galveston examined tens of thousands of neurons in mouse spinal cords. Inhibitory neurons, which dampen other cells' activity, swelled quickly after an injury, peaking at day two and returning to normal size by day 14. But excitatory neurons, which ramp up other cells' activity, stayed swollen for up to 35 days and more of them died. Giving mice bumetanide, a drug used to treat edema, decreased cell swelling and death and improved leg movement.

Neuron swelling may be an important part of spinal cord injuries in people, but more research is needed to understand how this process works and whether bumetanide might help, Chen says. — *Laura Sanders*

Mass Misma



tch

Confounding estimates of neutrino masses could shake cosmology's foundations

By Emily Conover

As the youthful universe congealed under the pull of gravity, matter knotted itself into galaxies, galaxy clusters and filaments, weaving a dazzlingly intricate cosmic web. This web's structure is thanks, in part, to the handiwork of neutrinos — lightweight, subatomic particles that surge through the cosmos in unimaginable numbers.

Because they streak about at high speeds and rarely interact with other matter, the particles weren't easily caught in the gravitational molasses of that latticework. So their presence hindered the formation of fine details in this cosmic filigree.

The masses of neutrinos are less than a millionth that of the next lightest particle, the electron, but no one knows exactly how massive they are. They are the only known type of fundamental subatomic particle for which this basic property is unknown, and some researchers suspect that this missing knowledge could be a gateway to a new understanding of physics.

"Neutrinos are one of the key particles that we do not understand as well as we do others, but that have nevertheless profound cosmological consequences," says particle cosmologist Miguel Escudero of the European particle physics lab CERN near Geneva.

The little particles' outsize role in sculpting the universe means they bridge the gap between the subatomic world, usually studied at particle accelerators or physics labs, and the cosmological one discerned by peering out at the heavens. So scientists are using observations of space and experiments on the ground in an attempt to solve this massive mystery.

But if you ask a cosmologist how much neutrinos weigh and ask a particle physicist the same question, you might get two different answers. The two groups' methods of gauging those masses are showing signs of a disconnect.

Recent cosmological data collected by the Dark Energy Spectroscopic Instrument, or DESI, favors masses that are unexpectedly small and creeping close to conflict with those of particle physics experiments. In fact, some interpretations of the DESI data suggest that neutrinos have no mass or even negative mass, normally a forbidden concept in physics (*SN: 12/27/14, p. 8*).

The intricate network of matter in the cosmos (shown in a computer simulation) is shaped, in part, by neutrinos and their unknown masses.

The odd result has physicists considering some tantalizing ideas — that neutrinos' masses might change over the history of the universe, or that the apparent negative masses are an

illusion caused by dark energy, the mysterious phenomenon causing the universe to expand at an accelerating rate.

DESI, located at Kitt Peak National Observatory in Arizona, collects detailed maps of galaxies and other objects. In April, DESI scientists made a splash by suggesting that the density of dark energy might change over the history of the universe (SN: 5/4/24 & 5/18/24, *p.* 6). The neutrino weirdness was overshadowed. But in the months since, physicists have realized that DESI might have big implications for neutrinos too.

Some scientists think the neutrino mass mismatch isn't universe-shattering. Instead, it may result from abstruse details about how the cosmological data are analyzed.

But if the effect holds up, it could hint at a massive shift. "I think that our description of the universe is too simple," says cosmologist Eleonora Di Valentino of the University of Sheffield in England. "Now that we have very strong and very sensitive measurements … it's time to complicate it a bit."

> "Neutrinos are one of the key particles that we do not understand as well as we do others."
>
> **MIGUEL ESCUDERO**

Massive confusion about neutrino masses

Neutrinos come in three varieties: electron neutrinos, muon neutrinos and tau neutrinos. The three are so-named because each is associated with an electrically charged particle: an electron or one of its heavier relatives, a muon or tau. Each neutrino variety can produce its charged partner when it interacts with other matter. To make things more complicated, each type doesn't have a definite mass but, thanks to the weirdness of quantum physics, a mixture of three different masses.

Today, the triumvirate suffuses the cosmos with hundreds of millions of neutrinos per cubic meter, outnumbering protons by a factor of about a billion. In the early universe, the particles were even more densely packed.

Although neutrinos are extremely lightweight, there's strength in numbers. The particles have been throwing their weight around the cosmos for billions of years, indelibly etching the night sky with their presence. They flit about not only the normal, visible matter that makes up stars and other spacefaring sundries, but also dark matter, an unidentified source of mass that bulks up galaxies around the cosmos.

Neutrinos' combined numbers are enough to not only alter the cosmic web, but also to influence the expansion rate of the universe. Those two factors allow scientists to gauge neutrino masses by peering into space. Neutrino masses on the bigger side would have resulted in a more rapid expansion of the universe and a less clumpy cosmos than smaller neutrino masses.

DESI maps out cosmic structures to determine that expansion rate, through an effect known as baryon acoustic oscillations, sound waves that imprinted circular patterns on the very early universe. By tracing those patterns at different points in the universe's history, scientists can track its growth, a bit like cosmic tree rings.

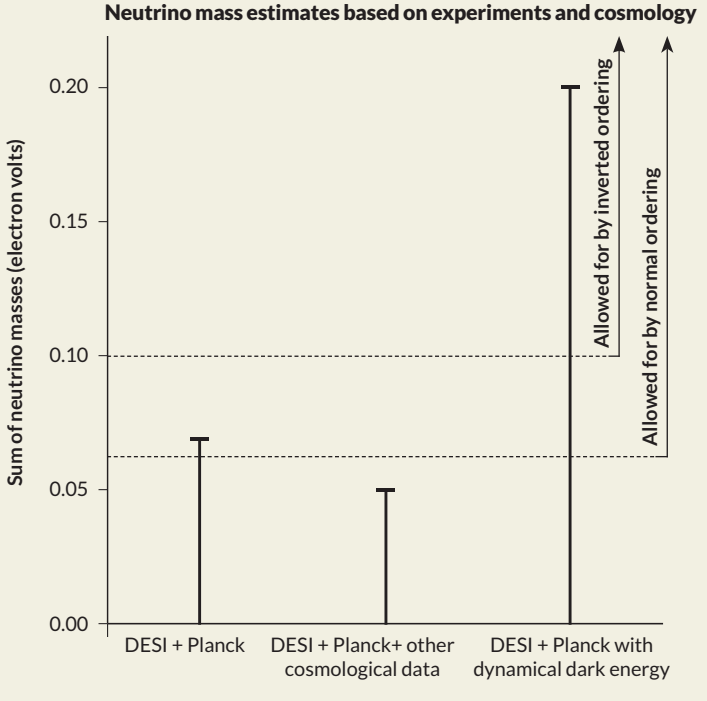
Meanwhile, the cosmic microwave background, light released 380,000 years after the Big Bang, reveals the clumpiness of the cosmos. As light from the cosmic microwave background traverses space, its trajectory is bent by the pockets of matter on its journey, much like light passing through a lens. The amount of this gravitational lensing tells scientists how clumpy the cosmos is.

Combining the measurements of clumpiness from the cosmic microwave background and the expansion rate from DESI lets scientists zero in on neutrino masses.

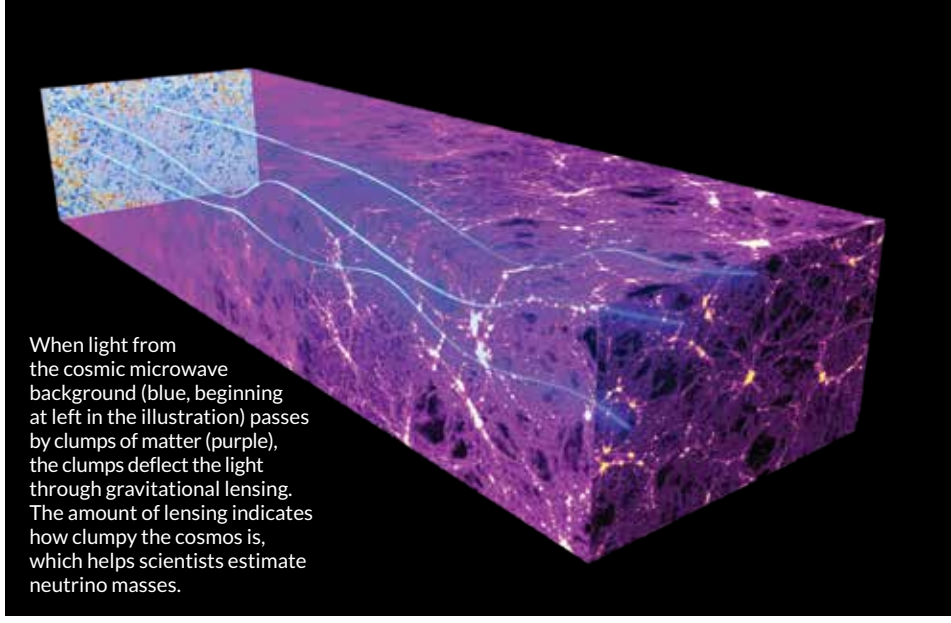
The DESI data, in combination with cosmic microwave background data from the European Space Agency's Planck satellite, provide a mass ceiling for neutrinos. Specifically, the sum of the three neutrino masses is less than about 0.07 electron volts at a 95 percent confidence level, researchers reported in April at arXiv.org. (An electron volt is a unit physicists use to quantify mass. An electron's mass is about 511,000 electron volts.)

In addition to a ceiling for neutrino masses, there's also a floor, based on laboratory particle physics experiments. Those experiments measure a phenomenon called neutrino oscillations, which results from the fact that each type of neutrino is a quantum mixture of different masses. The mass mélange means that neutrinos can change from one variety to another as they travel. What starts as a muon neutrino might later be detected as an electron neutrino.

Mass constraints Neutrino oscillation experiments put a floor on the sum of neutrino masses, depending on whether the masses have what's called normal or inverted ordering (dashed lines). Cosmological estimates based on DESI, Planck and other data put a ceiling on the sum. Some of those estimates, which vary depending on data used and assumptions, show little or no overlap with masses allowed by oscillations.



PREVIOUS SPREAD: ANDREW PONTZEN AND FABIO GOVERNATO, ESO; THIS PAGE: T. TIBBITTS



When light from the cosmic microwave background (blue, beginning at left in the illustration) passes by clumps of matter (purple), the clumps deflect the light through gravitational lensing. The amount of lensing indicates how clumpy the cosmos is, which helps scientists estimate neutrino masses.

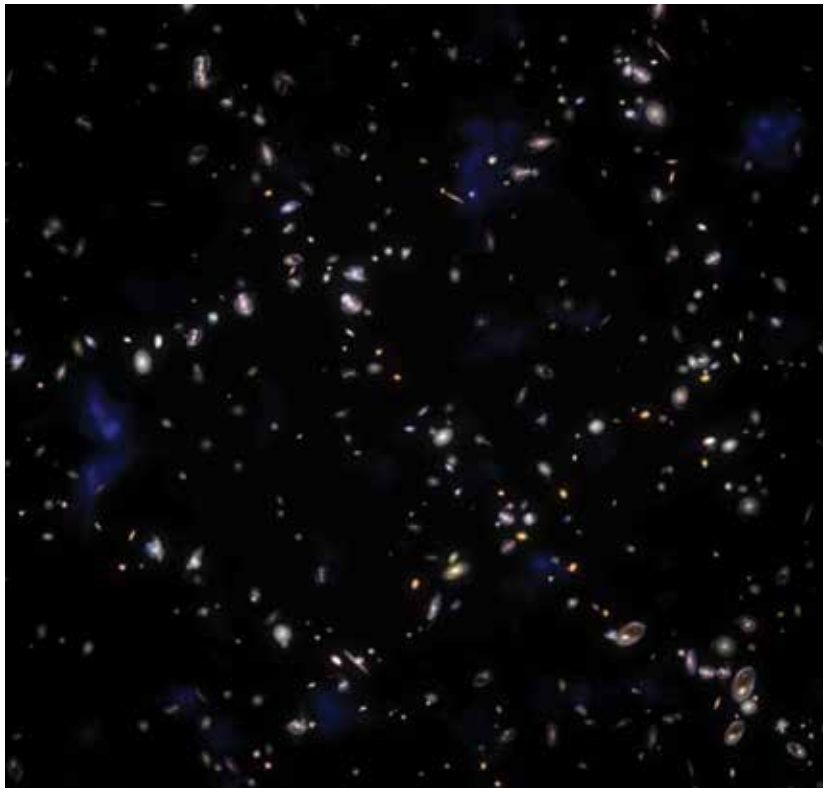
Scientists can spot this shapeshifting with detectors designed to capture signals of a neutrino interaction, such as brief flashes of light. Because oscillations depend on the relationship between the different neutrino masses, these experiments can't directly measure the masses themselves. But they do indicate that the sum of the three neutrino masses must be greater than about 0.06 electron volts.

That means DESI's rejection of neutrino masses more than about 0.07 electron volts is disconcertingly close to ruling out the entire range of masses allowed by oscillation experiments. The floor and the ceiling are almost touching.

There's still a little leeway — a crawl space, perhaps — for neutrino masses to live in harmony with both cosmology and oscillation experiments. But the DESI result is surprising for other reasons. For one, the value that DESI pinpoints as most likely for the sum of the neutrino masses is zero — no mass at all.

What's more, when additional cosmological data are added to the DESI and Planck data, such as catalogs of exploding stars that also gauge the universe's expansion rate, the upper limit on the mass shrinks further, to less than 0.05 electron volts, Di Valentino and colleagues reported July 25 at arXiv.org. The crawl space is essentially eliminated, leaving neutrino masses in a purgatory that's difficult to explain without proposing new ideas about the nature of the cosmos.

"If you take everything at face value, which is a huge caveat…, then clearly we need new physics," says cosmologist Sunny Vagnozzi of the University of Trento in Italy, another author of the paper



A phenomenon in the early universe called baryon acoustic oscillations generates subtle, ring-shaped patterns in the distributions of galaxies that are stretched as the universe expands (galaxies outside the rings are dimmed here to show the structure). To infer neutrino masses, scientists use the patterns to determine the universe's expansion rate.

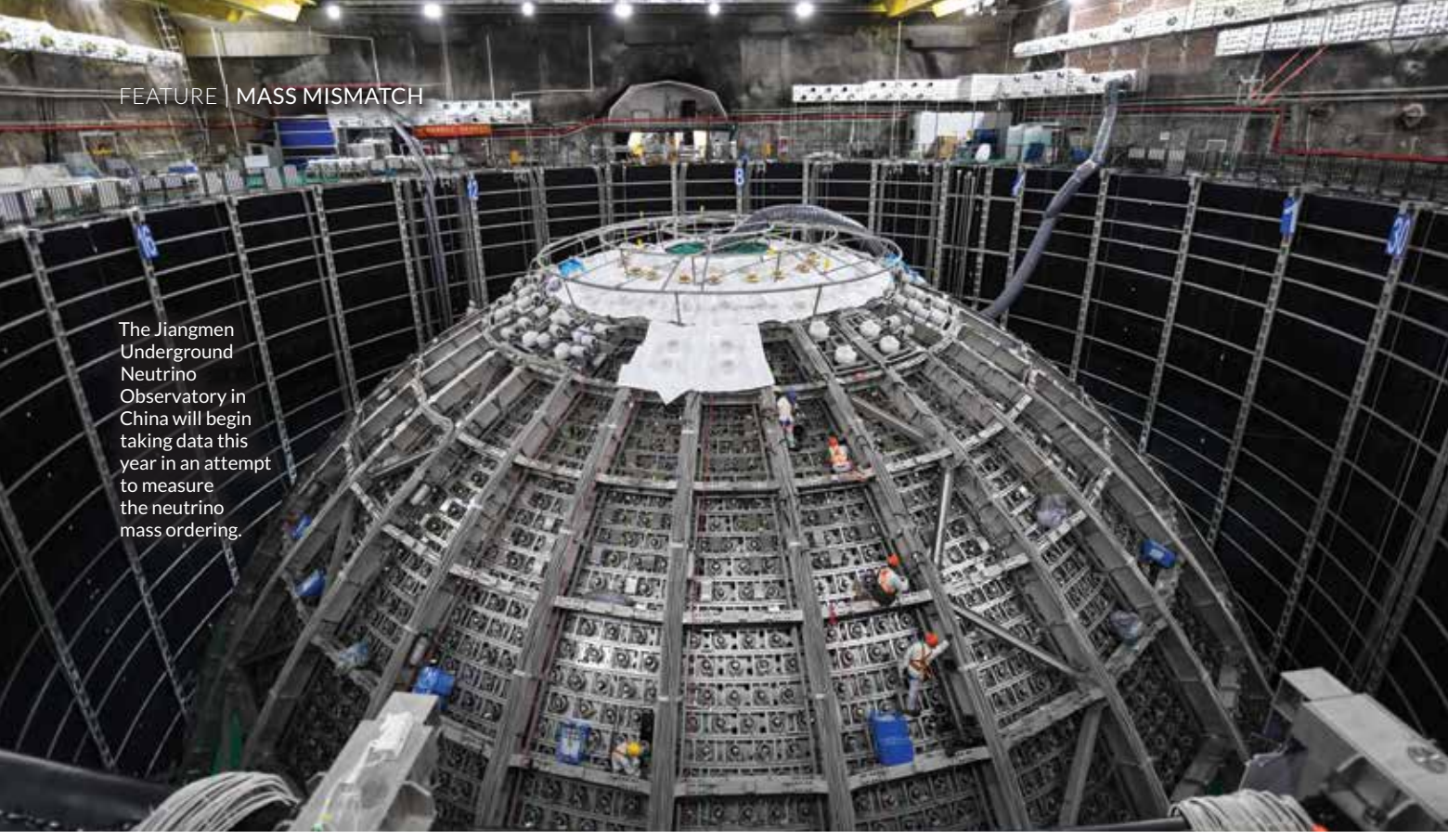
Even without the additional cosmological data, the DESI result, if taken seriously, would answer a major question: Which neutrino is heaviest? The three neutrino masses are labeled rather uncreatively with the numbers 1, 2 and 3. In one possible scenario called the normal ordering, mass 3 is heavier than masses 1 and 2. In what's known as the inverted ordering, masses 1 and 2 are heavier than 3. This matters because it determines whether there are two relatively light neutrino masses and one somewhat heavier one or two heavy and one light.

If the inverted ordering is correct, oscillation experiments imply the neutrino mass sum would be more than 0.1 electron volts. DESI squeezing the neutrino masses down to less than 0.07 electron volts not only leaves the normal ordering with little leeway, but it also seems to essentially rule out the inverted ordering.

"That's why everybody's going overboard," says cosmologist Licia Verde of the University of Barcelona, a member of the DESI collaboration.

Nixing the inverted ordering would be a big deal, with repercussions for a slew of theories and experiments. The ordering is so important that scientists designed an enormous experiment — the Jiangmen Underground Neutrino Observatory in China, planned to start up this year — aimed at measuring it. But particle physicists are not canceling their plans for the experiment, and no one is popping bottles of champagne to

FROM TOP: ESA AND THE PLANCK COLLABORATION; NASA'S GODDARD SPACE FLIGHT CENTER



The Jiangmen Underground Neutrino Observatory in China will begin taking data this year in an attempt to measure the neutrino mass ordering.

DENG HUA/IMAGO/ALAMY STOCK PHOTO

celebrate the demise of the inverted ordering.

The reason is that DESI's mass ceiling measurement exceeded expectations. "It was too good," says cosmologist Daniel Green of the University of California, San Diego.

Given the amount of data DESI collected, scientists would have expected an upper limit that was more than twice as large, pegging the mass to less than about 0.18 electron volts, he says, leaving the possibility of the inverted ordering alive and well. In fact, DESI wasn't expected to be able to rule out the inverted ordering — if the inverted ordering were incorrect — until it had taken several more years of data.

That has made physicists suspicious that something else is up.

The possibility of negative mass

If scientists take seriously DESI's preference for zero neutrino mass, there are a few ways to explain it, despite the fact that neutrinos in the lab indisputably have mass. Neutrinos could decay into other particles or annihilate with one another, Green and colleagues suggest September 17 in the *Journal of High Energy Physics*. Or perhaps neutrinos' masses vary over time.

But there's an even wilder possibility than zero mass: negative mass. Green suspected that "all of this funny behavior was because the data was actually going the wrong way. [The data] was seeing the 'opposite' of a neutrino." Namely, a neutrino with negative mass.

Whereas neutrinos with positive mass make the universe less clumpy, DESI and Planck might be finding the reverse, a universe that is clumpier than expected, meaning it has a larger-than-predicted variation in the density of matter from place to place. That could be conceptualized by a bizarro neutrino with negative mass.

In the DESI analysis, scientists didn't allow the neutrino mass to go negative. Perhaps DESI landed on zero only because it was forbidden from going lower.

So Green and colleagues tweaked the analysis to permit negative masses. The analysis homed in on −0.16 electron volts, the researchers reported.

Others similarly found that DESI's data implied negative neutrino masses. That's "kind of a crazy thing to say," says cosmologist Willem Elbers of Durham University in England. Negative masses in physics are hard to define and incorporate in theories, causing all kinds of conflict in equations. "We don't actually think that the neutrino mass is negative," Elbers says. Instead, "it's a symptom of some problem either in the data or in the assumptions that we make about how the universe evolves."

The negative mass could be a mirage of dark energy, Elbers and colleagues suggest. The standard picture of the universe assumes dark energy has a constant density, what's known as a cosmological constant. While the DESI data hint that dark energy is dynamical — that its density changes over time — DESI's neutrino mass number was determined assuming a cosmological constant.

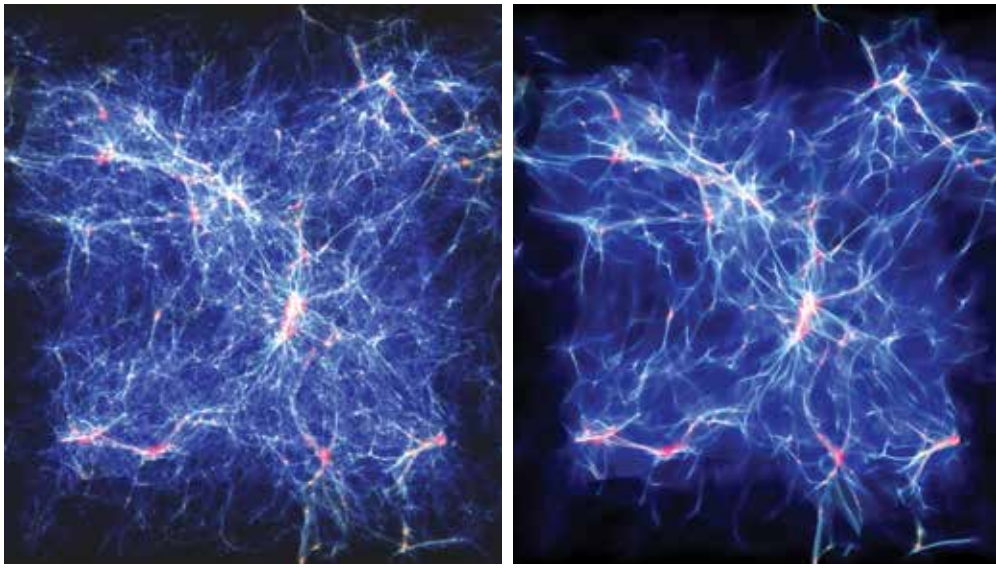
Allowing dynamical dark energy resolves the neutrino mass issue, Elbers and colleagues reported July 15 at arXiv.org. "It actually shifts the most likely value from something negative and unphysical to something that's right on the mark," Elbers says: 0.06 electron volts.

But not all theories of dynamical dark energy are alike. In general, scientists expect that dark energy's density either remains constant or gets diluted as space expands. But the model of dark

energy used by DESI and by Elbers and colleagues allow dark energy to go "phantom." That means dark energy's density increases as space expands. That type of dark energy is considered less plausible. It's difficult to explain within standard physics theories.

Using a model in which dark energy's variation is prohibited from going phantom actually made the neutrino mass mismatch worse, Vagnozzi, Di Valentino and colleagues reported in their paper.

That leaves scientists with no winning cosmological explanation for why the neutrino masses are smaller than expected.



Neutrino mass curbs the formation of fine details of the cosmic web. These simulations show the cosmic web with either massless neutrinos (left) or neutrinos with a summed mass of 500 electron volts (right). Brighter regions are more dense, and redder regions are hotter. To emphasize the neutrinos' impact, the right image was made with a much larger mass than neutrinos are thought to have and assuming neutrinos make up dark matter.

JULIEN BAUR/CEA

Problems with Planck

Rather than rethinking the universe, some scientists are taking a second look at the data.

Subtle issues in the cosmic microwave background data might be skewing things, some researchers suspect. In particular, the data from the Planck satellite are known to show an unexpected excess of gravitational lensing, that bending of the cosmic microwave background light that helps scientists deduce the neutrino masses.

More gravitational lensing is also what you'd expect from neutrinos with negative masses. In fact, earlier attempts to estimate the neutrino masses using Planck data combined with a predecessor of DESI also landed on unexpectedly small estimates. Perhaps Planck is the problem.

An updated version of the Planck data, using different methods of mapping out the cosmic microwave background, reduces this excessive gravitational lensing.

An analysis based on that updated Planck data, and removing two outlier DESI data points, eliminated the evidence for negative neutrino masses, Escudero and colleagues reported July 18 at arXiv.org.

Given that, Escudero says, "it seems premature to conclude there is a tension between the minimum value of neutrino masses we know from the laboratory and the lack of detection of neutrino masses in cosmology."

But, he notes, the analysis still found no evidence of a positive mass for neutrinos.

Taking earthly measurements

The cosmological measurements of neutrino mass rely on a variety of observations, and they hinge on the correctness of scientists' theory of the cosmos. If there's a missing link anywhere, that makes the neutrino mass estimates unreliable. So in the future, scientists hope to measure the neutrino mass directly, on Earth.

The KATRIN experiment in Karlsruhe, Germany, searches for the influence of neutrino masses on radioactive decays of tritium, a heavy form of hydrogen. When tritium's nucleus decays, it emits an antineutrino (the antimatter twin of a neutrino) and an electron. KATRIN aims to detect the effect of antineutrinos' masses on the energies of the electrons released in the decay.

While experiments like this could theoretically measure neutrino mass, their results aren't nearly as precise as those of cosmology. The sum of the neutrino masses must be less than 1.35 electron volts at a 90 percent confidence level, KATRIN researchers reported in June at arXiv.org. That's a much weaker limit than cosmology puts on the mass. So even though direct experiments are considered more reliable, they're not really telling scientists much that they didn't already know. Future direct experiments may further zero in on neutrino mass, but if neutrino masses are as tiny as cosmologists think they are, it will take some serious technological advancements.

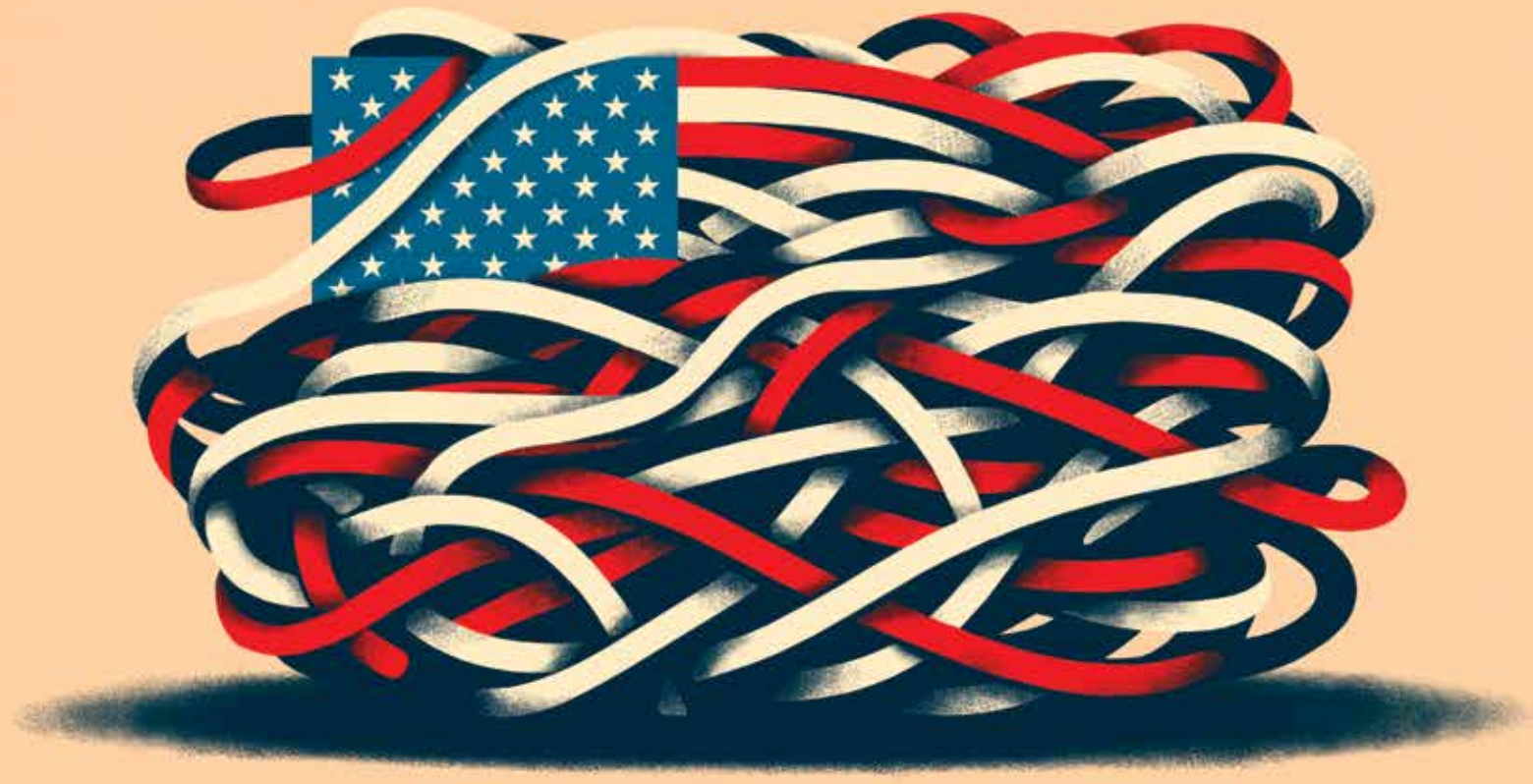
Still, the possibility of better understanding some of the most mysterious particles in the cosmos is tantalizing. "I find it particularly interesting that looking up at the sky can tell you something about a particle that is so light and tiny and small and subatomic," Verde says.

And if scientists can find agreement between neutrinos on Earth and in space, they'll have extra confidence that their theory of the universe is correct, Verde says. "If you can build a picture where everything hangs together, by combining both experiments that look at directly the infinitely small and experiments that look at the very big, it also offers support to the picture itself." ■

Explore more

- Learn more about DESI at www.desi.lbl.gov

State of Democracy



ROB DOBI/MOMENT/GETTY IMAGES PLUS

Is U.S. democracy in decline? Here's how political scientists are investigating

By Sujata Gupta

The United States' reputation as an exemplar of democracy appears to be eroding.

In a poll taken earlier this year, almost three-quarters of U.S. respondents agreed that the country's democracy "used to be a good example for other countries to follow, but has not been in recent years." People elsewhere appear to share that sentiment. The majority of poll respondents in Canada, the United Kingdom, Germany, Japan and South Korea also agreed with the statement.

More than 60 percent of U.S. respondents in another poll, from December 2023, believe that democracy in America is at risk depending on who wins the upcoming presidential election. Republican respondents see Democratic candidates as threatening the system and vice versa.

Now voters face the looming specter of the January 6, 2021, attack on the Capitol, in which supporters of former President Donald Trump attempted to halt the certification of the 2020 election. Echoes of that event have many questioning whether this year's election on November 5 will be free, fair and result in a peaceful transition of power.

A prominent metric that political scientists look to called Varieties of Democracy, or V-Dem — which hinges on the notion of free and fair elections — shows a slight dip in the health of U.S. democracy over the last decade.

Political scientists using that tool disagree over how to interpret that decline. Yet catching democratic erosion early is key to righting the course, says political scientist Rachel Beatty Riedl of Cornell University. "It's really important to pay attention to those tiny dips."

To understand the state of U.S. democracy, *Science News* went to experts with these five questions.

How do political scientists define and measure democracy?

Political scientists have long debated whether democracy is a matter of kind — a country is either a democracy or not — or a matter of degree.

Some 30 years ago, political scientist Adam Przeworski of New York University argued democracy exists when an incumbent government peacefully cedes power to the winning party following a loss at the polls.

"Democracy is a system in which [sitting] governments lose elections," Przeworski says.

The simplicity of this binary definition allows for ease of measurement, as elections and their aftermath are readily observable. And this litmus test has endured. "It actually works well most of the time," says Daniel Pemstein, a political scientist at North Dakota State University in Fargo.

But Przeworski's test has limitations. Even when he introduced his measure in the 1990s, he had trouble classifying some countries — Botswana, for instance. "Botswana was and still is a country in which there's relative freedom, freedom of the press, freedom of the unions. There are regular elections. Elections are never questioned by any observers, and yet the same party always wins," Przeworski says. "So there was no way for us to tell what would happen if they lose. Would they accept the defeat, or would they not accept the defeat?"

Today, Przeworski's measure shows that such hard-to-classify countries are increasing in number, which he suspects is due to a global trend away from democracy. But, he acknowledges, such small shifts are hard to capture with a binary measure.

How do you measure changes in democratic systems?

Many political scientists rely on metrics that treat democracy as existing along a continuum. The V-Dem project allows researchers and policy makers to evaluate a country's system of governance along several dimensions, including level of inequality, whether citizens feel heard, and the presence and strength of systems of checks and balances.

All those measures build from electoral democracy, says Michael Coppedge of the University of Notre Dame in Indiana and a principal investigator for the project. V-Dem's electoral democracy index focuses on the election period, including free and fair elections and other conditions surrounding the event, such as freedom of the press, respect for civil liberties, the right to organize and broad suffrage.

The more stringent and widely used V-Dem index of "liberal democracy" includes those factors and adds a close look at the years between elections, particularly a country's system of checks and balances.

The system used by V-Dem to measure the health of democracy involves some subjectivity. Political scientists in countries around the world provide ratings for questions about governance, such as those pertaining to election violence and interference, executive respect for the constitution and impartiality among public officials. Their responses range from 0 for the worst behavior and up to 5 for the best. V-Dem researchers then take those responses to calculate scores, ranging from 0 to 1 (most democratic), for each index it tracks, including electoral and liberal democracy.

The political scientists don't have to explain the

"Democracy is a system in which [sitting] governments lose elections."

ADAM PRZEWORSKI

rationale behind each rating, but analysts can look at which scores in the questionnaire have fluctuated over time to get a sense of their thought process, Coppedge says. "Our data is very good for tracking changes within countries over time."

In the United States, the liberal democracy score has been on a marked upward trend since 1900, the first year in the index. But scores have recently dipped—from 0.85 in 2015 to 0.77 in 2023. The decline in scores is linked to survey responses related to violence around the time of elections, perceptions that opposition parties cannot exercise oversight over the ruling party, and weakened checks and balances. Coppedge cites several events over the last few years that could help explain what the expert raters were thinking, including efforts in some states to prevent felons from voting even after they have completed their sentences and partisan efforts to block Supreme Court nominees.

Many political scientists view the violent events of January 6, 2021, as particularly troubling. On that day, Trump supporters who refused to accept President Joe Biden's November victory stormed the Capitol to try to overturn the election results. "That's a pretty obvious effort to subvert democracy," Coppedge says.

How troubling is the dip in the U.S. democracy score?

The U.S. score on liberal democracy remains on par with countries like the United Kingdom, which also scored 0.77 in 2023, and Canada, which scored 0.76. But researchers such as Riedl say that even small dips in scores warrant serious attention because pinpointing precisely when a country begins shifting toward autocracy is challenging yet key to thwarting further backsliding. And the U.S. dip is part of a larger global shift toward autocracy over the last decade, V-Dem researchers claimed in their 2024 annual report. More than 70 percent of the world's population, or 5.7 billion people, lived in autocracies in 2023 compared with 50 percent in 2003, the team found.

Baseline electoral democracy scores provide further evidence of a global decline in democracy. In 2003, 11 countries were in the process of autocratizing. In 2023, that number nearly quadrupled to 42.

But some researchers question these findings. Earlier this year, a pair of political scientists found there is no global backsliding trend. Andrew Little of the University of California, Berkeley and Anne Meng of the University of Virginia in Charlottesville quantified purportedly objective measures of democracy (versus the more subjective V-Dem index), including Przeworski's measure of incumbent losses at the polls, as well as executive constraints and attacks on the press.

There are over 200 countries in the world and, at any given time, some of them, such as Hungary and Venezuela today, will be undergoing democratic backsliding. But that does not make a trend, Meng and Little wrote in April in *PS: Political Science & Politics*. "The common claim that we are in a period of massive global democratic decline is not clearly supported by empirical evidence."

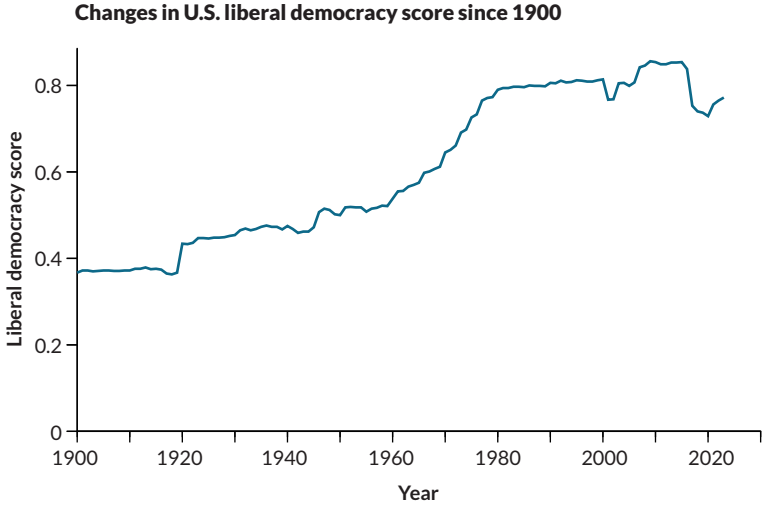
Meng and Little refrain from commenting on whether the United States is in a period of democratic decline. But they speculate that intensive media coverage of the supposed decline could be biasing the judgment of experts, such as V-Dem's raters. But Coppedge and his team say that they have found little to no evidence of such bias.

Regardless of how one calculates or interprets global trends, the odds of the United States turning into an autocracy are extremely low, political scientist Daniel Treisman of UCLA argued in 2023 in *Comparative Political Studies*. V-Dem data suggest that both wealth and duration protect a democratic country from reverting to autocracy. No democracy in the dataset that has survived for over 43 years has ever failed, Treisman notes.

Treisman's work builds on political scientists' long-standing observation that capitalism, and the wealth such a system generates, is linked to democracy. But trends over the last few decades suggest that the link might be weakening, Riedl and colleagues argued in a 2023 preprint in *World Politics*.

Treisman didn't include countries that have democratized over the last several decades, and he took a narrow approach to understanding the process of autocratization, Riedl says. "Treisman and

Dips in democracy
The U.S. liberal democracy score has trended upward since 1900, though there have been dips. Political scientists disagree on whether a dip in recent years is cause for concern.
SOURCE: V-DEM PROJECT



C. CHANG

others tend to focus on full regime change, democratic death, which is indeed very rare."

Subtler measures that look at the weakening of democratic systems paint a more nuanced picture. Riedl's team analyzed more than 100 episodes of democratic erosion across all countries in the V-Dem dataset since 1990. Thirty-eight of the 202 countries in the dataset experienced statistically significant reductions in democracy scores. Roughly half of those countries exceeded wealth levels thought to protect against such erosion.

What factors play a role in destabilizing democracy?

Political scientists have typically focused on forces that stabilize democracies in capitalist societies, such as wealth, education and labor, Riedl says. But they have paid less attention to capitalism's destabilizing forces, chiefly endemic inequality. That inequality, coupled with polarization—both a cause and effect of backsliding—helps promote populist leaders promising to make the system work for everyday people, regardless of whether the proposed solutions adhere to democratic principles, Riedl says. Such populist leaders may come to power through legitimate elections but then pursue autocratic agendas by weakening systems of checks and balances.

For instance, Hungary appeared to be a stable democracy during the 1990s and 2000s, with liberal democracy scores above 0.7. Those scores began plummeting when Viktor Orbán became prime minister in 2010, dropping to just over 0.3 by 2023. Orbán has spent years chipping away at the courts' independence, seeking to put the judicial system under control of the ruling party, packing the courts with partisan judges and extending judicial term limits.

"Changing the composition of the courts is a really significant pathway to authoritarianism," Riedl says.

In the United States, four factors could trigger democratic backsliding, political scientists Suzanne Mettler of Cornell University and Robert Lieberman of Johns Hopkins University wrote in March in the *Annals of the American Academy of Political and Social Science*. Those factors are polarization, conflicts over belonging, economic inequality and executive aggrandizement.

The January 2021 insurrection, in which all four factors converged for the first time in U.S. history, was a particularly troubling threat because it violates Przeworski's basic tenet of peaceful transition of power as core to democracy, Mettler says. "You

Democracy under fire

Four types of threats—polarization, conflict over who belongs, economic inequality and executive aggrandizement (presidential overreach)—have endangered U.S. democracy at various points in the country's history, according to political scientists Suzanne Mettler of Cornell University and Robert Lieberman of Johns Hopkins University. Here's a look at the country's past brushes with authoritarianism, which Mettler and Lieberman describe in their 2020 book, *Four Threats*.

1790s

Threat: Polarization

In the country's infancy, members of the ruling Federalist Party, most notably John Adams and Alexander Hamilton, abhorred the opposing Democratic-Republican Party. The passage of the 1798 Sedition Act made it a crime to publish material critical of the government, a move that Democratic-Republicans, including Thomas Jefferson, saw as blatantly authoritarian. Violence seemed imminent after the 1800 presidential election failed to produce a clear victor. But members of the House of Representatives selected Jefferson as the winner, and the country established the tradition of a peaceful transfer of power between parties.

1850s

Threat: Polarization, conflict over who belongs, rising economic inequality

The triple threat of political polarization, mounting tensions over slavery and the status of Black people in the United States, and economic inequality brought on, in part, by the Industrial Revolution jeopardized U.S. democracy. The founding fathers set that fight into motion with the three-fifths compromise, which counted three out of every five enslaved people toward a state's population and boosted slaveholding states' clout in the House of Representatives and Electoral College. When Kansas sought to become a state in the mid-1850s, violent conflicts broke out between the country's pro- and antislavery factions. Those tensions ultimately triggered the Civil War.

1890s

Threat: Polarization, conflict over who belongs, rising economic inequality

After the Civil War, authoritarian enclaves spread across the South as states imposed poll taxes and literacy tests to disenfranchise Black Americans and poor white people.

1930s

Threat: Executive aggrandizement

In an effort to lift the country out of the Great Depression and prevent a repeat, President Franklin Roosevelt pushed for reforms and regulations that gave the executive branch unprecedented control over banks and the stock market. During World War II, he expanded his office's ability to spy on everyday Americans.

1970s

Threat: Executive aggrandizement

The growth of the executive branch during the Cold War emboldened President Richard Nixon to heighten surveillance of Americans critical of the Vietnam War, as well as members of the Democratic Party. That includes a botched wiretapping of Democratic National Committee headquarters in what became known as the Watergate scandal. Journalists, judges and members of Congress reigned in Nixon, who resigned after facing impeachment.

FROM TOP: LIBRARY OF CONGRESS; JOHN L. MAGEE/WIKIMEDIA COMMONS; ALFRED R. WAUD/WIKIMEDIA COMMONS; LIBRARY OF CONGRESS; NATIONAL ARCHIVES & RECORDS ADMINISTRATION

In 2016, South Korea's National Assembly impeached President Park Geun-hye after a corruption scandal involving the president triggered protests.

AP PHOTO/LEE JIN-MAN

have to accept the outcome and let the winner govern. And if you get away from that, you just do not have democracy."

What helps keep democracy strong?

Finding and utilizing points of resilience, such as the courts, legislatures or a vibrant independent press, are key to strengthening democracy, according to experts.

In Brazil, for instance, the courts determined that former President Jair Bolsonaro had abused his power when he claimed, without evidence, that the country's election system was rigged ahead of his 2022 loss to Luiz Inácio Lula da Silva. In June 2023, justices blocked Bolsonaro from seeking re-election until 2030.

Even when voters believe checks and balances are weak, their voices, coupled with a robust media, can ward off threats, Riedl says. In 2023, she coauthored 15 in-depth case studies of countries showing signs of autocratization for the U.S. Agency for International Development.

South Korea, for instance, shows the need for constant vigilance. The country recovered from an autocratic turn in the last decade but continues to oscillate between democratic regression and recovery, according to the V-Dem project.

The country's score went from 0.6 in 2014 to 0.8 a few years later due, in part, to intense media exposure and coverage of then-President Park Geun-hye's central role in a massive corruption scandal. That reporting triggered months-long candlelight rallies demanding Park's impeachment. The country's independent National Assembly impeached Park in December 2016. In March 2017, the courts upheld the impeachment and forced Park out of office. Recent reports, though, show that the country's scores are now back in the 0.6 range due to the current administration's punishment of members of the previous presidential administration.

The United States has strong points of democratic resilience, Coppedge says. That includes powerful, independent media outlets and civic society organizations, intense competition between political parties, and public engagement at all levels in the process, whether it's learning about candidates' positions, supporting candidates through actions like canvassing and phone-banking and, most essential, voting.

"Institutions and government leaders," Riedl says, "can be empowered to be agents of democracy when they are given that push from below." ■

Explore more

- V-Dem Institute. "Democracy report 2024: Democracy winning and losing at the ballot." March 2024.
- Robert C. Lieberman and Suzanne Mettler. "The crisis of American democracy in historical context." *Annals of the American Academy of Political and Social Science*. March 20, 2024.

PODCAST

‘Does It Fly?’ separates fact from science fiction

Imagine you’re hanging out at a bar with your very enthusiastic friends, about two beers in, and someone brings up *Star Trek*. OK, but the transporter! How would that actually work? What about the TARDIS of *Doctor Who* — does that thing even make sense? It made for so many good stories, though, right?

That’s the premise — and tone — of the entertaining podcast *Does It Fly?*, hosted by astrophysicist and “mad scientist” (his words) Hakeem Oluseyi and actress, writer and “pop culture expert” Tamara Krinsky. Released roughly once a week since April, each episode centers on a science or technology concept from a popular sci-fi show or movie. The hosts spend most of 45 minutes pondering how well each concept works — does it “fly”? — not just technologically, but also as an engine for storytelling.

Does It Fly?
Roddenberry Entertainment
AVAILABLE WHEREVER YOU GET YOUR PODCASTS

Pondering the real-world feasibility of any given sci-fi tech is hardly a new concept; fandoms have enthusiastically wrangled over this sort of thing for decades (SN: 10/3/15, p. 28).

Does It Fly? acknowledges its place in this history at the outset. Oluseyi and Krinsky are, respectively, a self-proclaimed nerd and geek, and they emphasize that they’re coming at these concepts from a place of love and joy. Sometimes a little too much. Listening to the hosts’ banter can feel like lurking in a fandom forum chat, and it’s often tempting to fast-forward past that banter to get to the good stuff.

And *Does It Fly?* has some truly fascinating moments. Oluseyi’s astrophysics bona fides shine when he describes, for example, the quandaries of real-world *Star Trek* transporter technology, or ponders the feasibility of making *Star Wars*’ lightsabers by using magnetic fields to contain plasma into a deadly yet portable blade form. (Do lightsabers fly? Oluseyi says nah, not any time soon and probably never.)

Take the transporters, “one of the most iconic conceits in all of science fiction,” Krinsky says. The *Star Trek* device can send objects across great distances by converting them into energy and then reconstituting them in the delivery location. In reality, the closest thing we have to such a technology is quantum teleportation, in which quantum states of particles, but not the particles themselves, can be transmitted from one location to another. This is not that, Oluseyi says.

The most obvious issue, perhaps, with making a transporter work today is how to first break down an object into its basic units — and what are those, anyway? Molecules and atoms? Electrons and quarks? Even if you could, you’d need an immense amount of storage for all that data — far beyond what current technology allows. And even if we solve the storage problem centuries from now, Oluseyi adds, there’s yet another problem: how to properly record and then re-create all the dynamic data, like memories, that make up a person at any given moment.

The podcast’s interesting twist on sci-fi science — one that this writer particularly appreciated — is the discussion of how an imagined technology does or doesn’t serve the overall storytelling. For example, from a storytelling standpoint, the transporter is central to many of *Star Trek*’s most memorable episodes, Krinsky says. The device “transports” characters quickly into the action and drives plotlines around everything from cloning to “transporter psychosis.” The many spin-offs of the original *Star Trek* have also allowed the transporter’s engineering to evolve, showing, for instance, the technological breakthrough of transporting organic and not just inorganic materials for the first time.

Bottom line: Scientifically, the transporter doesn’t fly. But storywise, Krinsky says, “I would say hell, yes!”

The hosts’ cheerful and often unstructured conversation works well when they’re bouncing thoughts around about the physics of time travel, or the tornado-analyzing silver-ball sensors of the 1996 movie *Twister*, or the neurotechnology in Netflix’s *3 Body Problem*.

But not every fan favorite show or movie is amenable to this podcast’s format. An episode devoted to demonic possession à la *Beetlejuice* feels uneven and unmoored, largely because there isn’t much science discussed — or really to discuss — on the subject.

Listeners certainly won’t always agree with the hosts’ assessments. But maybe that’s part of the point. Each episode conveys the feeling of jumping into the middle of an ongoing discussion, one that is fully expected to continue after the hosts sign off.

That was my experience during a recent car trip. I listened to the TARDIS episode with my sister, a huge *Doctor Who* fan. We both enjoyed the mind-bending idea that the show’s beloved, time-traveling blue phone booth mimics a black hole in many ways: It manipulates time; it’s larger on the inside than the outside; and there’s even a hypothetical type of black hole, called a wormhole, thought to act as a portal through space. “Everything black holes do, the TARDIS does,” Oluseyi says, giving the not-a-phone-booth more or less a scientific thumbs-up.

But then Krinsky suggests that the TARDIS is flawed from a storytelling standpoint because the show sometimes flouts its own rules about how the TARDIS works, breaking a golden rule of sci-fi. My sister disagreed. Those logic leaps were fully justified, she said.

Let’s just say, I learned *a lot* about *Doctor Who* during that car ride. And as the miles flew by, a good time was had by all.

— *Carolyn Gramling*

UNEARTHING POTENTIAL

The Regeneron Science Talent Search (STS) is the nation's oldest and most prestigious science research competition for high school seniors. STS serves as a launching pad for some of the country's brightest young minds, with alumni going on to become leaders in their fields and winning Nobel Prizes, Fields Medals, MacArthur Fellowships and other accolades.

Gabriela Farfan, a 2009 STS finalist, is now the Coralyn W. Whitney Curator of Gems and Minerals at the Smithsonian Institution's National Museum of Natural History (NMNH). During the STS gala, Gabriela was seated next to Jeffrey Post, then-curator of the NMNH's gem and mineral collection. This auspicious seating arrangement sparked a mentorship that eventually led to Gabriela stepping into the curator role after Jeffrey's retirement in 2023.

Gabriela says STS helped her dream big: "It was the first time I truly considered what my long-term aspirations were—and believed that they could actually happen."

Learn more about Regeneron STS and apply to the 2025 competition by November 7: www.societyforscience.org/regeneron-sts

AUGUST 24, 2024

Let's talk neutrinos

Two dark matter experiments have spotted signs of neutrinos knocking into atomic nuclei in their detectors. The finding portends a future obstacle for the detectors, ***Emily Conover*** *reported in "'Fog' invades dark matter experiments"* (SN: 8/24/24, p. 12).

These detectors scan for dark matter's interactions with the nucleus of a xenon atom. Reader **Robert Walty** wondered how that could work. Doesn't dark matter interact with normal matter only through gravity?

So far, scientists have detected dark matter only through its gravitational interactions with normal matter. But the mysterious substance could potentially interact through other forces, **Conover** says. It is possible dark matter might interact via the weak nuclear force, for example. "That type of interaction is what these detectors are looking for," she says.

Walty also asked how a neutrino, which is much smaller than a proton, could slam into an entire atomic nucleus.

"Subatomic particles aren't like billiard balls of different sizes bouncing around. Instead, they act like waves," **Conover** says. If a particle's wavelength is longer than an atom's nucleus, it will interact with the nucleus as a whole, rather than with an individual proton or neutron. In the case of a neutrino hitting a nucleus, the interaction actually occurs through another particle, called a Z boson, which the neutrino exchanges with the nucleus. If the Z boson's wavelength is big enough, the whole nucleus will recoil as one.

Pollination and plastics

The electrostatically charged wings of moths and butterflies could draw pollen out of nearby flowers without the insects needing to land on the blooms, ***Anna Gibbs*** *reported in "Pollination via static electricity"* (SN: 8/24/24, p. 13).

Reader **Michael Skinner** asked whether that static could also attract microplastics and interfere with pollination.

Unfortunately, the answer is probably yes, says ecologist **Sam England** of the Natural History Museum in Berlin. Microplastics tend to be electrostatically charged, so they would likely be attracted to pollinators with the opposite charge, he says. The materials could also possibly mess with pollination, since they "are known to interfere with many different biological processes in plants," **England** says. But this has yet to be tested, so the magnitude of these potential effects are unknown.

Portraits of a rover

NASA's Perseverance rover has found its first possible hint of ancient life on Mars, ***Lisa Grossman*** *reported in "Mars rover finds a major surprise"* (SN: 8/24/24, p. 6).

Readers asked how the rover, nicknamed Percy, snapped the photo of itself featured in the story.

Percy's "selfies" are actually a team effort. The rover's WATSON camera is primarily designed for close-ups of rocks and captures only small parts of a scene. So engineers on Earth direct Percy to take dozens of photos of itself from various angles. Image processing engineers then use software to clean up and assemble the shots into a complete image.

Join the conversation

EMAIL feedback@sciencenews.org

MAIL Attn: Feedback
1719 N St., NW
Washington, DC 20036

Connect with us

A vital ocean current is stable, for now

Curving around the Florida peninsula, a key ocean current flows. For decades, scientists had thought it was weakening. That, in turn, had prompted speculation that a major system of currents — known for regulating Earth's climate — may have also weakened recently due to climate change.

But the bellwether ocean artery, known as the Florida Current, has actually been relatively stable in recent decades, researchers report September 5 in *Nature Communications*.

The Florida Current is a part of the Atlantic Meridional Overturning Circulation, or AMOC, a network of currents that circulate heat, salt and nutrients through the Atlantic Ocean. Some scientists have suggested that the AMOC could collapse sometime this century, dramatically cooling the Northern Hemisphere and raising the sea level along some Atlantic coastlines by up to 70 centimeters.

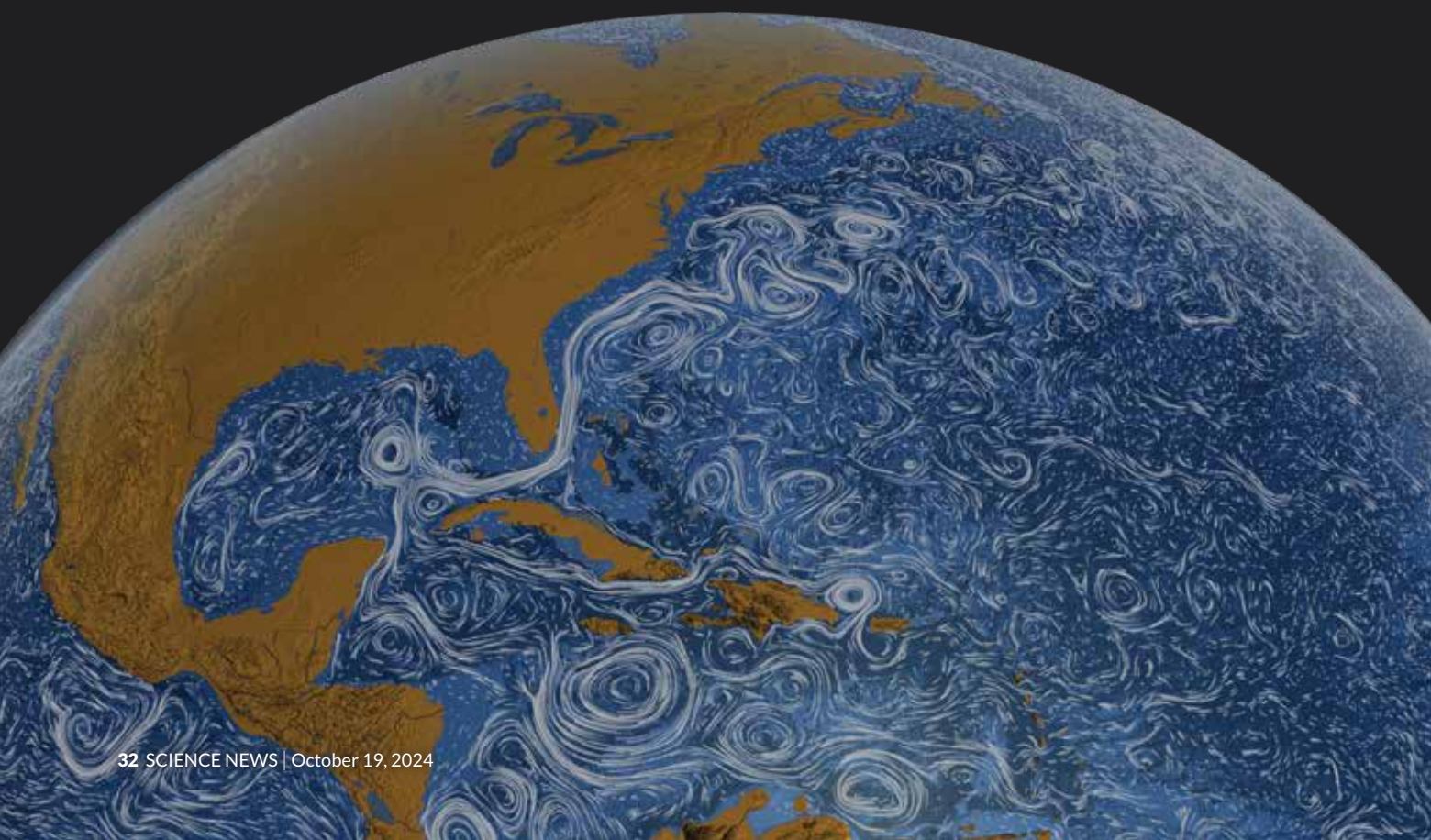
"The good news is that the AMOC is slowing down less than we thought, and that means that there's still time to avert a more serious slowdown," says oceanographer Hali Kilbourne of the University of Maryland Center for Environmental Science in Solomons. But because the reassessed data span only a few decades, she says, "there's still an outstanding question about whether or not the AMOC has slowed since preindustrial times."

In the subtropical North Atlantic, most of the water carried north by the AMOC comes from the Florida Current (visualized below), which whisks water from the Gulf of Mexico into the Gulf Stream (seen going up the U.S. East Coast and then across the Atlantic). Since 1982, a telecommunications cable spanning part of the Straits of Florida has been used to monitor the powerful current, providing the longest observational record of any AMOC component. Charged atoms in the seawater generate a voltage in the cable, which scientists use to calculate how much water the current carries on any given day.

But since 2000, there has been a failure to account for changes in Earth's magnetic field, oceanographer Denis Volkov of the University of Miami and colleagues found.

Correcting the data to account for the magnetic field changes almost eliminated the previously reported decline. The correction also shrank estimates of a recent decline of the AMOC by about 40 percent. While that's still a loss, Volkov says, it's barely significant: The system flow rate, which averages around 17 million cubic meters per second, declined by just 800,000 cubic meters per second each decade. It's not yet possible to say, he adds, whether the decline is a consequence of climate change or a natural fluctuation.

The takeaway is that the Florida Current does not indicate that the AMOC is slowing down. Or if it is, the observational record is too brief to detect the decline. Much of the work indicating an AMOC decline since preindustrial times uses proxy data that extend over thousands of years. The revised dataset, Kilbourne says, is still too short to alter our understanding of the AMOC's long-term evolution. — *Nikk Ogasa*



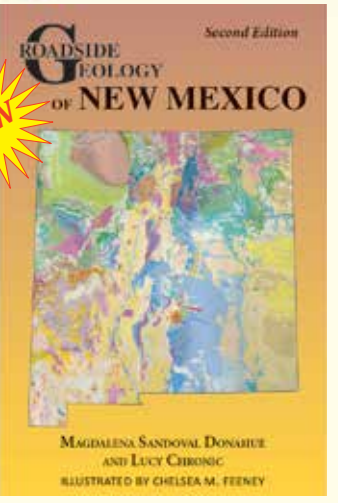
GODDARD SPACE FLIGHT CENTER SCIENTIFIC VISUALIZATION STUDIO/NASA

Making Road Trips More Interesting for More Than 50 Years!

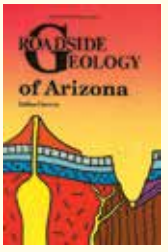
ROADSIDE GEOLOGY

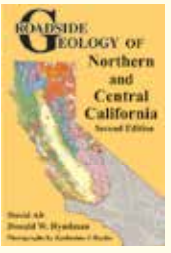
Fans of the Roadside Geology series never go on a trip without at least one of these books. Loaded with photos, maps, and informative text, they have answered travelers' geology questions since 1972.

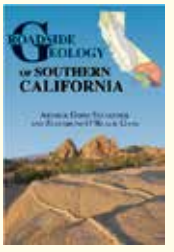
NEW

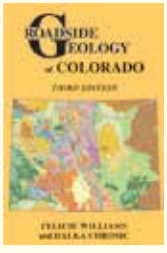


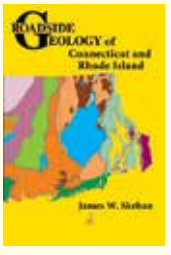
ROADSIDE GEOLOGY OF
NEW MEXICO
MAGDALENA SANDOVAL DONAHUE AND LUCY CHRONIC
368 pages, 6 x 9, paper $32.00

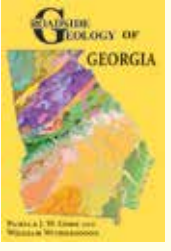


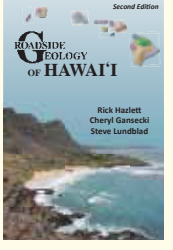


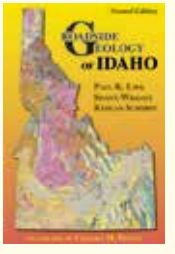


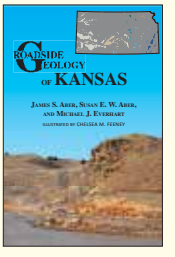


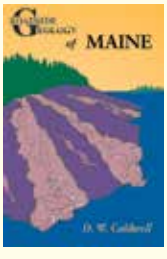


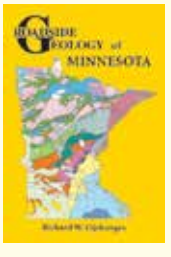


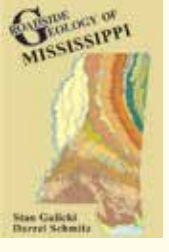


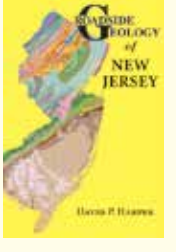


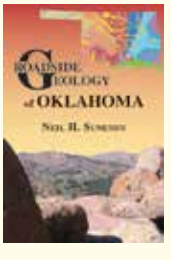


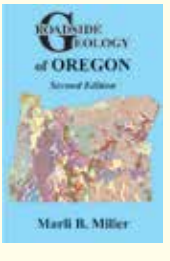


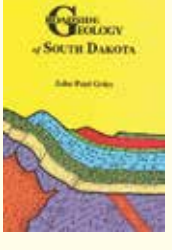


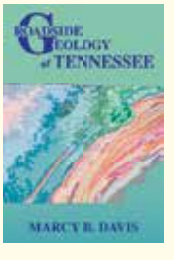


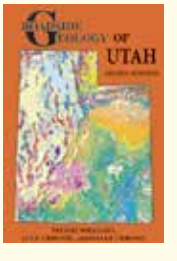


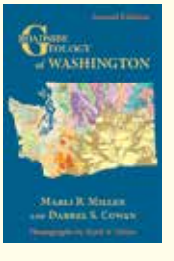


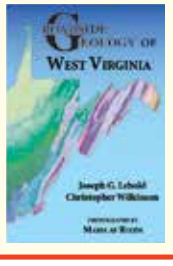


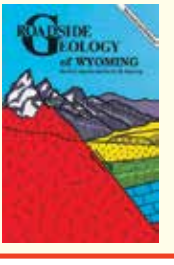


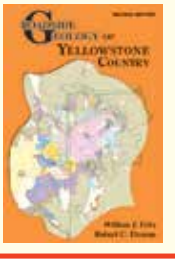












VISIT OUR WEBSITE FOR MORE INFORMATION ABOUT THESE TITLES AND MANY, MANY MORE!

MP MOUNTAIN PRESS PUBLISHING COMPANY

P.O. BOX 2399 • MISSOULA, MONTANA 59806

800-234-5308 • WWW.MOUNTAIN-PRESS.COM

UNIVERSITY OF NORTH CAROLINA
CHARLOTTE
WILLIAM STATES LEE
COLLEGE OF ENGINEERING

ONLY AT CHARLOTTE

Make an impact through the new Environmental Engineering degree.

Learn pollution prevention skills in water, soil and atmosphere resources

Address environmental challenges at the natural and built environment interface

Enhance water resources with innovative environmental engineering practices

*At UNC Charlotte, you'll become **Real World Ready** through intensive experiential learning.*

Explore Charlotte's engineering programs, including civil, computer, electrical, environmental, industrial, mechanical and more.

ENGR.CHARLOTTE.EDU