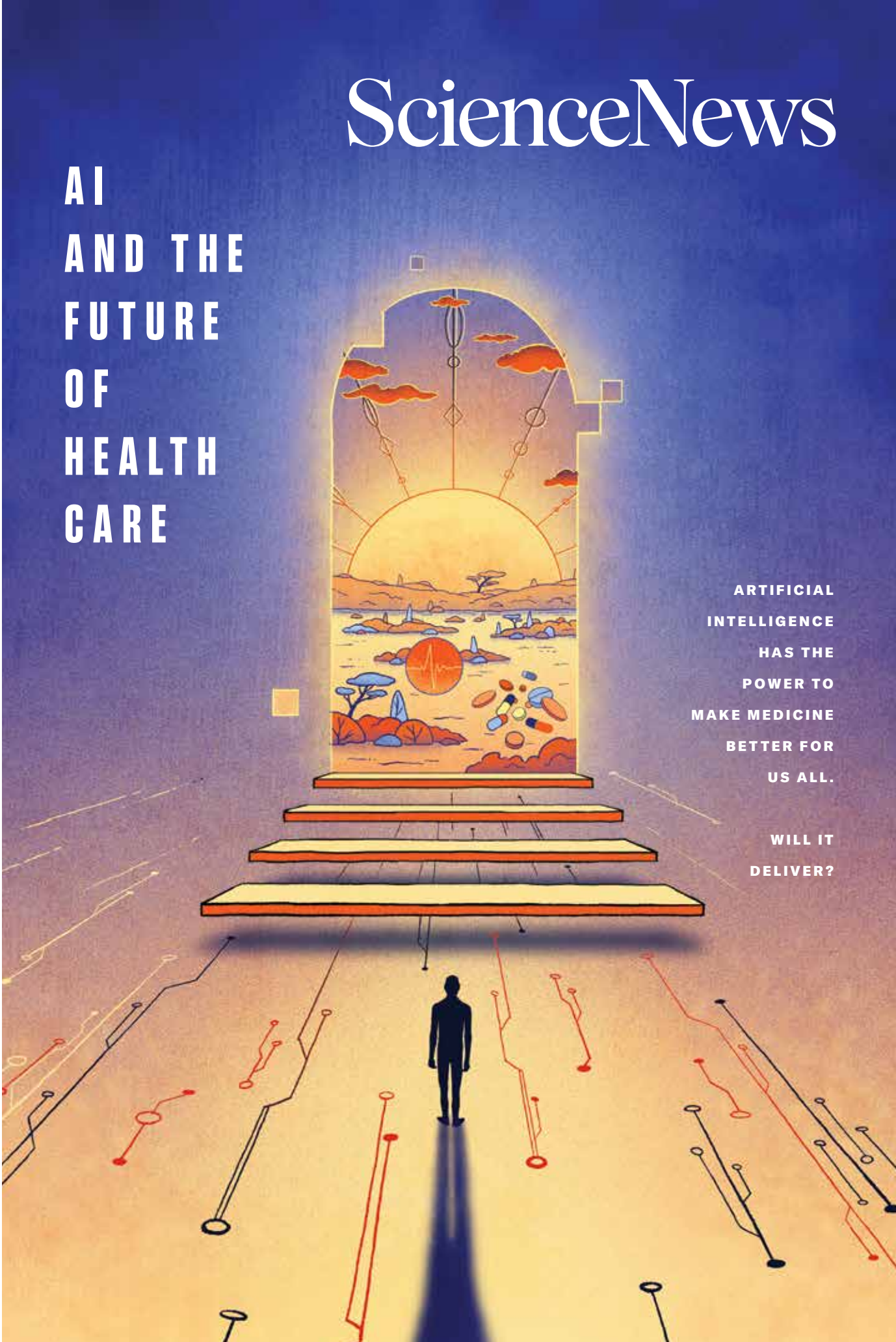
SCIENCENEWS.ORG

VOL. 207 NO. 1

JANUARY 2025

ScienceNews

AI AND THE FUTURE OF HEALTH CARE



ARTIFICIAL INTELLIGENCE HAS THE POWER TO MAKE MEDICINE BETTER FOR US ALL.

WILL IT DELIVER?

NEW SECRETS OF ANCIENT EGYPT – GROUNDBREAKING DISCOVERIES

A ROYAL EVENING WITH DR. ZAHI HAWASS

THE WORLD'S MOST FAMOUS ARCHAEOLOGIST

EVENT OF THE YEAR!

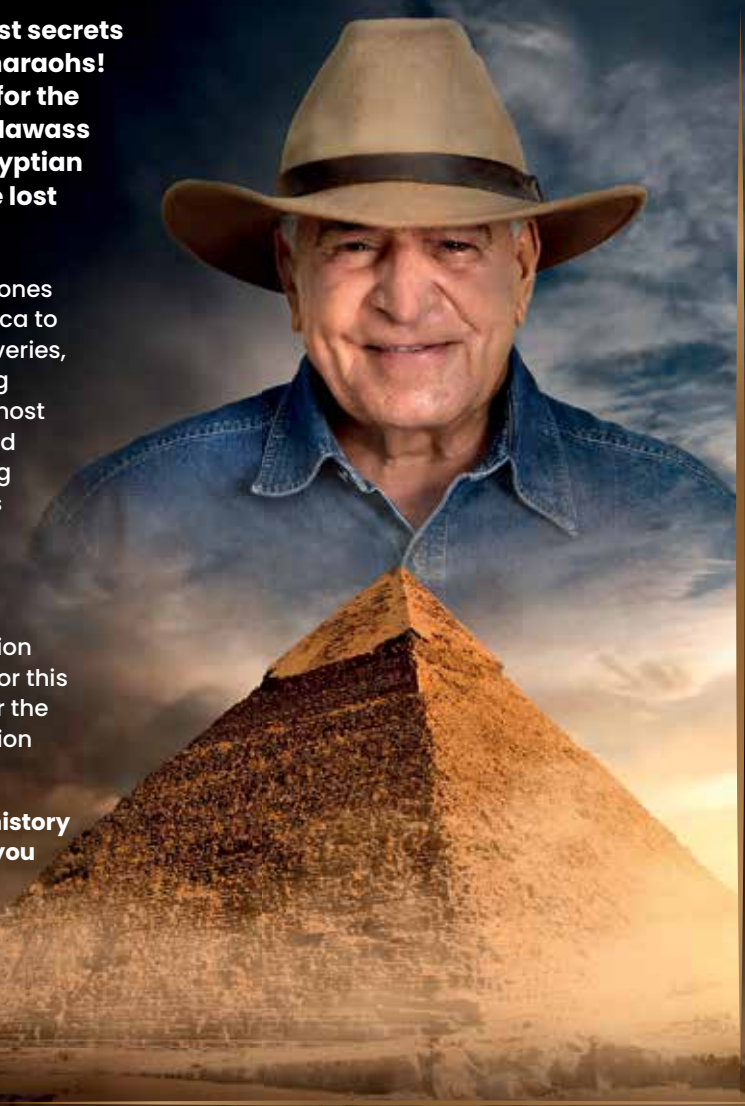
USA & CANADA GRAND LECTURE TOUR
MAY – AUGUST 2025

Discover the greatest secrets of the Land of the Pharaohs! The time has come for the legendary Dr. Zahi Hawass to unveil ancient Egyptian mysteries that were lost for millennia.

The real-life Indiana Jones returns to North America to share the latest discoveries, reveal groundbreaking finds drawn from his most recent excavations and make the most thrilling announcements of his remarkable career.

Join Dr. Hawass for a captivating all-new multimedia presentation prepared exclusively for this historic tour. Stay after the lecture for a Q&A session and a book signing.

This event will make history – live on stage – and you won't want to miss it!



May 1	Phoenix, AZ
May 3	Los Angeles, CA
May 6	San Diego, CA
May 9	Las Vegas, NV
May 11	Oakland, CA
May 14	Portland, OR
May 18	Seattle, WA
May 22	Denver, CO
May 25	Austin, TX
May 27	Oklahoma City, OK
May 29	Dallas, TX
June 1	New Orleans, LA
June 5	Tampa, FL
June 7	Orlando, FL
June 11	Nashville, TN
June 14	Atlanta, GA
June 16	St. Louis, MO
June 18	Charlotte, NC
June 21	Pittsburgh, PA
June 25	Columbus, OH
June 28	Chicago, IL
June 30	Minneapolis, MN
July 3	Cleveland, OH
July 6	Indianapolis, IN
July 9	Boston, MA
July 12	Baltimore, MD
July 16	Virginia Beach, VA
July 19	New York, NY
July 21	Philadelphia, PA
July 23	Washington, DC
July 26	Vancouver, BC
July 30	Toronto, ON
August 2	Montreal, QC

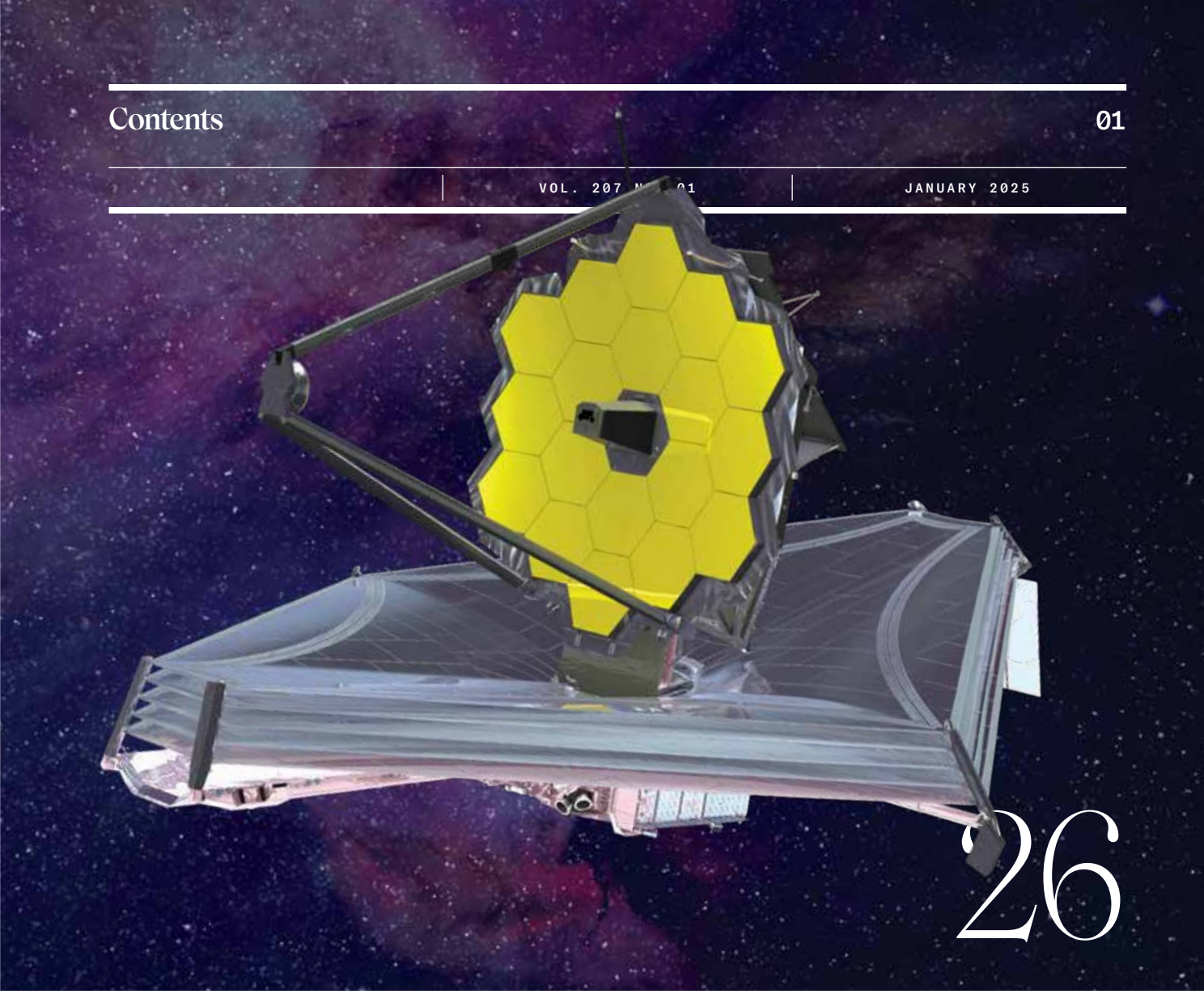
• THE LOST PYRAMID • MISSING ROYAL TOMBS • NEW FINDS AT THE VALLEY OF THE KINGS •
• PROGRESS IN THE GOLDEN CITY • THE ONGOING SEARCH FOR CLEOPATRA'S TOMB •
• SECRET ROOMS IN THE GREAT PYRAMID • KING TUT'S UNTOLD SECRETS • & MORE THRILLING REVELATIONS! •

SEATS ARE LIMITED – REGISTER NOW!

www.ZahiLectures.com contact@zahilectures.com 646-757-1717

Contents

VOL. 207 NO. 01 | JANUARY 2025



26

04 Editor's Note

06 Masthead

07 Contributors

08 Science Visualized

News

12 Pregnancy changes the brain forever

13 Megafire smoke endangers California's almonds

14 At long last, scientists detect Earth's hidden electric field

15 Electrical stitches speed up healing

16 DNA reveals menu choices of notorious man-eating lions

18 A surprise deep-sea menagerie

20 Fungus could turn garbage into dinner

21 The Health Checkup: Cold relief may be in your head

22 How an engineered virus could disarm herpes

23 A possible sign of alien life may not be E.T. after all

25 Coyotes may make 'puppy dog' eyes too

25 A *Dune*-inspired spacesuit would keep astronauts hydrated

26 In an epic cosmic clash, rivals begin to find common ground

27 Riflebirds wing it when flirting

28 Q&A: Bird poop launched U.S. global expansion

On the Cover

Illustration by Antoine Doré

NASA, ESA, CSA, NORTHROP GRUMMAN

REGENERON

We aim to push the bounds of science to make

LIFE-CHANGING MEDICINES

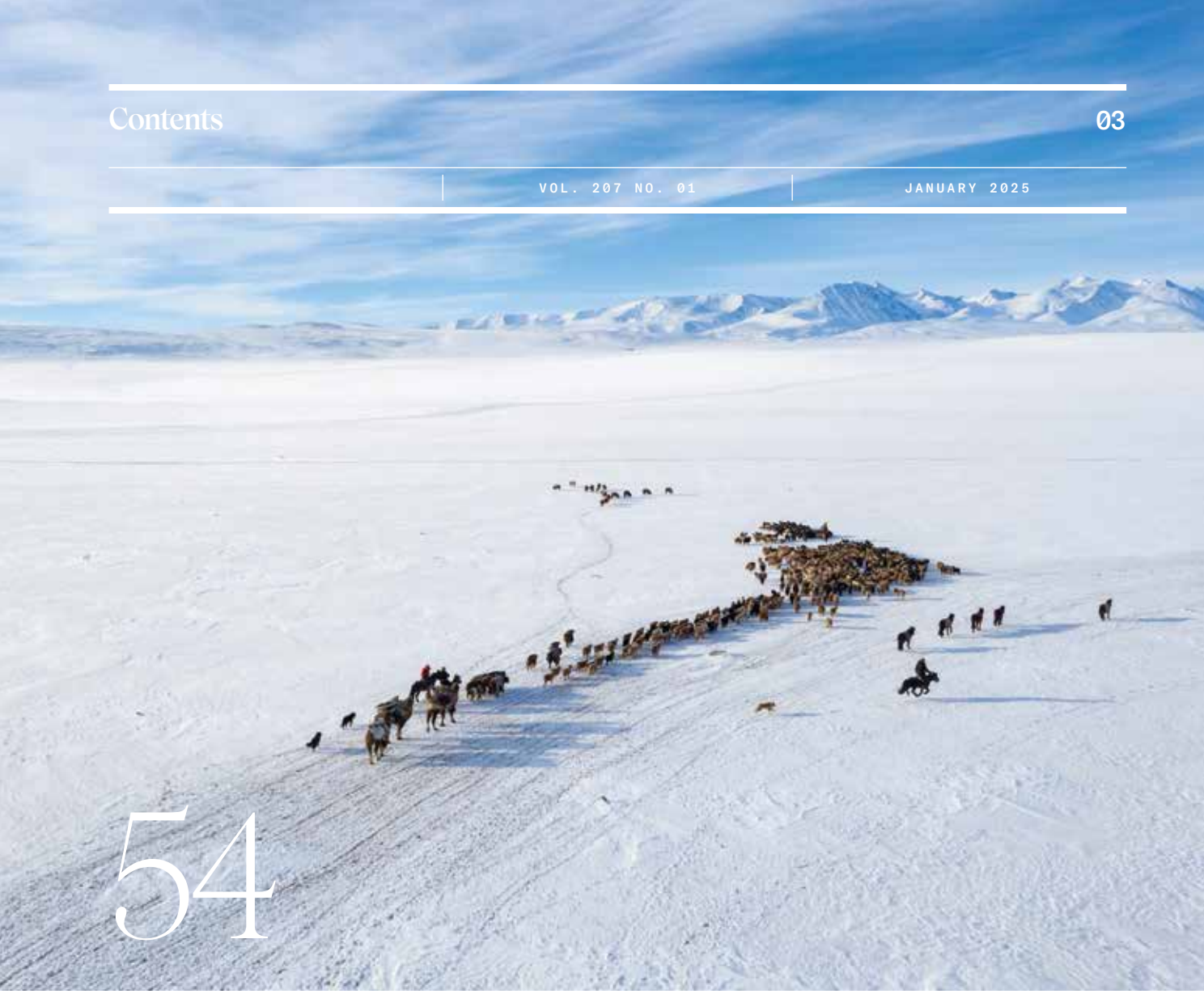
Regeneron is a leading biotechnology company that invents, develops and commercializes life-transforming medicines for people with serious diseases.

Founded and led for over 35 years by physician-scientists, Regeneron's unique ability to repeatedly and consistently translate science into medicine has led to numerous FDA-approved treatments and product candidates in development, almost all of which were homegrown in Regeneron's laboratories. Regeneron's medicines and pipeline are designed to help patients with eye diseases, allergic and inflammatory diseases, cancer, cardiovascular and metabolic diseases, hematologic conditions, infectious diseases, and rare diseases.

Learn more at Regeneron.com →

Follow @Regeneron

VOL. 207 NO. 01 JANUARY 2025



54

Features

Black Hole Dawn 32

Some black holes may have been born just after the Big Bang, before there were even stars and galaxies. If they exist, these primordial black holes just might solve the mystery of dark matter. *By Elizabeth Quill*

The Promise of AI in Medicine 42

Artificial intelligence has the potential to transform how doctors diagnose and treat disease, and how they care for patients. But scientists must first overcome ethical and technological challenges. *By Meghan Rosen and Tina Hesman Saey*

Secrets of Human Navigation 54

Scientists know surprisingly little about how people navigate in the real world. To understand how we find our way, psychologists are merging field research with the lab. *By Sujata Gupta*

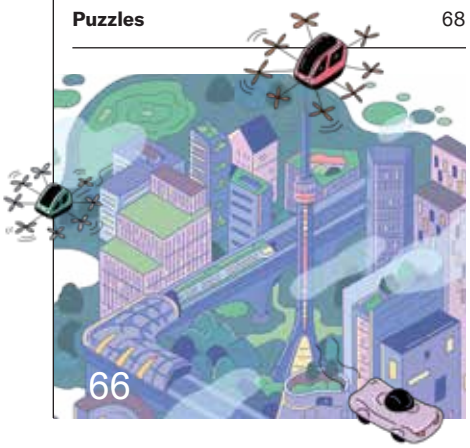
Curiosities

Reviews 62

Feedback 65

Technically Fiction 66

Puzzles 68



66

FROM TOP: JEREMY WOODHOUSE/GETTY IMAGES; KATHLEEN FU

Enter a new era for our storied magazine

Welcome to the next iteration of *Science News*! I'm thrilled to introduce a new look and format that includes everything you have always loved about this magazine, as well as new elements to enhance your experience. As our team embarked on this project, we knew we had to stay true to our 104-year-old mission of providing accurate, timely news about science to the public. So we proceeded carefully.

We surveyed readers (thank you for your insights), explored magazine industry trends and weighed how best to honor our legacy while ensuring that *Science News* will continue to be relevant for years to come. Most importantly, we wanted to better serve our readers, who range from intellectually curious people to STEM professionals to students at almost 6,000 high schools.

One immediately obvious change is the magazine's size and heft, with larger pages and twice the average number of pages. We've also upgraded our visual storytelling with more photography, illustrations and data visualizations. Images are key to understanding science, from a eureka moment sketched on a napkin to schematics of a complex process invisible to the eye. And we've added new ways to engage with science in our lives, including a health column, essays on science in popular culture and science-themed puzzles.

With this issue, we also move from publishing biweekly to a monthly format, with each month's magazine the equivalent size of one of our former double issues. This is the latest in a long evolution from *Science News*' roots as a bulletin mailed to newspapers to a consumer newsletter, a weekly magazine and a biweekly. The new publishing schedule makes it possible for us to deliver more in-depth coverage and amazing visuals while ensuring that you continue to get comprehensive coverage across the sciences.

We know many readers revisit the magazine, with some archiving issues for decades, so the paper has been upgraded to provide a premium experience. Our goal is to ensure that the monthly format will stand the test of time. We hope you enjoy exploring this issue, which delivers the coverage you depend on plus some new adventures. Let us know what you think. Email us at editors@sciencenews.org.

Nancy E Shute

Nancy Shute
Editor in Chief
nshute@sciencenews.org

Circle keeping ... has been an effective approach to fostering connectivity and learning about each other through shared stories, instead of plunging headlong into accomplishing goals. It has also been important for flattening established hierarchies by holding an equal space for every voice regardless of whether it is from a rookie or an established investigator."

–Ruma Banerjee, Vincent Massey Collegiate Professor of Biological Chemistry, University of Michigan Medical School, Co-Director, ASBMB MOSAIC program

Learn about the Circle process in these books and many more!

20% DISCOUNT with coupon code 1SCIENCE25

We accept purchase orders.

LIVING JUSTICE PRESS

Living Justice Press

https://livingjusticepress.org

651.695.1008 • ljp@livingjusticepress.org

Quantity discounts available

Science News

Society for Science, publisher of *Science News*, is a nonprofit organization best known for our award-winning journalism, world-class science competitions and STEM outreach programming aimed at increasing opportunities for all young people. For more than a century, *Science News* journalists have provided accurate, editorially independent coverage of science that gives people the information and context they need to evaluate the news and the world around them.

Science News
1719 N St. NW
Washington, DC 20036
(202) 785-2255

Alliance for Audited Media

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, 45429-0255
Editorial and Letters	feedback@sciencenews.org
Science News Learning	snlearning@societyforscience.org
Advertising and Sponsor Content	ads@societyforscience.org

Science News (USPS 484680, ISSN 0036-8423) is published 12 times per year, monthly by the Society for Science & the Public, 1719 N St. NW, Washington, DC 20036.

Subscribe to *Science News* Subscriptions include 12 issues of *Science News* and full access to www.sciencenews.org and cost $59 per one year (international rate of $77 includes extra shipping charges).

Subscribe www.sciencenews.org/subscription

Single copies are $9.99 plus shipping and handling ($1.01 domestic, $5.01 international). Periodicals Postage Paid at Washington, D.C., and additional mailing offices.

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.

VOL. 207 NO. 01 | JANUARY 2025

MEGHAN ROSEN
TINA HESMAN SAEY

SENIOR WRITERS

● FOR OUR COVER STORY about how artificial intelligence could revolutionize medicine and health care (Page 42), Rosen and Saey took an unconventional approach to transforming their mountains of reporting into a story. They invite readers to examine the potential of AI and the challenges to overcome in a series of vignettes imagining how AI might help. "Because AI's promise in medicine has yet to be realized and because of the speed at which the technology is moving, it was difficult to single out real-world examples," Saey says. "We wanted to illustrate how AI might touch the lives of everyone at every stage of life. Using fictional examples based on real-world technology allowed us to do that."

Sujata Gupta
Social sciences writer Sujata Gupta explores how bringing the real world into laboratory studies—and bringing elements of the lab into field research—can help scientists get a better grip on humans' navigation skills (Page 54). "The detail that has stuck with me didn't make it into this story," Gupta says. "One researcher I interviewed said that people studying navigation rarely consider locomotion. That seemed crazy to me as, when we spoke, I had just torn a couple ligaments in my knee and was hobbling around on crutches."

Elizabeth Quill
Primordial black holes, if they exist, would make up at least some of dark matter, freelance writer Elizabeth Quill reports (Page 32). "I was intrigued by the idea that black holes born just after the Big Bang might be lurking across the cosmos and might provide an explanation," says Quill, who is a former executive editor of *Science News*. Reporting this story was endlessly fascinating, she says. "Like a black hole, I have a voracious appetite."

Laura Sanders
The Health Checkup, a new monthly column, is your go-to place for perspectives on health news you can use. In the inaugural edition, senior neuroscience writer Laura Sanders explains how placebos might actually have some benefits when it comes to treating the common cold (Page 21). "I've long harbored a fondness for placebos," Sanders says. "Writing this column allowed me to share my respect for placebos—and the fascinating neuroscience behind them—more widely."

Shannon Rapp
Cap off your reading experience with a science-themed crossword puzzle (Page 68). It's brought to you by puzzle maker Shannon Rapp, a research administrator at a medical school who was previously a scientist and science educator. *Science News* is a perfect venue for her puzzles, she says. "I'm so excited and grateful to be the first crossword constructor for *Science News*!"

PARTICLE PHYSICS

GOING BIG TO UNRAVEL NEUTRINO MYSTERIES

By Emily Conover

● Deep underground in China sits what will soon be the largest neutrino detector of its type. Neutrinos and their antimatter counterparts, antineutrinos, are very lightweight subatomic particles with no electric charge. The Jiangmen Underground Neutrino Observatory, or JUNO, aims to determine which of the three types of neutrinos is heaviest. A roughly 35-meter-wide acrylic sphere, hidden beneath the white covering seen here, will contain 20,000 metric tons of liquid scintillator, which emits light when a passing antineutrino interacts with a proton in the liquid. Tens of thousands of photomultiplier tubes will watch for these glimmers. Water in the pit around the sphere will help filter out neutrino mimics. Set to start taking data this summer, JUNO will scrutinize antineutrinos released as by-products from two nuclear power plants. PHOTO BY ENRICO SACCHETTI

Meet the Hybrid That Never Needs Gas

A one-of-a-kind timepiece for the Impossible Price of $39!

Stauer Impossible Price ONLY $39

Innovation is the path to the future. Stauer takes that seriously. That's why we developed the ***Yellowjacket Hybrid Watch***, an impressive timepiece that's sure to turn heads. We originally priced the Yellowjacket at $399 based on the market for advanced sports watches … but then stopped ourselves. Since this is no ordinary economy, and everyone else has raised their prices, we decided to start at **90% OFF!** This technological marvel can be yours for **ONLY $39!** Only Stauer can offer you a price this good.

When it comes to purchasing a quality, timeless timepiece, there's one question every prospective buyer must consider: digital or analog. Both have their advantages. We say, why not have both?

Our Men's Yellowjacket Hybrid Watch is a surprising innovation. Its digital readout is powered by a precise quartz engine that combines both analog and digital timekeeping. Outfitted with a stopwatch, alarm, a.m./p.m. settings and day, date and month complications, this timepiece is hard to beat.

With its large face and handsome, masculine design, this watch is perfect for the back nine and the happy hour afterward. Water-resistant up to 3 ATM, this timepiece won't wimp out if it has a run-in with a water hazard. And best of all is the color of its case and band: This watch boasts two tones.

Lately, two-tone watches have been the toast of the luxury watch world: "Two-tone is the physical embodiment of work-hard, play-hard," says Hodinkee, a website that chronicles the watch industry. But where luxury brands are charging hundreds simply for their two-tone watch bands, we're asking **JUST $39** for an entire two-tone watch!

Act now! We only have ~~1,237~~ 731 available for this ad, and half have already sold! And if this watch doesn't live up to your expectations for some reason, return it for a refund with no questions asked.

Watch Specifications:
- Precision movement
- Two-tone stainless steel band
- Stopwatch, alarm, a.m./p.m. settings and day, date and month complications
- Water-resistant to 3 ATM

Men's Yellowjacket Hybrid Watch ~~$399~~
$39* + S&P *Save $360*

*You must use Insider Offer Code: YHW166-01 to get this price.

"Love the style and the combo of analog and digital!"
— Rich C., Plainfield, IL

JOIN MORE THAN 1 MILLION SMART PEOPLE WHO LOVE THEIR STAUER WATCHES

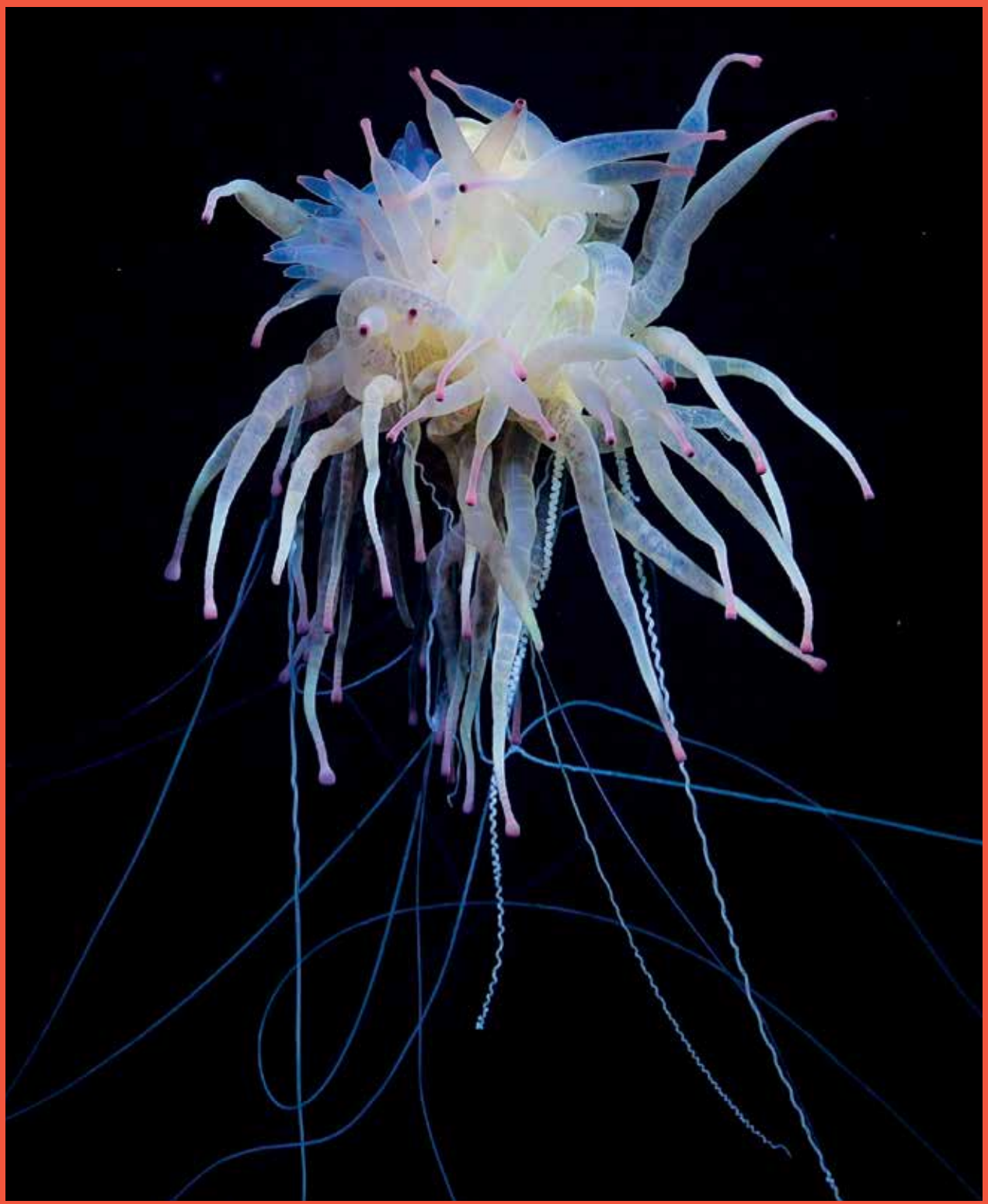
1-800-333-2045
Your Insider Offer Code: YHW166-01

Stauer, 14091 Southcross Drive W., Dept. YHW166-01, Burnsville, MN 55337 | **www.stauer.com**

Stauer® | AFFORD THE EXTRAORDINARY®

A so-called flying spaghetti monster (*Bathyphysa conifera*) is among the exotic creatures that make their home on newly surveyed seamounts in the southeastern Pacific Ocean (see Page 18).

News



NEUROSCIENCE

Pregnancy changes the brain forever

By Laura Sanders

● **Pregnancy overhauls a woman's body.** The brain is no exception. A detailed study of a woman's brain before, during and after pregnancy revealed sweeping neural changes, some of which persisted after her baby was born.

The dataset, published in *Nature Neuroscience*, is the first comprehensive view of the neural changes that accompany gestation — a sort of "what to expect when you're expecting" for the brain.

"The results of this case study are astonishing," says neuroscientist Clare McCormack of New York University Langone Health, who was not involved in the work. "Here we see, for the first time in humans, the extent of brain changes that are under way throughout pregnancy."

This research joins a small number of studies aimed at understanding the female brain at various stages of life. Collectively, the work suggests that the process of becoming a mother, called matrescence, is another stage of development, like the brain overhaul that happens in adolescence.

Earlier experiments mostly compared brains of women before and after pregnancy and inferred what happens in between. "There was a missing piece," McCormack says. "The nine months of pregnancy was a black box, and we could only guess what that trajectory looks like." With four MRI scans before pregnancy, 15 scans during pregnancy and seven scans in the two years after the baby was born, the new study follows cognitive neuroscientist Liz Chrastil of the University of California, Irvine, who realized she could be her own study subject.

Previous studies have found that the volume of gray matter in the brain, made largely of cell bodies but not predominantly the message-moving tendrils, is smaller after pregnancy than before it. The new study confirms that finding and goes further, showing the sweeping magnitude of that reduction. Gray matter volume was reduced in about 80 percent of the places in Chrastil's brain that the researchers studied, shrinking on average by about 4 percent of its starting bulk.

A shrinking brain sounds scary, but here, it isn't, says study coauthor Emily Jacobs, a cognitive neuroscientist at the University of California, Santa Barbara. In a news

↖ White matter tracts move information across the brain. As Liz Chrastil went through pregnancy, her tracts (each color marks one tract in this reconstruction) temporarily strengthened.

DANIELA COSSIO

briefing, she likened this process to Michelangelo chipping away excess marble to reveal David.

Chrastil was planning to undergo in vitro fertilization around the time that she and her colleagues began thinking about studying the brain throughout pregnancy.

Over the course of her pregnancy and afterward, Chrastil says she felt fine as her gray matter was reduced and refined, as the researchers expected.

But another change to her brain surprised them all. Some of her brain's white matter tracts grew stronger, peaking in the second trimester. These tracts are bundles of information-sending fibers that travel around the brain, and the stronger they are, the more efficiently they can carry information. By the end of Chrastil's pregnancy, her white matter tracts had largely returned to their pre-pregnancy strength.

Some of the changes, such as gray matter reductions, seem to be permanent, says Susana Carmona, a neuroscientist at the Instituto de Investigación Sanitaria Gregorio Marañón in Madrid. She and others have found evidence of these changes lasting years after pregnancy. "It's highly probable that these are lifelong," she says.

For now, the findings lead to more questions than answers, Chrastil says. Women's brains are woefully understudied. "It's somewhat shocking that we know so little at this point," she says.

With her many hours lying in a scanner, Chrastil has done her part to push the science forward. And she's not ruling out more.

"I only have one child," she says, a 4½-year-old boy who loves volcanoes and planets. "If I have a second one, I'll get back in the scanner." ✖

ENVIRONMENT

MEGAFIRE SMOKE ENDANGERS CALIFORNIA'S ALMONDS

BY SOPHIE HARTLEY

Wildfires may put some of America's favorite nuts at risk. The flames themselves aren't to blame — it's the long-lasting smoke from megafires that have been scorching the western United States.

When thick wildfire smoke blanketed California's Central Valley in the late summer of 2020 and again in 2021, it blocked the sunlight needed for photosynthesis. That disruption limited how much energy orchard trees stored over winter, researchers report in *Nature Plants*. In the year following a megafire, some almond orchards saw up to a 60 percent decrease in nut harvests. This alerted scientists to an understudied effect of wildfire smoke in the state that produces 80 percent of the world's almonds.

"Trees are just as susceptible to smoke as humans, and unfortunately, they can't escape it," says Jessica Orozco, a tree physiologist at the University of California, Davis. "They're just stuck."

Trees make most of their food during warm, sunny weather, using sunlight to photosynthesize carbon dioxide and water into oxygen and carbohydrates. Just like someone who cans the summer harvest for the chilly months, leafless trees rely on stored carbs to survive winter and fuel growth in early spring.

In 2018, Orozco and colleagues wondered how major environmental disruptions impact carbohydrate storage. The team collected twigs from over 450 almond, pistachio and walnut orchards in the Central Valley to establish a baseline. Orozco didn't realize how quickly the work would come in handy.

"We were in California when the fires happened. The smoke was just so dense that we couldn't go outside," says Orozco, who remembers looking out her window in 2020 at dark red skies and parking lots covered in ash. She and colleagues wondered how the trees were doing. "Then we were like, 'Well, we have the perfect dataset to look at this!' "

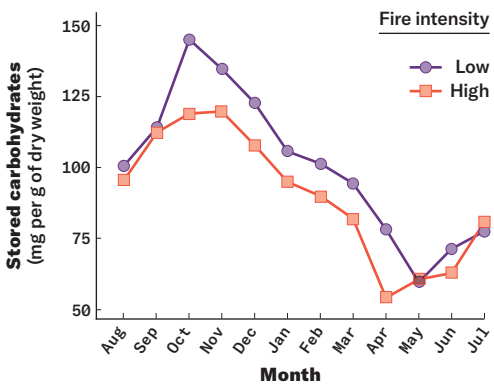
The team compared twig samples from years with more than two weeks of prolonged megafire smoke (2020 and 2021) and twigs from years with up to a week (2018, 2019 and 2022). After years with heavy smoke, orchard trees had fewer stored carbohydrates on average.

CONT. ON PAGE 14

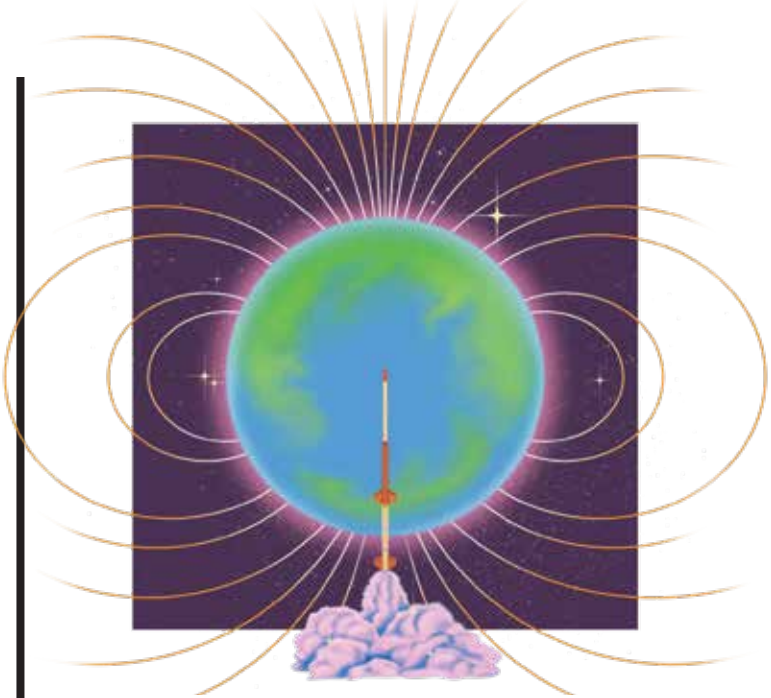
CONT. FROM PAGE 13 Smoke intensity also appeared to impact yield. Typically, one of the 56 almond orchards that the team procured harvest data from might produce a few thousand kilograms of nuts per hectare annually. During the years following wildfires, those numbers dropped. On average, the orchards produced 30 percent fewer nuts in 2021 and 2022. Some almond harvests shrunk by about 60 percent.

Growers have mainly been concerned about how wildfires affect crop quality, says Gabriele Ludwig, director of environmental affairs for the Almond Board of California. Smoke can taint vineyard grapes, resulting in undesirable flavors. Diminished sunlight keeps almonds from fully drying, which can result in mold. The study raises an aspect that hasn't been on growers' radar screens, she says. "What's the impact on photosynthetic capacity?" ✖

FIRES LOWER TREES' FOOD RESERVES



During years with high-intensity wildfires and prolonged smoke that disrupted photosynthesis, nut trees in California orchards had fewer stored carbohydrates in winter than during years with low-intensity fires. The graph shows averages for the high-fire-intensity years of 2020 and 2021 (red) versus the low-intensity years of 2018, 2019 and 2022 (purple). With less stored food for winter, trees tended to produce fewer nuts in spring and early summer.



FROM LEFT: J. OROZCO *ET AL*/*NATURE PLANTS* 2024; ILLUSTRATION BY AARON LOWELL DENTON

EARTH

At long last, scientists detect Earth's hidden electric field

By Lisa Grossman

● **For the first time**, scientists have measured a long-sought global electric field in Earth's atmosphere. This field, called the ambipolar electric field, was predicted to exist decades ago but was never detected, until now.

"That's the big whoop," says Glyn Collinson, an atmospheric scientist at NASA's Goddard Space Flight Center in Greenbelt, Md. "It's a whole fricking new planetary energy field that's never been measured before."

To solve the mystery, researchers built a rocket and transported it to the Arctic, where they braved polar bears and blizzards. The field is weak, only 0.55 volts — no stronger than a watch battery, Collinson says. But that's strong enough to control the shape and evolution of the upper atmosphere, features that could have implications for Earth's habitability.

"It's fundamental to the DNA of our planet," says Collinson, who reported the new measurement in *Nature* with colleagues.

The existence of the ambipolar electric field was first predicted in the 1960s, at the dawn of the space

↑ A rocket launched into the atmosphere detected a faint but powerful electric field arising from Earth's poles.

age. Spacecraft flying over Earth's poles detected a supersonic outflow of charged particles from the atmosphere, the polar wind.

The most reasonable explanation for that speedy wind was an electric field in the atmosphere. The idea is that sunlight can kick electrons out of atoms in the upper atmosphere. Those negatively charged electrons are lightweight and energetic enough that they want to float out into space. The positively charged oxygen ions left behind are heavier and want to sink down in Earth's gravity.

But the atmosphere wants to remain electrically neutral, keeping an equal balance between electrons and ions. The electric field forms to keep the electrons tied to the ions and prevent them from escaping.

Once established, the field can act as a booster for lighter ions like hydrogen, giving them enough energy to break free of Earth's gravity and zoom away as the polar wind. The field can also pull heavier ions higher up in the atmosphere than they would otherwise reach, where other forces can yank them into space as well.

That was the hypothesis. But until recently, the technology to detect the field didn't exist. The field is "so weak, it was just assumed you'll never measure it," Collinson says.

He realized the measurement had never been taken after he and colleagues tried to measure a similar field on Venus. A search for a paper reporting the strength of Earth's field for comparison came up empty.

"We were like, 'Game on!' " Collinson says. The team developed an instrument, a type of photoelectron spectrometer, to detect the electric field and mounted it on a rocket.

Getting to the launchpad in Svalbard, Norway, was a journey, requiring a 17-hour boat ride to get to the Arctic archipelago. Several team members fell ill with COVID-19 on the way. And a major escalation in the war between Russia and Ukraine had begun just a few months earlier.

"At the time, there was a certain amount of nervousness about firing off rockets," Collinson says. "Polar bears were the least of it. We had war and plague."

Two more days of blizzards kept the rocket grounded. When it finally launched on May 11, 2022, it went straight up through the atmosphere to about 770 kilometers, measuring the energies of electrons every 10 seconds. The flight lasted 19 minutes. At the end, the rocket splashed into the Greenland Sea.

The rocket measured a change in electric potential of 0.55 volts between the altitudes of 248 kilometers and 768 kilometers — exactly enough to explain the polar wind on its own, without any other atmospheric effects.

The measurement is solid and exciting, says planetary scientist David Brain of the University of Colorado Boulder. But it's only one data point from one rocket. "I think CONT. ON PAGE 16

ILLUSTRATION BY REMIE GEOFFROI

HEALTH & MEDICINE

ELECTRICAL STITCHES SPEED UP HEALING

By Andrea Tamayo

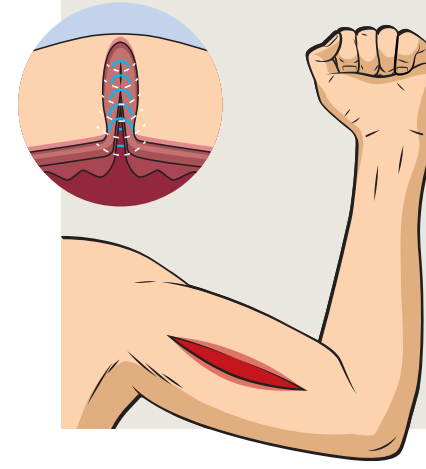
● Stitches are getting a shocking upgrade. In an experiment in rats, a new strong, flexible thread hastened wound healing by transforming muscle movement into electricity, researchers report in *Nature Communications.*

If the material is deemed safe for people, it "could change how we treat injuries," says materials scientist Chengyi Hou of Donghua University in Shanghai.

Pumping electricity through stitches can speed healing, but previous technologies relied on bulky batteries. The new sutures (illustrated below) are powered by the body itself. When muscles around the sutures contract and relax, the thread's middle layer rubs against the outer shell, transferring electrons to the shell and generating electricity. Because the thread is made from biodegradable polymers and magnesium, it can be absorbed by the body over time.

Hou and colleagues applied the thread's electrical stimulation to wounded mouse tissue in lab dishes. After 24 hours, treated artificial wounds were about a third of the size of untreated wounds.

In animal experiments, rats treated with the electrical sutures made a quicker recovery and were less likely to develop an infection than rats treated with traditional sutures. ✖



CONT. FROM PAGE 15 this result is a really great result that argues there should be more measurements like this," he says.

Collinson agrees. He and colleagues recently received NASA approval for a follow-up rocket.

Because the ambipolar electric field helps control how quickly a planet's atmosphere escapes into space, it probably plays some role in making a planet hospitable to life, Collinson says. Scientists think that Mars used to be more like Earth but lost much of its atmosphere to space over time. Venus also may have once been much wetter than it is today.

Both planets also have ambipolar electric fields, but they may have been better off without them.

"If this process didn't exist at Venus and Mars, then I think it's possible Venus and Mars would have lost less oxygen," and therefore less water, Brain says.

Earth's ambipolar electric field helps kick its oxygen out into space, too. But Earth has one key advantage over Mars and Venus: a global magnetic field to guide charged particles around the planet. "The electric field is the engine that gets the particles moving," Brain says. "The magnetic field is sort of the road that the particles move along."

Earth's magnetic field means oxygen can escape more easily near the poles than from any other part of the atmosphere. That could help explain why Earth has kept its habitable atmosphere for so much longer than Venus or Mars.

"Fundamentally, what makes a planet habitable is going to be many things," Collinson says. "But I think comparing these different energy fields across different planets is a way to answer the question, why is the Earth habitable? Why are we here?" ✖

FIELD MUSEUM OF NATURAL HISTORY

ANIMALS

DNA reveals menu choices of notorious man-eating lions

By Jake Buehler

● **A pair of male lions that roamed Kenya** more than a century ago gained notoriety as the "man-eaters of Tsavo." To be sure, the big cats hunted and ate people building a local railway. But a novel DNA analysis of hairs stuck in the cats' tooth cavities is revealing a diverse — and occasionally surprising — menu.

The roughly 130-year-old dietary log consists of oryx, zebras and, yes, humans, researchers report in *Current Biology*. Unexpectedly, traces of wildebeest also showed up: The

herbivores weren't known to roam the Tsavo region at that time, so the finding raises questions about how predator met prey. The analysis, which was sensitive enough to identify two separate giraffes from the same subspecies, may be useful for better understanding the lifestyles of long-dead animals and the ecosystems they lived in.

"The method opens up a new avenue of inquiry into the past," says anthropological geneticist Ripan Malhi of the University of Illinois Urbana-Champaign. Scientists could perhaps reconstruct diets from thousands of years ago.

↖ To study the Tsavo lions' diet, scientists analyzed DNA of prey hairs stuck in holes in the lions' broken teeth.

The famed lions' preserved skulls and skins have been housed at the Field Museum of Natural History in Chicago since 1925 and contain hints about what caused the animals' predilection for hunting humans. Both lions had damaged and broken teeth, which may have made eating large, strong herbivores more challenging.

Packed deep within the cavities of the broken fangs are mammal hairs. Malhi and colleagues wondered if DNA could spill the lions' dietary secrets. Researchers have probed the genetics of Siberian woolly mammoths by studying the DNA in ancient hairs, says integrative evolutionary biologist Alida de Flamingh, also of the University of Illinois Urbana-Champaign.

"What makes our study unique is that rather than starting with a known animal, we are analyzing hairs and hair clumps to identify the animals that the hairs originated from," she says.

The team extracted DNA from mitochondria — energy-producing structures in cells — and compared it with the mitochondrial DNA of more than 20 African animal species.

Matches turned up for prey species including giraffe, oryx, waterbuck, zebra and wildebeest. In 1898, the closest wildebeest grazing area to where the lions were killed was about 90 kilometers away. "It suggests that the Tsavo lions may have either traveled farther than previously believed, or that wildebeest were present in the Tsavo region during that time," de Flamingh says.

Tyler James Murchie, a paleogenomicist at the Hakai Institute on Quadra Island, British Columbia, is surprised that the DNA survived for this long in the museum. The diverse menu was also a surprise, he says. "These lions were quite successful, it would seem, having this kind of diet breadth despite the one [lion] having such a major tooth fracture."

De Flamingh is now comparing hair clumps found in layers of soil in the tooth cavities. "Layers in lower parts of the tooth cavity represent prey eaten earlier in life," she says. "Layers at the top of the cavity are from recently eaten prey." The layers may reveal dietary changes over time.

"This study," Murchie says, "exemplifies how much unique, hidden genetic information might be lurking in the crevice of a bone or artifact in a museum somewhere that's just waiting for a clever researcher to ask an interesting question." ✖

ANIMALS

A SURPRISE DEEP-SEA MENAGERIE

BY JAKE BUEHLER

Some 1,400 kilometers off the coast of Chile, deep-sea creatures drift along a garden of sponges and corals growing on the flanks of a 3,100-meter-tall undersea mountain.

A monthlong survey of mountain ecosystems in the remote seas of the southeastern Pacific Ocean has not only turned up a never-before-seen seamount but also revealed many species of sea life that might be new to science. Eighty species were observed in this part of the ocean for the first time, the Schmidt Ocean Institute in Palo Alto, Calif., announced.

The seamount discovery was a surprise, says oceanographer Jyotika Virmani, the institute's executive director. Satellite imaging of the area had shown only a low-resolution bump on the seafloor. The mammoth seamount is thousands of meters high, with a summit that sits 994 meters below the ocean surface.

Using a diving robot to film and explore that seamount plus nine others, expedition researchers found a teeming ecosystem, including a garden of sponges and ancient corals about twice the width and breadth of a basketball court. The garden isn't as dense as shallow-water reefs, which are "absolutely chockablock with corals," Virmani says, but still impressive for such a deep reef.

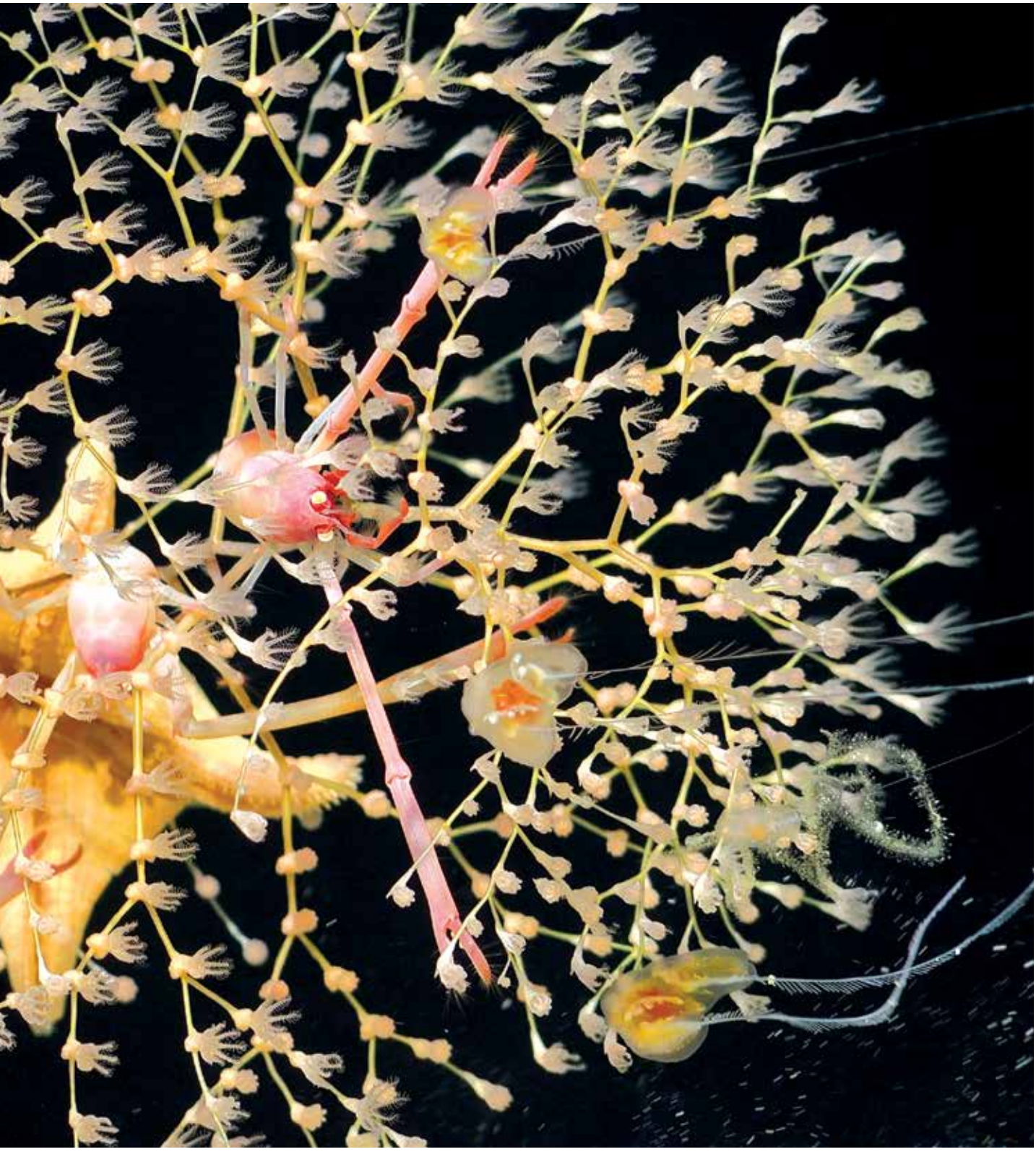
The robot encountered the ghostly white Casper octopus, named for its uncanny resemblance to the cartoon specter Casper the Friendly Ghost. The species has yet to be formally described by scientists, and until now was known only from the North Pacific. The team also gathered the first footage of a living *Promachoteuthis* squid. "It's been brought up in nets," Virmani says. "But they've never been living samples."

Twenty of the encountered species may be previously unknown, adding to 150 possible new species from two previous expeditions. The animals include sea anemones, urchins, shrimp and a squat lobster. The team also found a fossil that may be from a newfound species of ancient whale, Virmani says. "This part of the world is very poorly explored at the moment, but it does hold a lot of interesting wildlife." ✖

ROV SUBASTIAN/SCHMIDT OCEAN INSTITUTE (CC BY-NC-SA 4.0)

→ Scientists spotted a feathery golden coral harboring a sea star, comb jellies and reddish squat lobsters.

VOL. 207 NO. 01 | JANUARY 2025



SCIENCE & SOCIETY

Fungus could turn garbage into dinner

By Anna Gibbs

● **Using microbes to transform foods** through fermentation is the secret behind many culinary favorites, from cheeses to beer. But what if, instead of transforming one food into another, microbes transformed food *waste* into tasty bites?

Enter *Neurospora intermedia,* an orange-colored fungus that thrives when grown on food waste products such as soybean pulp and orange peels. By using it to ferment by-products that might otherwise be thrown away, the fungus could help reduce waste while producing tasty, nutritious foods, biologist Vayu Hill-Maini and colleagues report in *Nature Microbiology.*

Hill-Maini came across *N. intermedia* while studying red oncom, a Javanese meat substitute made by fermenting pulp left over from soy production. "The idea is, let's learn from this very robust traditional approach," says Hill-Maini, of Stanford University. "Let's see what's going on, what fungus is involved, what is the process."

After discovering that *N. intermedia* dominated red oncom samples, Hill-Maini and colleagues at the University of California, Berkeley further learned that the fungus has enzymes that break down cellulose and pectin, sugars that humans can't digest well on their own.

Also striking, Hill-Maini says, was that *N. intermedia* strains in oncom were genetically different from wild strains but similar to strains found on food waste, such as sugarcane fiber in Taiwan. That pattern suggests that humans unintentionally domesticated the fungus. That's similar to how the use of *Penicillium* to make blue cheese caused that fungus to change genetically.

"Humans have turned to a fungus to grow on something that we can't eat," Hill-Maini says of *N. intermedia*. "The fungus then breaks it down, makes more of itself, and in doing so, makes [the waste] more palatable." And more nutritious: Fermentation can up the protein content of by-products.

The next question was whether *N. intermedia* is appealing to people who aren't used to it. Researchers presented red oncom to 61 taste testers in Denmark. Overall, they liked the texture and flavor, describing it as "mushroom" or "nutty."

Different combos of fungus and growing substrate can lead to different flavors. Chef Rasmus Munk of Alchemist, a two-star Michelin restaurant in Copenhagen, experimented with growing *N. intermedia* on a bland rice custard. After a few days with the fungus, the custard looks like it's been dusted with cheese — and the flavor has transformed to taste like pineapple.

Hill-Maini is excited about using *N. intermedia* at an industrial scale. Waste from food production, like soybean pulp left over from making soy milk, could be fermented. That's what the researchers at Alchemist's food lab are studying: new ways to use microbes to turn waste into delicious food that's sustainable. ✖

ILLUSTRATION BY ANDREW RAE

VOL. 207 NO. 01 | JANUARY 2025

THE HEALTH CHECKUP

COLD RELIEF MAY BE IN YOUR HEAD

BY LAURA SANDERS

The viruses of cold and flu season are upon us, and in us, where they're causing misery upon misery. But don't worry. You can hop online, and for a mere $24.95, buy yourself a bottle of Zeebo Relief pills, designed to ease your bothersome symptoms. The key ingredient? Absolutely nothing. They're placebos, and as such, they contain no active ingredients, not even sugar. The tagline: "You are the active ingredient."

Maybe you're rolling your eyes. Is there any reason to think that pills of nothing could work? Yes, it turns out. And in fact, many of us may have a similar placebo, of sorts, sitting in our medicine cabinets. It's phenylephrine, and it's been on the market for decades. This decongestant is in over-the-counter cold medications sold by brands such as Sudafed PE and DayQuil.

Yet in 2023, an advisory committee to the U.S. Food and Drug Administration combed through data on whether the drug, taken by mouth, worked and concluded it unstuffed people's noses no better than a placebo. Now the FDA is considering whether to pull this particular decongestant from store shelves. (The scrutiny involves only the pill form of the drug; the nasal spray form, along with other types of decongestants, have no such baggage.)

Before you cull your medicine cabinet, the issue raises some intrigue. In particular, the phrase "no better than a placebo." It's not necessarily that phenylephrine doesn't make you feel better; it's that the placebo does, too.

In a 2016 study, for instance, people took either the drug or a placebo, an inert substance that's generally thought to do nothing. Over the seven-day trial, both groups felt better by roughly the same amount. This highlights the "power of expectation," says Michael Bernstein, an experimental psychologist at Brown University's Warren Alpert Medical School. "Here you have a drug that people have taken for years, a drug that people really feel like works," he says. "And it does work." Just not in the way you might think.

We usually expect a drug to work through some sort of fancy molecular action, a precise biological effect. But in this case, that effect comes from our beliefs. Neuroscientists don't have the placebo effect figured out, but they have some good ideas about how parts of the brain create expectations and beliefs.

And those beliefs can hold power, even when we know we're taking a placebo. Bernstein and colleagues are working on a study right now that involves full honesty. After a visit to an emergency room, people who receive a prescription for an opioid pain drug are also given a placebo and told all about it. "Our goal is to see whether or not the open placebo can reduce how many opioids they're taking after they get discharged from the ER," he says.

That level of forthrightness might be a little too much to strive for if you're a parent of a kid with a nighttime cough. But a spoonful of "medicine" might bring relief. A 2014 study found that a child's cough responded equally well to colored, flavored water and agave nectar, and both "treatments" beat nothing. "Knowingly using a placebo to treat cold symptoms in young children may constitute good medicine," the authors of an accompanying editorial wrote. Many parents already dole out placebos without even knowing it. "If your kid has ever gotten a scrape or a cut and you said, 'I'll kiss it to make it better,' that's basically just a placebo," Bernstein says.

As you consider phenylephrine's role in your life, take a moment to consider that your mind might be a powerful ally in your fight against your cold, even if it knows full well what you're trying to slip past it.

A placebo won't work for every condition, nor will it help everyone, as this one-star review of the Zeebo pills makes clear: "Totally doesn't work." But before you make up your mind, consider this four-star review: "It does what it's supposed to do." Whatever you think that might be. ✖

HEALTH & MEDICINE

HOW AN ENGINEERED VIRUS COULD DISARM HERPES

BY MEGHAN ROSEN

The words *herpes* and *spread* in the same sentence don't typically spell good news. Unless, that is, you're talking about a busybody new engineered virus.

That virus includes designer DNA called a gene drive that spreads from one herpes simplex virus to another. It may be a first step toward an entirely new way of treating the infection, researchers report in *Nature Communications*.

For now, the team has shown that the gene drive DNA sequence can copy and paste itself into the genomes of other herpesviruses during an infection in mice. The ultimate goal is to create a version that shuts down herpes simplex virus, says Keith Jerome, a virologist at the Fred Hutchinson Cancer Center in Seattle.

Jerome ultimately wants to be able to say to patients: "You don't ever have to worry about this virus again. It's never going to cause disease. You're never going to infect another person. It just doesn't matter to your life anymore."

Though some may consider herpes more annoyance than agony, "these viruses have a tremendous effect on people's health," Jerome says. They can cause a huge range of symptoms — some people don't even know they're infected while others experience painful, oozing sores around the genitals or mouth. More than 4 billion people globally are estimated to have a form of herpes.

Current therapies include antivirals, but they just tamp the virus down. They don't eradicate it. Herpes can lie dormant in nerve cells for months or years and then roar awake again, spawning fresh blisters. Infection lasts a lifetime.

A therapy that disables the slumbering virus could potentially cure the infection. But how to do it? Marius Walter, a Fred Hutch virologist, remembers reading an article that claimed designing gene drives in viruses was impossible. "That got me thinking," he says.

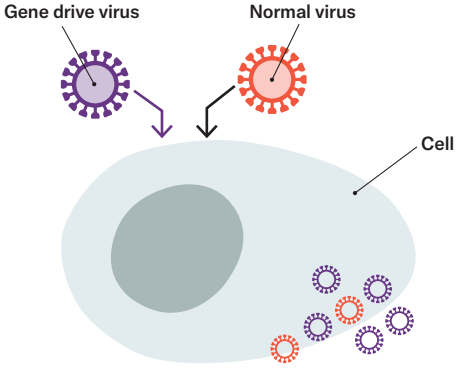
For years, scientists have investigated gene drives in insects. Researchers can create mosquitoes with a parasite-resistant gene that spreads rapidly in new generations. That could be useful in preventing malaria, though no gene drives have been tested in the wild.

Walter was curious if a similar strategy could work in viruses. Instead of a gene drive that spread from mosquito parent to mosquito young, he wanted one that spread from one virus to its neighbors. Walter and Eric Verdin of the Buck Institute for Research on Aging in Novato, Calif., did just that. A gene drive they made could hop to other herpesviruses in a petri dish, the duo reported in 2020.

That gene drive contained a CRISPR gene editor that chops other viruses' DNA. When the viruses repair themselves, they use the gene drive as a template, copying the engineered DNA into their genomes. It's how one gene drive virus can multiply into many.

In the new work, Walter's team tried the technique in mice, infecting them with two different viruses. One was a herpesvirus designed to glow yellow. The second was a gene drive virus that included genetic instructions for making a red fluorescent protein.

A GENE DRIVE IN ACTION



Scientists engineered a herpesvirus to include a gene drive (purple) that spreads from one virus to another in an infected cell (gray). The gene drive has a CRISPR gene editor that cuts other viruses' DNA. When a virus repairs itself, it copies the gene drive into its genome. Over time, more and more natural herpesviruses (red) transform into the modified version.

M. WALTER *ET AL*/*NATURE COMMUNICATIONS* 2024, ADAPTED BY METALEAP

The researchers looked at mouse tissues under a microscope and saw both yellow and red — a sign that cells could be infected by multiple viruses at once. And the relative amount of each color changed over time. After four days, up to 90 percent of virus in the brain was red. That meant almost all of the yellow virus had been converted into the gene drive version, Walter says.

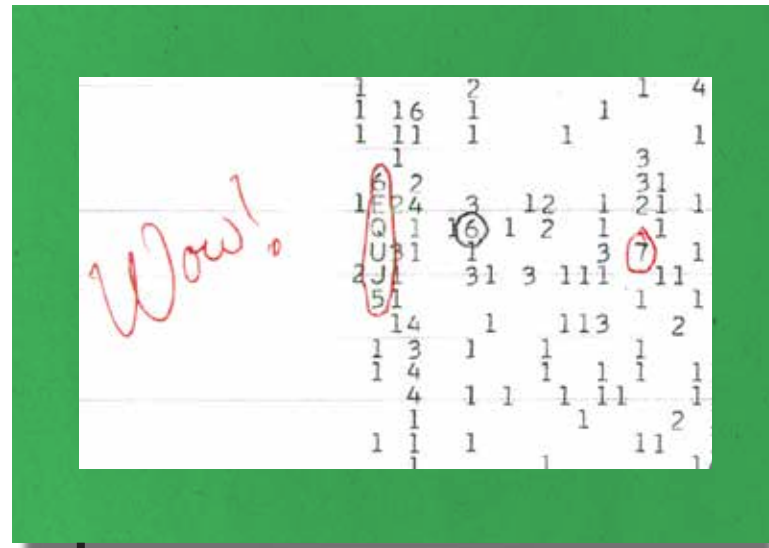
"This paper is quite a tour-de-force," says Nikolai Windbichler, a molecular biologist at Imperial College London who works on gene drives in insects. "It's a huge amount of work."

The gene drive could also spread to dormant viruses, tests in mice that had been previously infected with herpes revealed. Targeting this "sleeping" virus is key for future therapeutics, Walter says.

The next step is to create a gene drive that does more than change a virus's color. Future versions would change a herpesvirus from something that causes disease to something that's less infectious, or causes less severe symptoms. "Our goal is to turn these into real therapies that help people," Jerome says.

The technology is far from therapeutic use, says Hongsheng Dai, a virologist at Southern Medical University in Guangzhou, China, who has also published work on a herpesvirus gene drive. Some of the viruses became resistant to the gene drive, protecting them from its gene-editing powers. That's a problem if you're trying to wipe out a particular virus, Dai says.

But Walter doesn't seem too worried. There are work-arounds to resistance, he says. Scientists can target the gene drive to different areas of the virus genome, for one. That's something that will need to be investigated, he says. ✖



BIG EAR RADIO OBSERVATORY AND NAAPO

↑ A printout of data taken at the Big Ear Radio Observatory in 1977 showed a signal so bright it prompted its discoverer to write "Wow!" in the margin.

ASTRONOMY

A possible sign of alien life may not be E.T. after all

By Lisa Grossman

● **One of the most compelling** potential signs of extraterrestrial communication might have an astrophysical explanation.

Called the "Wow!" signal, the bright burst of radio waves has defied explanation since its discovery in the 1970s. Now, scientists using archived data from the Arecibo Observatory in Puerto Rico suggest a new source for the signal: a cosmic hydrogen cloud that emitted light like a laser.

"We have probably the best explanation so far," says astrobiologist Abel Méndez of the University of Puerto Rico at Arecibo. He and colleagues describe the idea in a paper posted at arXiv.org.

The original "Wow!" signal was detected decades ago by the Big Ear radio telescope at Ohio State University. As the telescope scanned the sky, a computer program converted incoming radio signals to a series of letters and numbers representing their intensities and printed it out overnight.

Each morning, astronomer Jerry Ehman and his colleagues would look over the printouts for anything interesting. When Ehman saw a signal from the night of August 15, 1977, he recognized it as something exceptionally bright. CONT. ON PAGE 24

CONT. FROM PAGE 23 Even more intriguingly, it was in a narrow wavelength range associated with neutral hydrogen atoms. Astronomers interested in the search for extraterrestrial intelligence, or SETI, had previously suggested this wavelength could be a natural calling frequency for alien civilizations. Ehman circled the signal and wrote "Wow!" in the margin in red pen.

The signal has never been seen again. Astronomers have suggested several nonalien explanations for the original, including comets and interference from Earth-orbiting satellites or space debris. But none of them fully hold up.

In search of similar signals, Méndez and colleagues sifted through some of the last data taken by the Arecibo radio telescope before it collapsed in 2020. From February to May 2020, Arecibo's antenna tracked the sky similar to how Big Ear had in the 1970s, letting the team compare the data directly.

Méndez wasn't expecting to find much. "I knew about the 'Wow!' signal for a long time, like everybody. But I dismissed it, probably like many astronomers, as some fluke," he says. "Not an astronomical event. And definitely even less, aliens."

But to his surprise, the Arecibo data showed several signals that looked a lot like "Wow!" — only dimmer. He realized that the signals corresponded to clouds of cold atomic hydrogen scattered around the galaxy. "I said, 'Wait, wait, wait!' That was the moment," Méndez says. "If it was brighter for a moment, that would be it. That would be the 'Wow!' signal."

The next question was how the clouds of hydrogen could briefly brighten. Méndez and colleagues have an idea: A bright radio source, from something like a magnetized dead star, could emit a flare and zap the cloud with energy. That energy could excite the hydrogen atoms in a particular way and trigger a maser, a laserlike effect in which all the atoms emit light in the same wavelength at the same time.

That would be an unusual phenomenon, Méndez admits. Such hydrogen masers have been built in labs on Earth, but few have been observed in space, and none at this frequency. The perfect alignment of a magnetar, a cold hydrogen cloud and the Big Ear would have been lucky, too, though that could help explain why the signal was seen only once.

If this explanation turns out to be correct, it could complicate SETI searches. If astronomers ever detect another strong signal at this frequency, it would be unclear whether it was from aliens or glowing hydrogen clouds.

"The SETI project has been looking precisely for this kind of event," Méndez says. "If we have a natural process that can produce that, that could be a false positive."

Other astronomers are reserving judgment until the details of the maser effect are fleshed out more, which Méndez and colleagues plan to do in a follow-up paper.

"He's suggesting a phenomenon that has never been observed," says SETI astronomer Jason Wright of Penn State. "The set of physical conditions is extremely delicate and specific, and it's not clear if that's even possible."

But even if the "Wow!" signal was naturally occurring, "that would be cool," Wright says. "The false positives of SETI can lead to amazing science." For example, when astronomers first spotted pulsars, they called the spinning stellar corpses LGM for Little Green Men.

"It wasn't aliens," Wright says, "but it was still a Nobel Prize." ✖

"The false positives of SETI can lead to amazing science."

— Jason Wright, Penn State

PRISS ENRI/UNSPLASH

ANIMALS

Coyotes may make ‘puppy dog’ eyes too

By Susan Milius

● **Coyotes have face muscles that** look capable of making that big-eyed, sad-puppy face that dogs have used to melt human hearts for eons. That discovery supports a rethink of humans’ history with dogs, say biologist Patrick Cunningham of Baylor University in Waco, Texas, and colleagues.

The researchers examined a little facial muscle called the LAOM at the upper, outer side of each eye in 10 coyote cadavers from Texas. The LAOM looks substantial enough to pull the top eyelids upward, the team reports in *Royal Society Open Science*. That’s the move that creates puppy eyes.

Since at least 2019, scientists have discussed how the evolution of face muscles that create a look so potent for managing humans was something that arose during canine domestication. The undomesticated gray wolf (*Canis lupus*) doesn’t have such musculature, even though it’s a close relative of our special canine pals.

But the narrative may not be so neat. African wild dogs (*Lycaon pictus*) have the cuteness muscles — and now Cunningham and colleagues have shown that the coyote (*C. latrans*, shown above) has them, too. How coyotes deploy those pleading looks in the wild is still unknown. But this array of potentially puppy-eyed relatives for the domesticated *C. familiaris* “changes the conversation,” says comparative biologist Sarah Kienle, who heads the Baylor lab where Cunningham does his work. The communicative power of the sad-puppy eye muscles seems “potentially more of an ancestral trait rather than something that’s evolved as part of this dog-human relationship.” ✖

TECHNOLOGY

A *DUNE*-INSPIRED SPACESUIT WOULD KEEP ASTRONAUTS HYDRATED

By Adam Mann

● In the science-fiction series *Dune*, the desert-dwelling Fremen of the arid planet Arrakis recycle their body’s moisture using specially designed outfits called stillsuits. Inspired by such imaginings, a new prototype spacesuit converts astronauts’ urine into drinkable water, researchers report in *Frontiers in Space Technologies*.

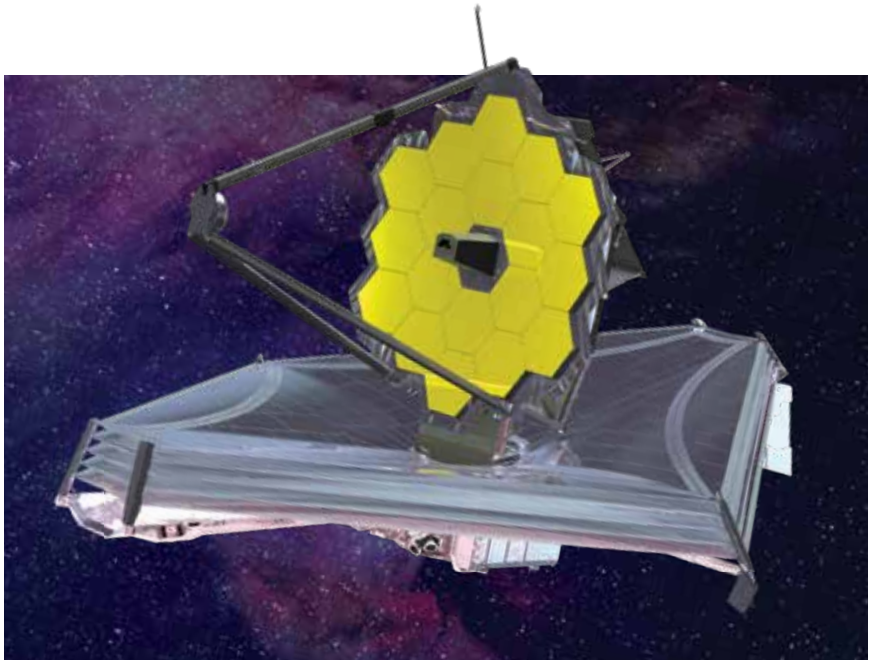
“I’ve been a fan of the *Dune* series for as long as I can remember,” says Sofia Etlin, a space medicine and policy researcher at Cornell University. “Building a real-life stillsuit was always a bit of a dream.”

While suited up in space, astronauts relieve themselves into a multilayered, diaperlike garment that contains a super-absorbent polymer. But the garment is uncomfortable, leaks and can cause urinary tract infections.

Current spacesuits also incorporate an in-suit drinking bag, or IDB, that carries less than a liter of water. Astronauts sometimes go for eight-hour spacewalks, which often include enormous amounts of physical exertion, Etlin says. NASA’s future Artemis missions to the moon will probably see explorers spending at least that much time or longer on the lunar surface, though plans have them carrying IDBs of the same size.

Etlin and colleagues designed a new type of undergarment with a collection cup that goes over an astronaut’s private parts. Urine is routed into a filtration system that removes salty water from the urine and then uses a pump to take the salt out of that water. The filtered water is enriched with electrolytes and sent into the IDB. The system, powered by a 20.5-volt battery, can purify half a liter of water in five minutes.

Sweat — which fictional stillsuits also collect — would be easier to filter than urine, Etlin says. But she and colleagues decided to focus on a single waste product for their first prototype. “One step at a time,” she says. ✖



COSMOLOGY

In an epic cosmic clash, rivals begin to find common ground

By Emily Conover

● **The biggest clash in cosmology** might be inching closer to resolution, thanks to the James Webb Space Telescope.

Scientists disagree over the universe's expansion rate, known as the Hubble constant. There are two main methods for measuring it: one based on exploding stars called supernovas and the other on the universe's oldest light, the cosmic microwave background. The two techniques have been in conflict for a decade. If this "Hubble tension" is real and not the result of a measurement error, it would demand a drastic shift in how scientists understand the universe.

Papers by two central players in the debate raise hopes that observations from JWST will solve the question of whether the discord is real, once and for all.

The two teams disagree on whether that tension even exists. One team says there's no strong evidence for it in JWST data while the other group says the data strengthen the case. "I'm even more intrigued by the Hubble tension," says cosmologist Adam Riess of Johns Hopkins University, a leader of one team.

But the two camps are seeing eye to eye on one thing: distances to nearby galaxies, which are needed to deduce the universe's expansion rate from supernovas. "That's real progress," says Wendy Freedman, a cosmologist at the University of Chicago who leads the other team. Agreement on distances gives newfound confidence that the dispute is close to resolution. "I'm pretty optimistic that in the next couple of years, the questions that we're talking about now, we will have resolved those," she says.

Scientists' theory of the universe, the standard cosmological model, is based largely on unknowns. Dark matter, a substance that adds unseen mass to galaxies, has never been directly detected. Dark energy, a phenomenon that causes the universe's expansion to accelerate, is likewise a total question mark. But the model has proved extremely successful in describing the cosmos.

↑ **The James Webb Space Telescope (illustrated) could help scientists better measure how fast the universe is expanding.**

NASA, ESA, CSA, NORTHROP GRUMMAN

Starting from the ancient light of the cosmic microwave background, scientists can use the standard model to determine today's expansion rate. That technique finds that space is expanding at 67 kilometers per second per megaparsec. (One megaparsec is about 3 million light-years.) But measurements of supernovas peg the number at about 73 km/s/Mpc. The conflicting estimates hint that something may be wrong with the standard model.

To determine the expansion rate via the supernova technique, cosmologists measure the distances to many distant supernovas. That requires a technique called a distance ladder to translate nearby distances to those farther out. Under scrutiny is the second rung of this ladder, in which scientists observe certain types of stars — typically pulsating stars called Cepheids — to determine distances to the galaxies they reside in, as well as to supernovas in the same galaxies. Observing these stars with JWST, which has better resolution than the Hubble Space Telescope, could suss out flaws in the measurements for that rung.

Freedman and colleagues used Cepheids plus two other types of stars to measure distance. JWST data on all three yield an expansion rate of about 70 km/s/Mpc. Given measurement uncertainties, that's close enough to the cosmic microwave background number that it doesn't require a rethink of the cosmos, the team reports at arXiv.org. But it doesn't fully rule out the existence of the Hubble tension.

Despite agreeing on distances, the teams still differ on the Hubble constant. That could be due to the small number of measurements made with JWST so far, Riess and colleagues report in the *Astrophysical Journal*. If Freedman's team picked different galaxies to observe, the value of the Hubble constant would have been larger, the group argues.

Freedman wants to keep looking for unidentified issues known as systematic uncertainties that could be artificially pushing estimates of the Hubble constant higher. One concern is crowding — many stars lumped together in the same place, throwing off measurements of the Cepheids. In 2023, Riess' team found no evidence of crowding in JWST data. But that effect might be more prominent at larger distances than have been studied so far with JWST, Freedman suggests.

If different distance measurements disagree, says cosmologist Saul Perlmutter of the University of California, Berkeley, "then it may suggest that we still have to get to the bottom of systematic uncertainties first before we get as concerned about a major problem with the cosmological model."

But many physicists are bullish about the Hubble tension. Various other methods have also found higher-than-expected expansion rates, says physicist Eleonora Di Valentino of the University of Sheffield in England. "The Hubble tension is still very robust." ✖

70 km/s/Mpc

A new estimate of the universe's expansion rate based on stellar observations collected by the James Webb Space Telescope. Another set of data puts the expansion rate at 67 kilometers per second per megaparsec.

ROWAN GREGORY/GETTY IMAGES

ANIMALS

RIFLEBIRDS WING IT WHEN FLIRTING

By Susan Milius

● Video of riflebirds' extreme wrist flares and feather noises reveals how these show-offs do their dazzle.

Riflebirds, a group within the birds of paradise native to Australia and New Guinea, have long fascinated biologists with their courtship displays. Among Victoria's riflebirds (*Ptiloris victoriae*), a male repeatedly fans out dark, satiny wing feathers into a curved arc (shown above). He sways his head rhythmically and opens his mouth to a soundtrack of short, sharp thwacking sounds.

How males manage the loud percussion was a mystery to science, says Thomas MacGillavry, a zoologist at the University of Veterinary Medicine Vienna. Researchers thought the birds clapped their wings together. Instead, a male uses his beak to play his feathers like an instrument, MacGillavry and colleagues conclude in the *Biological Journal of the Linnean Society*.

They managed to get new film of a male in action and examine specimens of Victoria's riflebirds and related species. As a male Victoria's riflebird swings his head, he periodically closes his beak, briefly hiding the lovely yellow throat lining. The beak whacks against fanned out feathers as it swings over them, like a stick dragged against a picket fence.

That arc of feathers is a marvel in itself. It curves strikingly inward, like a cape curling forward. To create such a curve takes an extremely flexible wrist.

"It looks like the males are doing something analogous to a body builder flexing," MacGillavry says. In the birds, it's the wrist that does the bending. The wrist of a dead Victoria's riflebird could be flexed 237.1 degrees. The wrists of other preserved *Ptiloris* species bent a few more degrees. That's "something no other birds can do," MacGillavry says. At least, as far as we know. ✖

Q&A

BIRD POOP LAUNCHED U.S. GLOBAL EXPANSION

BY SUJATA GUPTA

In December 1855 and January 1856, a trio of vessels set sail from the United States to Jarvis and Baker islands, coral atolls in the central Pacific Ocean. The ships carried representatives from the newly formed American Guano Company and an expert tasked with examining the quality of the islands' bird poop. After estimating the quantity of guano available and taking samples, the entourage claimed the islands in the name of the company and the United States. That move marked the country's first effort to acquire territory overseas.

U.S. ownership of those islands became official in August 1856 when President Franklin Pierce signed into law the Guano Islands Act, which permitted the country to claim sovereignty over any allegedly uninhabited or unclaimed territory to secure access to guano, a prized fertilizer.

The act was meant to provide the United States with a guano supply outside of Peru, home to the most coveted, nitrogen-rich guano in the world. But the law gave more than the gift of bird poop, says environmental sociologist Mauricio Betancourt of Washington and Lee University in Lexington, Va. It enabled the United States to seize some 100 far-flung islands, 10 of which remain in U.S. possession.

When the guano craze ended decades later, the United States turned many of those islands into military bases and strategic refueling stops. During the Vietnam War, the military used Johnson Atoll, a Pacific island acquired in 1858 through the Guano Islands Act, to store and later incinerate the chemical weapon Agent Orange.

"Not enough emphasis has been placed on the ecology (and specifically on guano) as the historical basis of the U.S. empire," Betancourt writes in the journal *Socius*.

The idea that the U.S. empire was built on bird poop reflects more than a change in historical narrative. This and other examples of ecological imperialism illuminate how land grabs to acquire resources alter the environment and occasionally advance scientific knowledge. *Science News* spoke with Betancourt to learn more about the neglected story of guano and its modern-day repercussions. This interview has been edited for length and clarity.

Q What triggered the guano frenzy?

A The guano trade began because Europe had a problem of soil depletion. In the 1800s, Britain was undergoing an agricultural revolution. It was maximizing the yield of some cash crops of wool, cereals for grazing, et cetera. That increased food production.

Justus von Liebig, one of the foremost German chemists, argued back then that soil fertility had to be replenished because removing nutrients couldn't be done indefinitely. That could provoke a problem of soil exhaustion.

German naturalist Alexander von Humboldt brought samples of guano back to Europe in 1804 after traveling to Peru, so Europeans were well aware of its remarkable fertilizing properties. And so they brought guano all the way from Peru to Britain around Cape Horn because the Panama Canal didn't exist. Americans followed suit. The guano trade catalyzed the construction of the Panama Canal.

Q What made Peru's guano so great?

A Liebig clearly communicated to the scientific public in Europe that nitrogen was one of the key fertilizing elements.

The guano on islands off Peru stands alone in terms of the nitrogen content because of its location in a place where it very rarely rains. So the guano retains its percentage of nitrogen, and it's not washed off or watered down by the rain. Pacific guano was not as good, actually. It's more humid, so the guano has a higher concentration of phosphate relative to nitrogen.

Q How did intense guano excavation affect Peruvian ecosystems?

A Because of upwelling, a lot of nutrients at the bottom of the ocean are resurfaced near Peru. This also happens off Namibia, the Canary Islands and California. But being closer to the equator, Peru's guano has a very high concentration of nutrients. Phytoplankton attract a lot of zooplankton. There are so many birds because there's a lot of fish. The guano is the culmination of the transmission of all of those nutrients from the ocean to the phytoplankton, zooplankton, fishes and birds.

Guano diggers built settlements on Peru's islands. You had hundreds of people living there for 40 years. That scared the birds. There are no precise estimates of the size of the populations back then. Probably there were about 50 million birds. Today, there are [roughly 4 million] birds.

Q Once Peru's guano supply was exhausted, nations turned to another source of nitrogen: Chilean nitrates. What was the impact?

A The nitrates were of geological origin found in desert salts, but it's the same story of ecological imperialism. Chile's nitrates were also exhausted eventually. And this prompted the War of the Pacific from 1879 to 1883, between Chile backed by Britain versus Bolivia and Peru. Bolivia and Peru lost the war and had to cede part of their territories in perpetuity to Chile.

Q How did the world satisfy its appetite for fertilizers after that?

A The German chemist Fritz Haber discovered a chemical reaction in the early 1900s whereby he could use molecular nitrogen gas from the atmosphere and combine it with hydrogen in a very energy-intensive reaction to produce ammonia. Basically, he discovered how to synthesize fertilizer from nitrogen in the air, which is, to this day, the process whereby most synthetic fertilizer in the world is produced.

Many people claim that reaction allowed the population explosion in the 20th century. Haber was even awarded the Nobel Prize for chemistry in 1918 for developing this reaction, partly stemming from what guano taught the world.

Q Is guano still sought-after?

A It's interesting because it's pretty much for domestic consumption in Peru. But it's also exported in a sense. Farmers apply it to coffee. The nutrients end up accumulating in the coffee. And that coffee gets exported to Europe and to the U.S. ✖

HENRY DEWITT MOULTON/WIKIMEDIA COMMONS

↓ From roughly 1845 to 1880, prospectors in Peru (shown here loading up a cart in 1865) dug up 15 million metric tons of seabird guano for fertilizer. To put that number in perspective, it would take the residents of New York City 37 years to produce that much excrement.

This Is How You *Walk the Walk*

Comfort and class go hand in hand with our Walking Stick Collection. Yours for ***ONLY $59 each!***

They call walking the "perfect exercise." It gets your heart pumping, clears your head and fills your lungs with fresh air. Not bad, but we found a way to make it even better. Before you take your next 10,000 steps, add a little strut to your stroll. Take a Stauer Walking Stick anywhere and I promise that you'll feel like a conquering hero. Heads will turn. Doors will open. Its powers will astound you.

What's the secret? Pure class. Our Stauer Walking Sticks are a tip of the top hat to turn-of-the-century tradition. Today these tributes to a gentleman's power, prestige, and posture are fetching as much as $200,000 at auction. But only Stauer can deliver a modern version of these vintage classics that looks and feels as good as the original for **only $59 each**!

Stauer Walking Stick Collection

A. Derbyshire	~~$79~~*	**$59** +S&P	*Save $20*
B. Earlsford	~~$79~~*	**$59** +S&P	*Save $20*
C. Knightsbridge	~~$79~~*	**$59** +S&P	*Save $20*
D. Hinwick Hare	~~$79~~*	**$59** +S&P	*Save $20*
E. Gentleman's	~~$79~~*	**$59** +S&P	*Save $20*

- **36" long • Imported Eucalyptus wood**
- **Etched & sculpted solid brass handles with varying finishes**
- **Rubber tips • Supports up to 250 lbs.**
- **All models available in 40" height—call for details.**

Your satisfaction is 100% guaranteed. Experience the comfort and class of our exquisite ***Walking Sticks*** for 30 days. If you're not feeling the power and prestige, simply send it back within 30 days for a refund of the item price. At Stauer, we walk the talk.

Limited Edition. Only 500 each available for this ad only! These handcrafted beauties take months to craft and are running (not walking) out the door. So, take a step in the right direction. Call today!

PRAISE FOR STAUER WALKING STICKS

"An excellent walking stick. Solid and elegant. Perfect for a night out. Well crafted."

– J. from Pacific Grove, CA

1-800-333-2045

Your Insider Offer Code: WSC309-01

You must use the insider offer code to get our special price.

Stauer®

14091 Southcross Drive W., WSC309-01
Burnsville, Minnesota 55337 www.stauer.com

**Discount is only for customers who use the offer code versus the listed original Stauer.com price.*

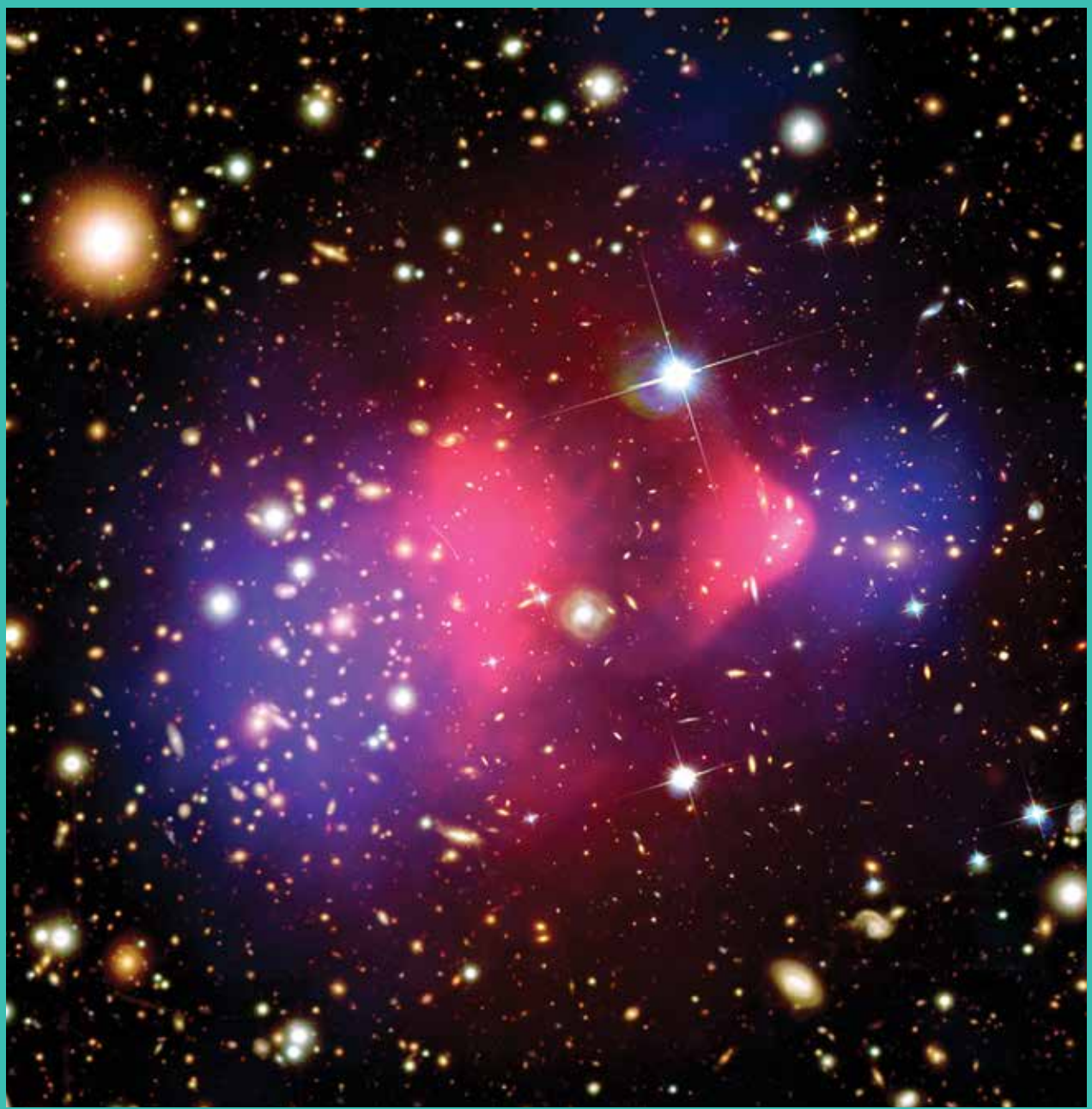
Stauer... *Afford the Extraordinary.*®

BBB ACCREDITED BUSINESS
Rating of A+

CONSUMER AFFAIRS ACCREDITED

Exquisite walking sticks not shown actual size.

Features

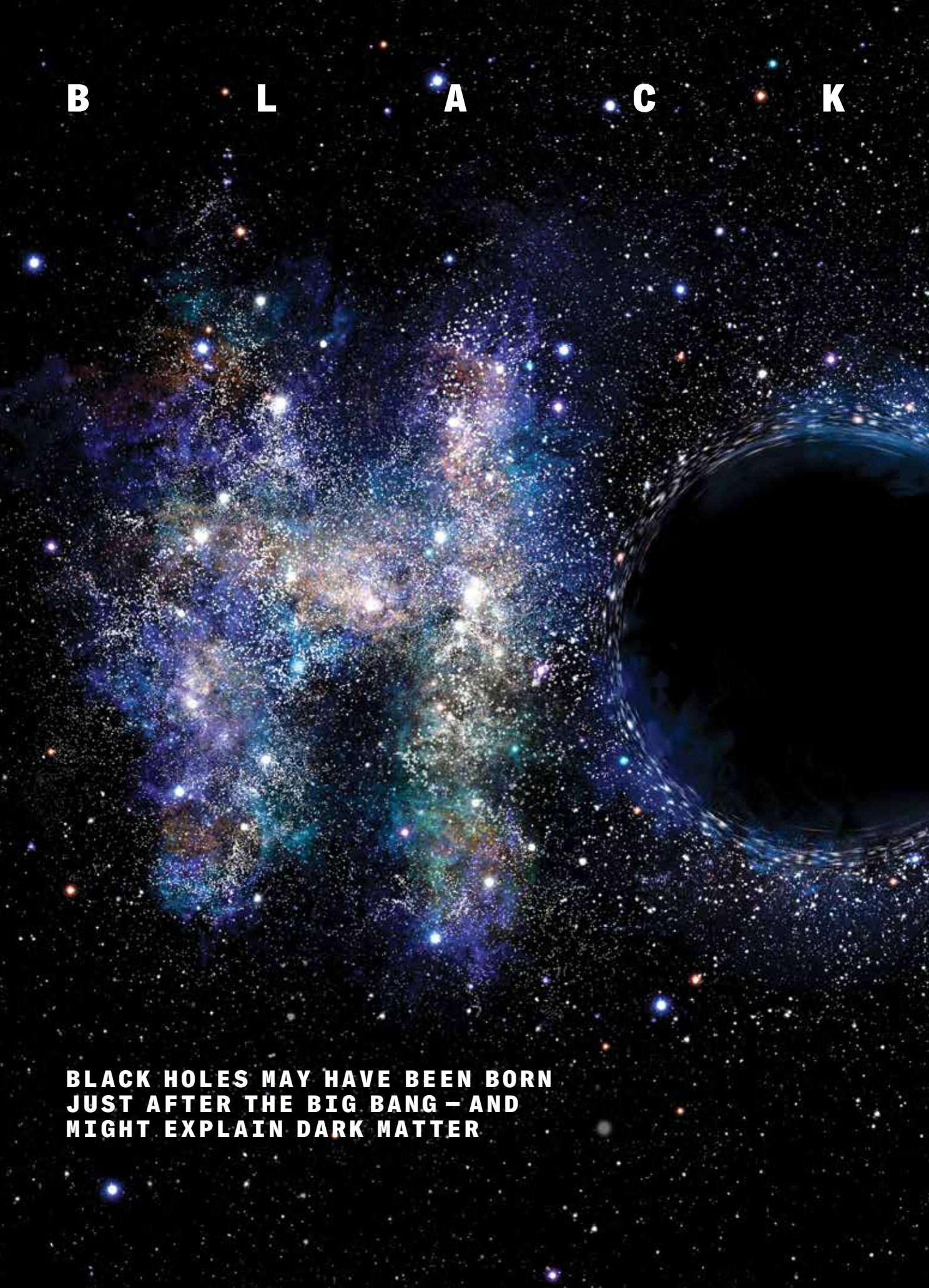


X-RAY: CXC/NASA & CFA, M. MARKEVITCH *ET AL*; OPTICAL: NASA, STSCI, MAGELLAN, UNIV. OF ARIZONA, D. CLOWE *ET AL*; LENSING MAP: NASA, STSCI, ESO WFI, MAGELLAN, UNIV. OF ARIZONA, D. CLOWE *ET AL*

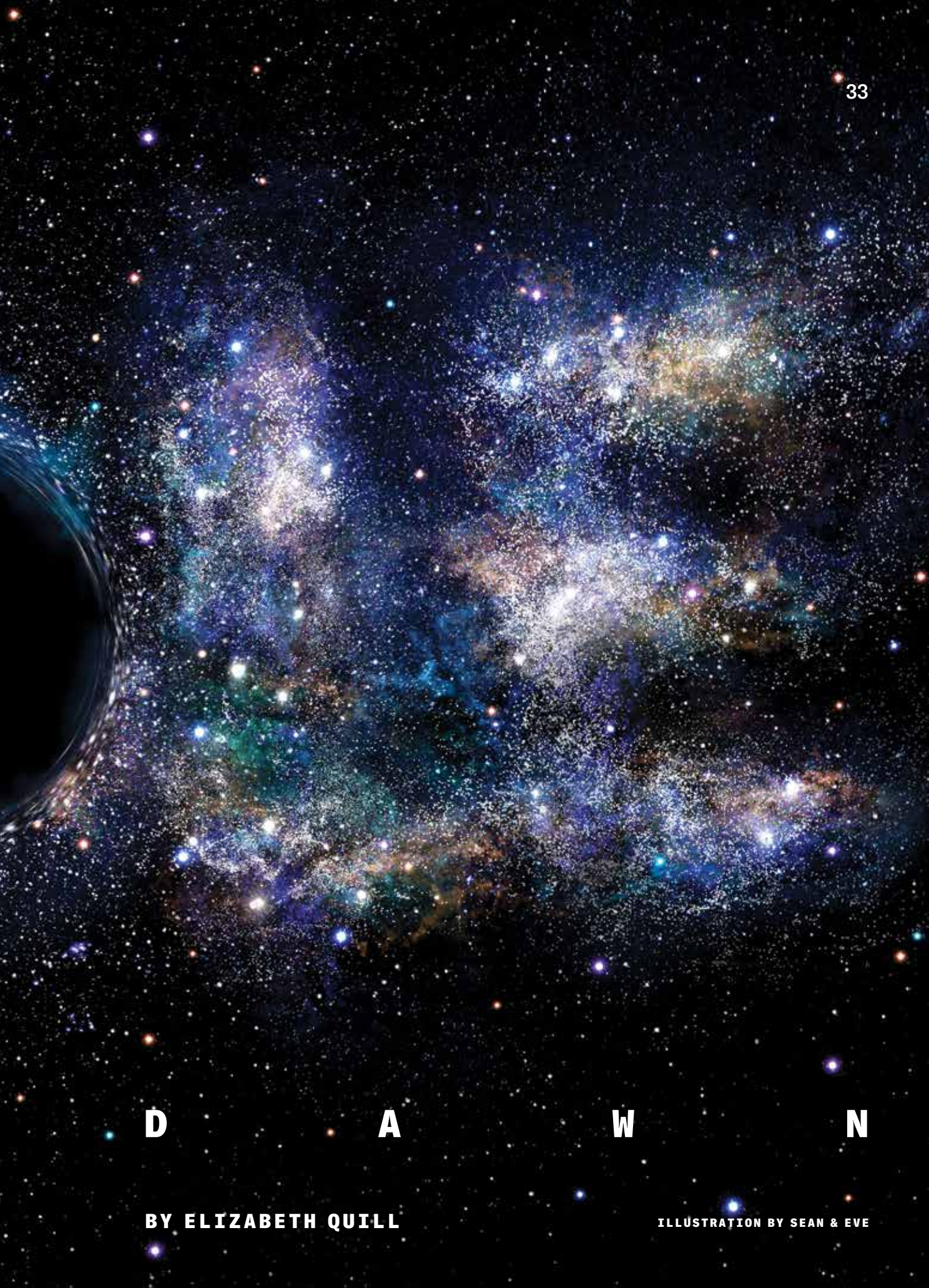
COSMOLOGY

DARK MATTER EXISTS. BUT WHAT IS IT?

● About 3.8 billion light-years from Earth, a galaxy cluster shot through another in one of the most energetic events since the Big Bang. Telescope observations of the aftermath, dubbed the Bullet Cluster (composite image shown), revealed "smoking gun" evidence that dark matter exists, scientists reported in 2006. Hot gas (pink) contains most of the cluster's ordinary matter while most of the mass (blue) is confined to areas with no visible matter. More dark matter clues might lie in another cosmic entity, primordial black holes (see Page 32). — *Cassie Martin*



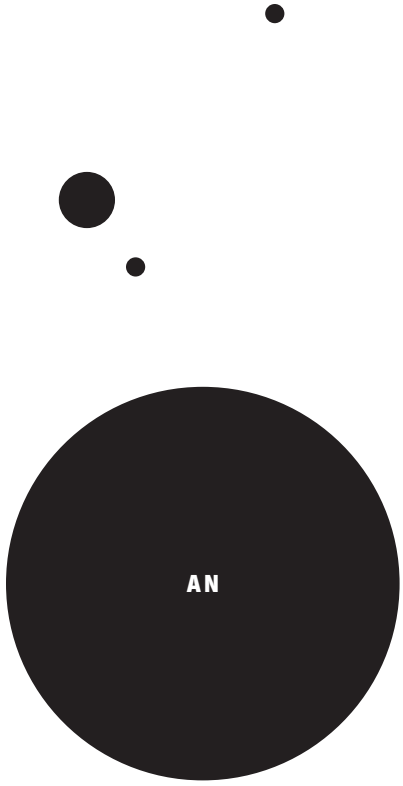
BLACK HOLES MAY HAVE BEEN BORN JUST AFTER THE BIG BANG — AND MIGHT EXPLAIN DARK MATTER



D A W N

BY ELIZABETH QUILL

ILLUSTRATION BY SEAN & EVE



undiscovered population of ancient black holes may be lurking throughout the universe. These bottomless cosmic pits would have a lot in common with more familiar black holes; in some cases, the two may be indistinguishable. But unlike their kin, these undiscovered black holes wouldn't have formed from a massive star collapsing in on itself, nor would they be peers of the supermassive black holes that feed at the centers of galaxies.

Instead, these black holes would have been born in the earliest epochs after the Big Bang — before stars and galaxies even appeared.

Called primordial black holes, these hypothetical objects have attracted interest since the 1960s. Stephen Hawking wrote one of the earliest papers about their potential existence. Just a few years later, his investigation of primordial black holes led him to perhaps his most famous idea, that black holes leak energy — now called Hawking radiation — in a way that slowly robs them of their mass.

Now, after decades of pondering primordial black holes, scientists sound genuinely optimistic about the possibility of detecting them. There's been a surge of interest in the field. Researchers new to primordial black holes are teaming up with longtime investigators to pin down the data that could prove these black holes exist. If they do linger across the universe, they'd be emitting Hawking radiation, bending starlight, colliding with other cosmic objects and each other, perhaps even gobbling up stars from the inside out.

In other words, they'd be shaping the cosmos in observable ways.

In 2023, a team that includes cosmologist Bernard Carr, who coauthored a pivotal early paper with Hawking on the subject, outlined more than 20 lines of evidence that might support the existence of primordial black holes. In a recent historical review, Carr predicted we'll have an answer within the next decade.

"I would bet you, say, 70 percent — maybe 60 or 70 percent — that they exist," says Carr, a professor emeritus at Queen Mary University of London. "And that's partly wishful thinking because I prefer them to exist, but it's something that's trying to be objective."

If primordial black holes are out there, they could help solve one of the biggest mysteries in cosmology: What is dark matter? This elusive substance is six times as abundant as all the ordinary stuff we're familiar with, from people to planets to pickleballs. Its gravitational influence is credited with holding galaxies together and scaffolding all the cosmic substance we can see. But despite decades of searching, no one yet knows what it is.

Primordial black holes could account for some of the dark matter out there. Some researchers believe that these black holes may account for all of it. But their existence isn't a given. Their formation requires new physics, some critics point out. Among the researchers now studying these black holes are true believers, those hoping to disprove the idea and everyone in between.

"There's certainly more people who are excited now," says Anne Green, an astroparticle physicist at the University of Nottingham in England who coauthored the historical review with Carr but considers herself agnostic on the question of existence. "And it probably is that there is more cause for excitement."

Black holes everywhere

The recent surge in interest traces its origins to 2016. That year, scientists reported that gravitational waves, ripples in spacetime predicted by Einstein's general theory of relativity, had been detected from a pair of merging black holes. The discovery, recognized with the Nobel Prize in physics the next year, opened a new window on black holes.

"Once we knew we could directly observe black hole mergers with gravitational waves, this became a probe," says cosmologist Will Kinney of the University at Buffalo in New York. "Every time you create a new tool, a new way to observe the universe, then you start asking questions differently." He says the current interest in primordial black holes is a good example of that.

Until the gravitational wave data

started pouring in, there were two types of black holes known to exist in abundance. The first, "stellar" black holes, forms when a very massive star runs out of fuel and its core collapses in on itself. These black holes generally have masses between five and 10 times the mass of the sun, and sometimes as much as 20 times or more.

The second abundant type, supermassive black holes, sits at the centers of galaxies and can weigh in at billions of times the mass of the sun. Perhaps these ones formed early in galactic history from the direct collapse of gas, or through successive mergers of stellar black holes. In either case, they grew as they fed on anything in their grip.

But when the Advanced Laser Interferometer Gravitational-Wave Observatory, or LIGO, reported those first colliding black holes in 2016, the objects were more massive than many people expected, with each one in the pair weighing as much as 30 suns.

Simeon Bird, a cosmologist at Johns Hopkins University at the time, recalls puzzling over the masses with his adviser shortly before the results became public. Why would LIGO's first detections be of what are thought to be relatively rare black holes rather than something more common?

"Maybe it's a primordial black hole," Bird recalls saying with a laugh. "What a silly idea." But that supposedly silly idea quickly turned into a paper making the case that LIGO may have detected dark matter in the form of primordial black holes. Reports from other teams pointed to the same possibility. In the years since, LIGO in the United States has been joined by Virgo in Italy and KAGRA in Japan. So far, the collaboration has detected more than 80 black hole mergers.

In addition to the surprising black hole masses that Bird and others puzzled over, some scientists are intrigued by the slow spins of the black holes, the number of mergers between black holes of dramatically different masses and how often black holes seem to be merging across cosmic time.

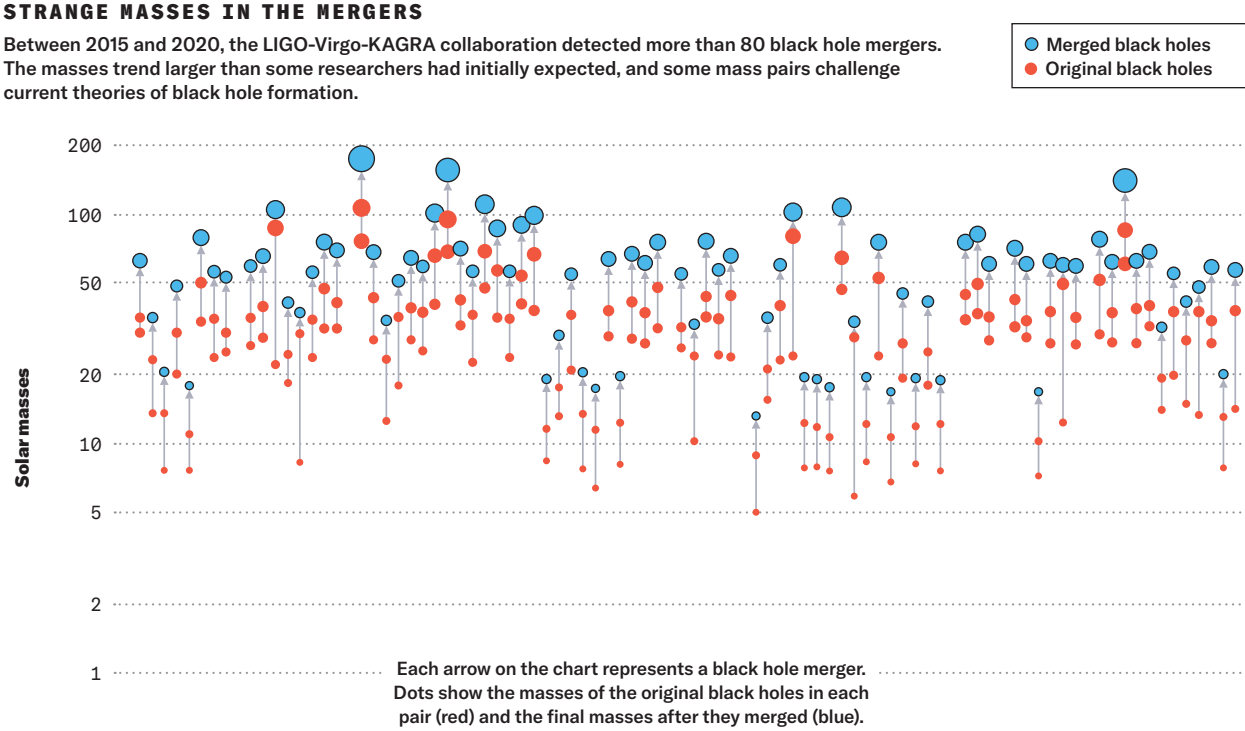
"There are many properties that are bizarre," says Sébastien Clesse, a cosmologist at the Université Libre de Bruxelles in Belgium. Primordial black holes could help explain the unexpected findings.

Making a primordial black hole

In the tiniest of the tiniest fractions of a second after the Big Bang, when the universe was nothing but a hot, compact ball of energy, scientists believe it expanded exponentially, growing by a factor of at least 10^{25} in less than a trillionth of a trillionth of a trillionth of a second — a period known as inflation. During this time, quantum fluctuations would have generated extreme changes in energy density. Some pockets may have become so dense that they could have collapsed in on themselves, popping off

STRANGE MASSES IN THE MERGERS

Between 2015 and 2020, the LIGO-Virgo-KAGRA collaboration detected more than 80 black hole mergers. The masses trend larger than some researchers had initially expected, and some mass pairs challenge current theories of black hole formation.



LIGO-VIRGO-KAGRA COLLABORATION, FRANK ELAVSKY, AARON GELLER/NORTHWESTERN UNIV., ADAPTED BY METALEAP

primordial black holes.

This is just one picture researchers have come up with to explain how primordial black holes could have formed just after the Big Bang, some 13.8 billion years ago. There are other proposed mechanisms across the earliest moments of the universe, including cosmic string loops or colliding bubbles.

"The only ingredient you really need is a large energy density," says theoretical physicist Florian Kühnel of the Max Planck Institute for Physics in Munich.

No matter how and when these primordial black holes formed, though, they would have appeared in a range of masses far more diverse than what we see today. There'd be black holes about the mass of a wildebeest (a couple hundred kilograms), as well as ones with the mass of Mount Everest (tens to hundreds of trillions of kilograms). Black holes with roughly the masses of asteroids would still be microscopic. And there'd be black holes with the masses of planets and stars, perhaps all the way past a million solar masses.

Some of those primordial black holes might account for the unexpected gravitational wave findings, Carr, Clesse, Kühnel and Juan García-Bellido of the Universidad Autónoma de Madrid argue in a 2021 paper in *Physics of the Dark Universe*.

The largest of the primordial black holes might resolve another open question: how supermassive black holes, especially those detected early in the universe, could have grown so big so quickly. Clesse and García-Bellido suggested as early as 2015 that if primordial black holes exist, they could have served as seeds for today's supermassive ones.

The 2021 paper sets out a plausible picture, says Bird, now at the University of California, Riverside. But more ordinary astrophysics may still explain the puzzling black hole observations. Part of the challenge is that scientists don't know enough about black holes in general. There's not yet a clear picture of how they are distributed, how commonly they merge or how their surroundings influence feeding, growth or evaporation due to Hawking radiation.

Studying the physics of black holes surrounded by gas and dust, as they are in the universe, is tricky. Many models simply don't account for that.

"We have gorgeous, gorgeous theorems that have rightly earned our colleagues Nobel Prizes," says David Kaiser, a physicist and historian of science at MIT, "and these results are almost entirely studying black holes and nothing else, speaking loosely."

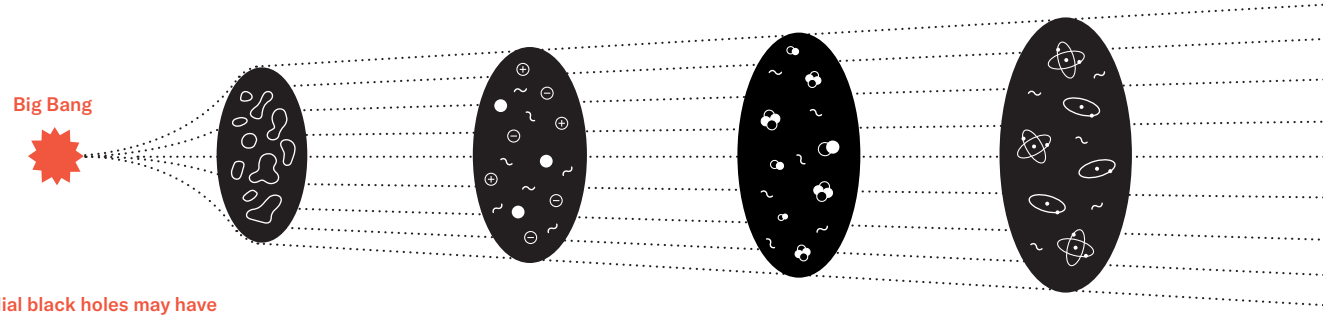
Detecting primordial black holes

Despite all that's unknown, there are two observations that most scientists agree would definitively point to a primordial black hole, and much of the recent excitement is about how to spot such signs.

The first would be a black hole detected from before the first stars formed, perhaps within the first hundred million years after the Big Bang. Since it couldn't

A BRIEF HISTORY OF THE UNIVERSE

This timeline shows key milestones in the history and evolution of the universe, starting with the Big Bang roughly 13.8 billion years ago.



Primordial black holes may have formed within the first fractions of a second after the Big Bang.

10^{-36} seconds	1 microsecond	<3 minutes	380,000 years
Inflation Rapid expansion	**First baryons** Neutrons and protons form	**First nuclei** Hydrogen and helium nuclei form	**First atoms** Nuclei gain electrons to make atoms

"IF LIGO FOUND A ONE-SOLAR-MASS BLACK HOLE, THEN EVERYONE WOULD BE CONVINCED PRIMORDIAL BLACK HOLES ARE REAL."

Earl Bellinger
Yale University

have formed from stars, it must be primordial, the thinking goes. Existing gravitational wave detectors can't look back that far, but future ones might. The space-based LISA gravitational wave observatory, planned for launch in the 2030s, and the Einstein Telescope and the Cosmic Explorer, both in the planning phases, could reach this ultra-ancient epoch.

The second possible certain sign, which could perhaps be found with existing observatories, would be a black hole about the mass of the sun or less. That would be hard to understand through typical formation mechanisms, leaving primordial black holes as the most plausible explanation.

García-Bellido is leading a group looking for these black holes in the current gravitational wave data, and the team is already studying some candidates.

"If LIGO found a one-solar-mass black hole, then everyone would be convinced primordial black holes are real," agrees stellar astrophysicist Earl Bellinger of Yale University. He says he can think of no other reasonable process that would yield that mass.

"And if it is less than one solar mass, even better."

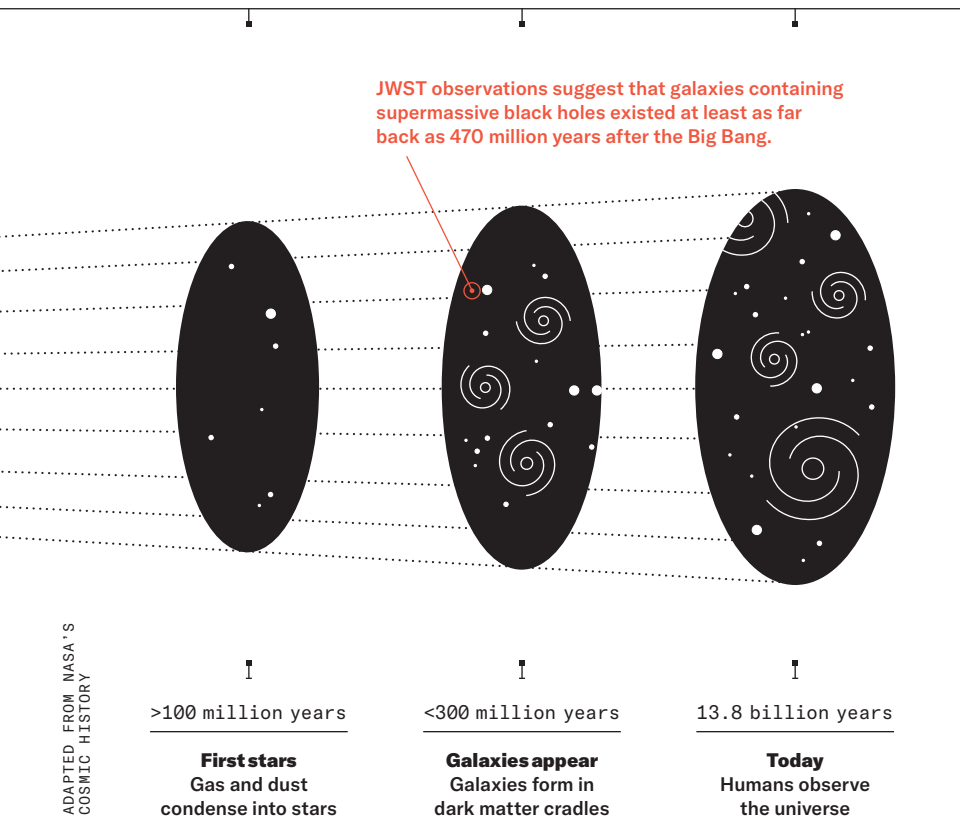
The Einstein Telescope and the Cosmic Explorer would boost the search for black holes roughly the mass of the sun or less. And some teams are eyeing radically different types of detectors that would look for gravitational waves from black holes the mass of a planet, an asteroid or less.

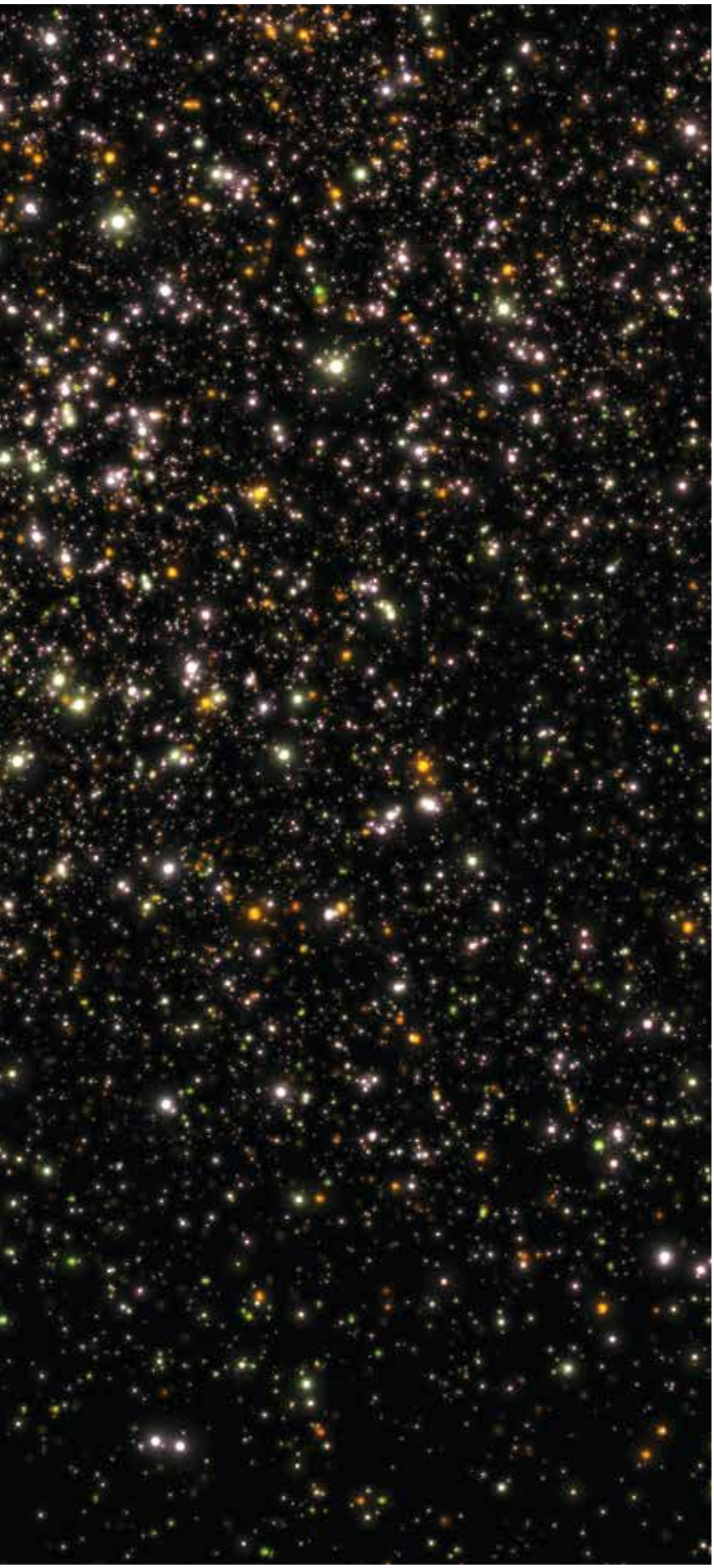
But gravitational waves might not be the only way to detect such a black hole. Some researchers have other ideas. Bellinger, for example, recently asked the question: What would happen if a small primordial black hole lurked inside a star? A lot of eminent physicists, including Hawking, have explored this question before. But there's not a solid understanding of how fast a black hole with a mass similar to the moon or an asteroid would feed and grow within a star, and thus whether the star's light would escape the black hole's pull.

"The black hole has this all-you-can-eat buffet, which is the stellar plasma, and you might think the star just falls into it, which might happen," Bellinger says. "But if it falls in almost at an angle, you expect everything around that to get heated up. If it gets heated up, it exerts some pressure and some luminosity flows out."

Bellinger, Kühnel and colleagues decided to investigate several scenarios for stars with black holes inside, dubbed Hawking stars. The team reported the results in December 2023 in the *Astrophysical Journal*.

"The most fun scenario is if the energy does get out," Bellinger says. In that case, you'd see a type of red giant known as a red straggler. Such stars (for which there are other, perhaps more plausible explanations)





NASA AND G. BACON/STSCI

An illustration shows a black hole in a globular cluster.

have been found in abundance in dwarf galaxies near the Milky Way that are thought to be dominated by dark matter. Bellinger and colleagues note that studies of how the intensity of light from these stars oscillates could distinguish a Hawking star from a red straggler that formed in another way, thus offering evidence for primordial black holes.

What about closer to home? In September 2024, two separate teams of researchers suggested how a primordial black hole passing through our solar system might be detected. Clesse and others argued that a black hole the mass of an asteroid would be hefty enough to tweak the orbits of satellites, including those used for GPS navigation. The other team, which included Kaiser and colleagues from MIT, described how such a primordial black hole might disrupt the orbit of Mars.

Kaiser and theoretical physicist Elba Alonso-Monsalve, also of MIT, have even suggested that there might be a way to detect a long-gone population of ultra-tiny primordial black holes.

In a recent study, the team investigated the formation of primordial black holes slightly after inflation but still only around 10^{-20} seconds after the Big Bang. At that time, subatomic particles known as quarks and gluons floated freely, not yet bound up in protons and neutrons.

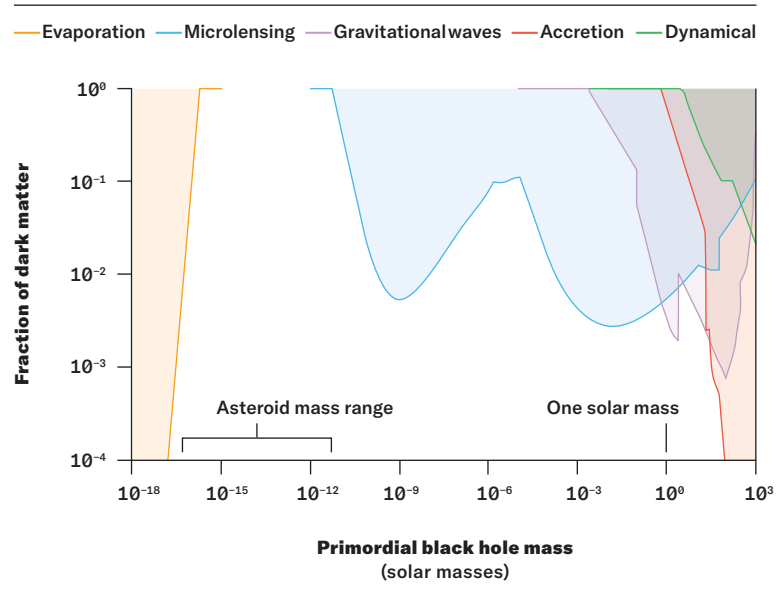
As black holes formed across a range of masses, they would have swallowed up these quarks and gluons, along with a quantum property called color charge that the particles possess. For big enough black holes, the amalgamation of color charges would cancel out, leaving no net color charge. But that wouldn't be true for the measliest black holes.

Any primordial black holes small enough to have color charge would have evaporated via Hawking radiation by now, but they could have left a calling card that scientists can look for, Alonso-Monsalve and Kaiser reported in June in *Physical Review Letters*. As just one example, the evaporation of color-charge black holes could have affected the ratios of the light elements hydrogen, helium and lithium that formed from the plasma of the early universe.

If clear signs of color-charge black holes are discovered, they'd point to the existence of larger primordial black holes without color charge still around today. And it's today's primordial black holes that have the potential to resolve the dark matter question.

DARK MATTER BOUNDARIES

Scientists have turned to various types of evidence, including the five shown here, to determine whether primordial black holes at different masses can account for dark matter. Below, shaded regions show the mass ranges that most scientists agree can be ruled out as accounting for a substantial amount of dark matter.



Explaining dark matter

As an explanation for dark matter, primordial black holes have long been in the shadow of another popular candidate: hypothetical subatomic particles. Half a century ago, there were compelling reasons for particle physicists to believe a lot of new and exotic particles would soon be discovered, Kaiser says. With high hopes, scientists went out en masse to find them.

When the Large Hadron Collider, the world's most powerful particle accelerator, turned on in 2008 near Geneva, it was expected to find proof of such particles, notably WIMPs, short for weakly interacting massive particles. Others sought particle dark matter high and low with massive detectors in underground laboratories and even a compact detector on the International Space Station. But so far, there's no evidence.

Green, of the University of Nottingham, compares the search for WIMPs to looking for a needle in a haystack — now we're most of the way through the haystack with no needle found. It doesn't mean the particles aren't there, but confidence that they'll be found is starting to dwindle.

"There's now probably thousands of people working on the WIMP detection experiments, and they absolutely shouldn't stop," Green notes. "But I've not necessarily got the champagne on ice."

In one way of viewing it, primordial black holes aren't a far-fetched dark matter candidate. Because we know that black holes generally exist, some researchers argue, primordial black holes are a simpler explanation than new and exotic particles. On the flip side, primordial black holes do require new physics in the form of adjustments to current models. Standard pictures of inflation, for example, don't generate extreme enough fluctuations in energy densities on their own.

"If I just write down a model for inflation, it doesn't produce any black holes at all," Kinney says. "I have to really do some violence to that in order to get it to make black holes in the first place."

Regardless of what sounds more plausible, if a primordial black hole is found, it is by definition dark matter. Primordial black holes, like other black holes, are dark; they don't interact with other matter much except through gravity. And they have two other important

properties that would align with our current understanding of dark matter: They are cold (meaning they move slowly) and considered non-baryonic (since they formed before protons and neutrons dominated the universe). But just because primordial black holes are dark matter, that doesn't mean their existence would fully resolve the mystery. To do so, they'd have to be abundant enough to explain all the universe's missing mass. Much of the past primordial black hole research has focused on putting limits on how abundant they could be.

Consider the itty-bittiest ones. They can't account for dark matter because they're long gone. At the other extreme, the gravitational influence of the most massive primordial black holes, and the radiation given off as they feed, would've already given them away.

Various types of measurements made over several decades have suggested that for all but one mass range, primordial black holes can't be abundant enough to account for more than a small portion of dark matter. Those measurements come from hunts for what are called massive compact halo objects, or MACHOs, in the Milky Way, as well as observations of the relic light left over from the Big Bang, gamma-ray studies and more.

One effort reported in 2024 in *Nature*, for example, looked at 20 years' worth of data for the telltale magnification of distant starlight that primordial black holes or other massive objects would cause. The researchers concluded that primordial black holes from about four times the mass of the Earth up to 860 solar masses could make up no more than 10 percent of the universe's dark matter.

Based on such observations, most scientists believe that only black holes with masses somewhere around the mass of asteroids (say about 10^{20} grams, or roughly one trillionth the mass of the sun) could make up the majority of dark matter. Still, a small group of primordial black hole enthusiasts, including Carr, Clesse and others, don't think existing evidence is strong enough to rule out primordial black holes around the mass of the sun as dark matter candidates.

"Considering the idea that primordial black holes might contribute to dark matter in some way is not too much of a stretch," Kinney says. "The fact that the black holes might be all of the dark matter, that's a tougher sell for me."

It's always possible that dark matter isn't just one thing, but a mix of types of things. Ordinary matter is a mix of particles, after all. Or it could be that neither primordial black holes nor WIMPs are part of the answer. Though dark matter is a widely accepted idea, it's even possible that it doesn't exist at all, and instead scientists need to revisit ideas about how gravity works.

Theoretical physicist Marek Abramowicz of the University of Gothenburg in Sweden believes that some modifications to the theory of gravity can explain away the dark matter puzzle. He acknowledges being among a minority, but he adds: "Fortunately in physics, we are proving things either by calculation or observation, and not by voting." Abramowicz bets that primordial black holes will be ruled out as an explanation for dark matter in the next few years.

Even if primordial black holes turn out not to exist, working on them won't have been for nothing, Clesse says. The concept of Hawking radiation, for example, which is considered a scientific triumph, was born from research on the topic. Plus, he notes, all the scientists studying primordial black holes are gaining a ton of insights into the physics of the early universe.

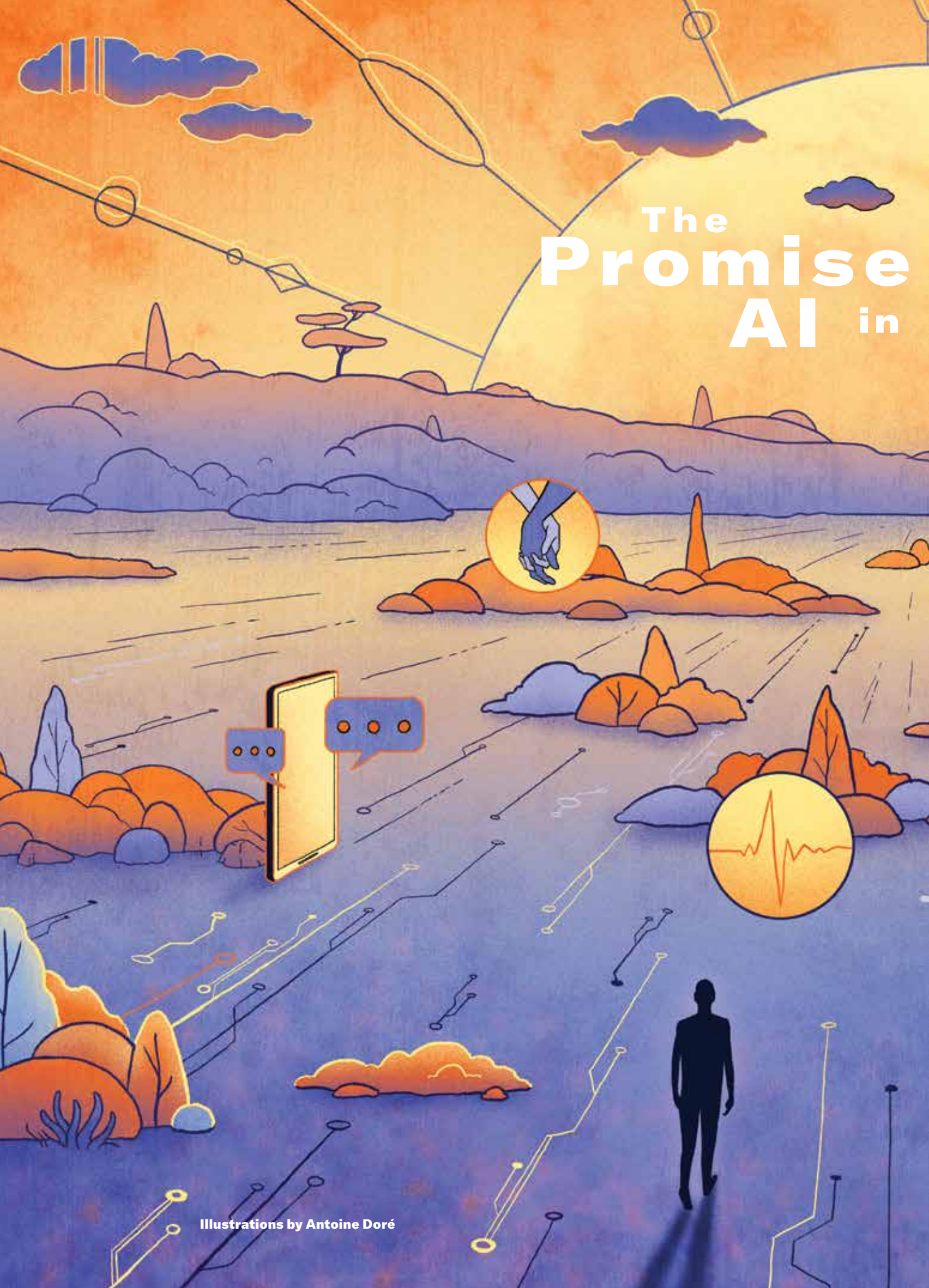
"It is not useless," Clesse says. "It is science." ✖

"FORTUNATELY IN PHYSICS, WE ARE PROVING THINGS EITHER BY CALCULATION OR OBSERVATION, AND NOT BY VOTING."

Marek Abramowicz
University of Gothenburg

Elizabeth Quill is a freelance writer and editor based in Washington, D.C., and former executive editor of *Science News*.

The Promise of AI in



Illustrations by Antoine Doré

# of Medicine

HERE'S HOW ARTIFICIAL INTELLIGENCE COULD TRANSFORM HEALTH CARE — IF SCIENTISTS CAN OVERCOME ETHICAL AND TECHNOLOGICAL CHALLENGES

By Meghan Rosen and Tina Hesman Saey

The U.S. health care system is rife with problems — as many Americans have experienced firsthand. Access to quality care is patchy, and medical costs can leave people with lifelong debt for treatments that don't always work. Frustration and anger at the system's failures were a flash point in the presidential election and may have factored in the December murder of UnitedHealthcare's CEO.

True progress in transforming health care will require solutions across the political, scientific and medical sectors. But new forms of artificial intelligence have the potential to help. Innovators are racing to deploy AI technologies to make health care more effective, equitable and humane.

AI could spot cancer early, design lifesaving drugs, assist doctors in surgery and even peer into people's futures to predict and prevent disease. The potential to help people live longer, healthier lives is vast. But physicians and researchers must overcome a legion of challenges to harness AI's potential.

How do doctors ensure that AI is accurate, accessible to all patients, free from bias, respectful of patient privacy and not used for nefarious purposes? "Will it work everywhere? Will it work for everyone?" artificial intelligence expert Rama Chellappa asked at a workshop at the Johns Hopkins University Bloomberg Center last August.

We talked with dozens of scientists and physicians about where AI in medicine stands. Again and again, researchers told us that in most medical areas, AI is still in its infancy, or toddlerhood at best. But the field is growing fast. And though AI-enabled medical devices have been in use since the 1990s, the level of interest, investment and technologies has soared in the last few years.

Some clinics now use AI to analyze mammograms and other medical images, scrutinize heartbeats and diagnose eye diseases, but there are many more opportunities for improving care. AI is unlikely to replace doctors, though. Instead, in many cases, it would be a tool used alongside human hands, hearts and minds.

The stakes are high. If efforts fail, it means billions of dollars wasted and diverted from other interventions that could have saved lives. But some researchers, clinicians and engineers say that AI's potential for making lives better is so high, we have to try.

To grasp its magnitude, we've envisioned six scenarios where patients could encounter AI. Six fictional people at six points in life, six glimpses into the galaxy of ways artificial intelligence may improve health — and a heap of hurdles researchers may face along the way.

Will AI's promise be fulfilled? Time will tell.

#01

A **digital twin** could forecast future health ←

When Miranda was born so was her digital twin, Mirabella. As Miranda grew, her twin did, too. Every aspect of the girl's life was digitized and analyzed in Mirabella's computer code.

Doctors read Miranda's genetic instruction book, or genome, from cover to cover. Cells taken from her umbilical cord were reprogrammed into stem cells and then into organoids and tissues that were doused with thousands of drugs and chemicals. Those data were fed into Mirabella so doctors could run computer simulations to see how Miranda might respond later in life to medications or accidental exposure to chemicals.

Periodic stool samples and skin swabs tracked which bacteria, viruses, fungi and other microbes lived in and on Miranda. Those data formed Mirabella's digital microbe collection and helped to forecast Miranda's gut development, skin conditions, food sensitivities and even her brain health.

As an adult, Miranda developed pancreatic cancer. Simulations run on Mirabella had predicted the possibility, and Miranda's doctors caught the tumor early. Doctors examined the tumor's genome and how the cancer cells responded to

treatment. Mirabella got a digital replica tumor. Mirabella and the virtual tumor participated in simulated clinical trials testing prospective treatments. The results helped doctors choose therapies that banished Miranda's cancer.

Thanks to aging interventions suggested by virtual experiments, Miranda enjoyed a healthy old age. When Miranda died at 102, Mirabella lived on as a perpetual clinical trial participant helping to improve other people's health.

The ability to create such complete digital twins doesn't exist, at least not yet. Building such virtual humans will require merging and analyzing wildly different types of data to craft a truly personalized representation of the patient. But researchers are working on it. Today's digital twins aren't full-body representations. Some represent a single organ, such as the heart. Those twins may help design customized medical devices, plan complex heart surgeries or understand how sex hormones may affect heart rhythms. Other still experimental twins model the immune or nervous system.

And it may never be possible to exactly replicate a person, says Roozbeh Jafari, an electrical engineer and computer scientist at MIT Lincoln Laboratory in Lexington, Mass. But digital twins could help doctors better personalize health care. Doctors "have a lot of data, but the knowledge that they apply when they take readings from you is based on the studies that have been conducted on groups, on communities. Best-case scenario, those groups would be representative of you," he says. But often data from study groups isn't representative of a patient, and even when it is, aggregated data

Digital twins should forecast health in the same way multifaceted simulations can predict the path of a hurricane.

still aren't truly personalized.

Digital twins would be more than personal data repositories, says Tina Hernandez-Boussard, a medical informatician at Stanford University. They should forecast health in the same way multifaceted simulations can predict the path of a hurricane. And they'd go beyond precision medicine based on genetic data toward precision care. That type of care considers social and environmental factors that may also influence health, factors such as living in a food desert.

That holistic view is important, says Joseph Wu, a cardiologist at Stanford. "The human mind is the major player in our human health," he says. Our mind-set determines what foods we'll eat and how much, who we socialize with and the quality of those relationships, our exercise patterns, jobs, stress levels, whether we'll get vaccinations and take our prescribed medications and so much more. DNA and stem cell data can't predict what type of society a person will be born into or which infectious diseases they might be exposed to. A true digital twin would incorporate those factors and change as a person's circumstances change, Wu says.

Such data are hard to come by for vulnerable populations, including the uninsured and people from marginalized or underserved communities. Some people may not feel comfortable sharing their data. "This notion of a virtual you, a digital you, can be scary," Hernandez-Boussard says. Others lack comprehensive data because they can't take time off work, get a ride to appointments or afford additional testing not covered by insurance.

Transparency about what data AI are using and why is also important, Hernandez-Boussard says. For instance, being Hispanic or Black is a predictor for bad outcomes of pregnancy. But race alone is the wrong data point to explain the connection. "There's not a genetic or an ancestral component to why it's linked," she says. "When we start breaking that down, we see, well, wait, it's related to nutrition. It's related to chronic hypertension. It's related to prenatal care." Explaining to clinicians and patients what information goes into these models and how they're built, she says, is important for building trust.
— Tina Hesman Saey

An **AI chemist** could discover new types of antibiotics ←

After a wrestling tournament, a high schooler named Esteban noticed that one of the scrapes on his shoulder wasn't healing. The skin was hot, red and hard. A doctor diagnosed him with a bacterial skin infection and prescribed antibiotics. The drugs didn't work.

The bacteria were the dreaded "superbug" methicillin-resistant *Staphylococcus aureus*, or MRSA, which don't respond to antibiotics commonly used against them. If the doctor couldn't find an effective drug, the bacteria might spread to the bloodstream, which could be deadly. Fortunately, an AI identified a new antibiotic that squashed the infection. Esteban soon healed, and he went back to the mats.

AI already scours databases of millions of chemical compounds for drugs that could treat a variety of illnesses, including superbug infections. Computer algorithms have been used since the 1990s to predict chemical structures and their functions, says Erin Duffy, chief of research and development for CARB-X, a global nonprofit that supports development of new antibiotics.

But tools for finding new antivirals, antifungal drugs and bacteria-killing antibiotics are sorely needed. The ranks of bacteria resistant to antibiotics are growing, and they killed more than a million people worldwide in 2019. Still, most people give the drugs little thought. "Antibiotics are considered almost like water," Duffy says. "Nobody thinks about it until you don't have them."

Many pharmaceutical companies have dropped out of the business of developing antibiotics, citing the expense of drug development and lack of profitability. But AI may streamline

discovery, development and design enough to get big drug companies back in the game, Duffy says.

In the last decade or so, deep learning, which is based on artificial neural networks, has been the AI approach of choice for many drug hunters, says Jim Collins, a bioengineer at MIT. He and colleagues recently tested large collections of chemical compounds to find ones that could kill specific types of bacteria and trained a graph neural network on that data. These tools, used for processing data that can be described in graphs, are good at recognizing connections in images and in chemical compounds. The researchers then asked the AI to comb through millions of chemicals it had never seen before and flag which ones might be good antibiotics.

AI models trained to find antibiotics against different bacteria discovered two new classes of antibiotics. Halicin — named for the rogue AI in the movie *2001: A Space Odyssey* — can kill a wide range of bacteria, Collins and colleagues reported in *Cell* in 2020. And abaucin can kill *Acinetobacter baumannii*, a pathogen that has developed resistance to many drugs, the researchers reported in *Nature Chemical Biology* in 2023.

One problem is no one really knows exactly how any given AI model decides whether a molecule would make a good antibiotic. Researchers may be hesitant to trust something they can't probe and understand. "AI today ... is a black box," says Rama Chellappa, a computer and biological engineer and interim codirector of the Data Science and AI Institute at Johns Hopkins University. "You wonder, how is it doing it? If it makes a mistake, you want to be able to explain."

Collins, who cofounded the nonprofit Phare Bio based in Boston, wants to understand the patterns AI sees. Demystifying the process may allow researchers to find and refine new classes of antibiotics. And it might reassure scientists wary of black box predictions. "Many of my colleagues are dissatisfied with simply a number without a mechanistic explanation or without a justification for that number," Collins says.

To get AI to show its work, he and colleagues made a new graph algorithm. The AI was fed data about a library of chemicals that can kill bacteria and that the AI predicted won't harm human cells. It assigned values to the arrangement of atoms and bonds inside each chemical, mapping their structures. Once it had learned what an antibiotic should look like, the researchers had the AI sift through more than 12 million compounds it had never seen before.

It found some potential antibiotics that contained ring structures already known to kill bacteria. It also discovered others with chemical structures that scientists previously didn't know had antibacterial activity, Collins and colleagues reported in *Nature* in 2024. Those include two compounds that killed *S. aureus* and *Bacillus subtilis* almost as well as the powerful antibiotic vancomycin does. In other experiments, this new class of antibiotics also killed MRSA and some other antibiotic-resistant bacteria.

AI holds promise for finding new antibiotics and predicting whether the drugs will poison people along with bacteria, but the toxicity predictor comes with ethical concerns, Collins says. "These tools potentially make it easier to identify compounds with new mechanisms of action that are toxic for which we don't have antidotes."

But he doesn't think that should limit the use of AI tools. "It's really important to have them open and widely available so that they can be used by groups around the world for good." At the same time, scientists should develop countermeasures to things that could be dreamed up by nefarious AI, as well as to natural toxins. Collins is already working on an AI for marine toxin antidotes.

— Tina Hesman Saey

Many pharmaceutical companies have dropped out of the business of developing antibiotics. But AI may get big drug companies back in the game.

#03

Chatbots could make mental health care more accessible to all ←

Emma is 21 years old and has a history of eating disorders. Her doctor has referred her for inpatient treatment for anorexia, but the estimated wait time is a month. To help bridge the gap, Emma downloads a mental health AI chatbot. But instead of helping change her troubling thoughts and behaviors about food, the chatbot gives her diet tips.

The woman in this story is fictitious, but the scenario comes straight from reality. In 2023, the National Eating Disorders Association shut down its chatbot, Tessa, after it gave inappropriate diet advice to a user.

That's one concern about using chatbots for mental health issues, says Gemma Sharp, an eating disorders researcher and clinical psychologist at the University of Queensland in Brisbane, Australia. "A chatbot is only as good as the data it's trained on," she says. If a bot never learned how to respond to certain questions, it could spit out answers that are wrong — or even dangerous.

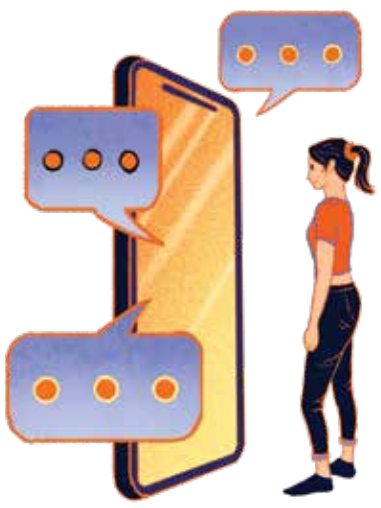
Sharp and others in the field can tick off a litany of other potential concerns with AI chatbots, including how to safeguard people's privacy, whether a chatbot can recognize an imminent crisis and provide appropriate help, and the possibility of unnatural responses to people's queries.

But these less-than-perfect helpers do have some built-in benefits. They're widely accessible, available 24/7 and may help people feel comfortable discussing sensitive information.

Users today can pick from a long list of mental health chatbot apps, with names including Woebot, Mello and Earkick. Cute avatars often bely sophisticated computation. AI chatbots use natural language processing, a type of artificial intelligence that lets computers communicate using human language. Many use large language models like ChatGPT, which scientists trained on vast stores of data, including text from web pages, articles and books on the internet.

Alternatively, researchers like Sharp can train the AI on actual conversations between therapists and patients, so it can respond in a way that feels more natural than a scripted response. Sharp's latest bot is geared toward supporting people wait-listed for eating disorder treatment. She wrapped up a clinical trial in December and plans to make the bot available early this year.

Chatbots are also being adopted in other areas of mental health. Luke MacNeill, a digital health researcher at the University of New Brunswick in Canada, tested the mental health chatbot Wysa on people with arthritis and diabetes. In a trial with 68 people, those who used Wysa for four weeks felt less anxiety and depression than before they started using the app, MacNeill and colleagues reported in *JMIR Formative Research* in 2024. Those who didn't use Wysa saw no change.



If a bot never learned how to respond to certain questions, it could spit out answers that are wrong—or even dangerous.

People liked the bot's convenience, MacNeill says, and "the fact that they could basically say anything to the chatbot and not have to worry about being judged." But Wysa's answers could get repetitive, and users sometimes felt as if the chatbot didn't understand what they were saying.

Those findings echo what computer scientist Sabirat Rubya discovered when analyzing over 6,000 user reviews of 10 mental health chatbot apps. But overall, users liked the bots' humanlike way of interacting, Rubya's team at Marquette University in Milwaukee reported in 2023.

These apps are still "far — way far — from perfect," Rubya says. The responses can feel very one-size-fits-all. For instance, most chatbots tend to overlook whether people have a physical disability, which can be frustrating for users unable to do certain exercises the bots recommend. And bots tend to speak to people in the same way, regardless of age, gender or cultural differences.

Asking users to fill out a questionnaire before chatting could help bots understand who they're talking to, Rubya says. In the future, more chatbots will likely rely on ChatGPT, which could make conversations even more humanlike. But dialog currently generated with these chatbots is prone to bias and can contain errors.

MacNeill says he wouldn't trust a chatbot with mental health emergencies. Something could go wrong. Instead, "you should probably go seek out a real mental health professional," he says.

Sharp's team trained its wait-list chatbot to send alerts to appropriate services if it detects a user having a mental health emergency. But even here, human help can offer what bots cannot. If a patient in her office is having a crisis, Sharp can drive them to the hospital. A chatbot "is never going to be able to do that," she says.

Blending human and AI services may be best. Patients could receive personal support from clinicians when needed — or when clinicians are available — and electronic support from AI bots for the times in between. "I'm glad that we have this technology," Sharp says. But "there's something quite special about human-to-human contact that I think would be very hard to replace."

— Meghan Rosen

#04

AI robots could perform surgery all on their own ←

The year is 2049. A small crew of astronauts is en route to Mars, the first time humans have embarked on a mission to the Red Planet. Deep in the shuttle's bowels, Ava, a 40-year-old engineer, has noticed a flash of pain in her lower belly. It comes and goes at first, but then worsens when she walks. Appendicitis. Without an operation, Ava could die. But there's no human surgeon on board. Instead, her life depends on artificial intelligence.

An AI-enabled robot able to perform an appendectomy with no human oversight might sound like science fiction. Especially considering what's available today. The most widely used surgical robot, called da Vinci, relies on human operators. A fully autonomous bot that slices, sutures and makes decisions all on its own "definitely is a ways away," says Axel Krieger, a medical roboticist at Johns Hopkins University. But he and other scientists and doctors are laying the groundwork for such a system.

Teams around the world are experimenting with ways AI can assist during surgery. Many of these technological assists rely on computer vision, a type of AI that interprets visual information, like the video feed of a laparoscopic surgery. Scientists recently tested one such system, SurgFlow, during an operation to remove a patient's gallbladder. SurgFlow could recognize steps in the procedure, track surgical tools, identify anatomical structures and assess whether the surgeon had completed a crucial step, Pietro Mascagni and colleagues reported in a proof-of-concept demonstration in the *British Journal of Surgery* in 2024.

In 2022, an AI-enabled surgeon stitched up a wound inside living pigs, suturing together the tubular halves of the small intestines, with no human input.

One day, such a system could be "an extra set of eyes that assist the surgeon," says Mascagni, a surgical data scientist at France's IHU-Strasbourg.

Further along is Sturgeon, now used routinely during brain surgery in the Netherlands at the Princess Máxima Center for Pediatric Oncology in Utrecht. Rather than offer a second set of eyes, Sturgeon gives surgeons a kind of superpower: the ability to rapidly riffle through a tumor's DNA and figure out its subtype. That information helps surgeons determine how much tissue needs to be carved away during surgery.

Pathologists typically identify tumor subtype by examining samples under a microscope, which can be inconclusive. Sturgeon can analyze DNA data in real time and come up with a diagnosis. The whole process takes about 90 minutes or less — fast enough for surgeons to get and use the intel during an operation, says Jeroen de Ridder, a bioinformatician at the UMC Utrecht and Oncode Institute.

In 18 out of 25 surgeries, Sturgeon offered the correct diagnosis, de Ridder's team reported in *Nature* in 2023. In the seven remaining cases, the AI abstained. That's important, de Ridder says, because making the wrong diagnosis is "the worst thing that can happen." It could lead to a surgeon cutting out too much brain tissue or leaving bits of an aggressive tumor behind.

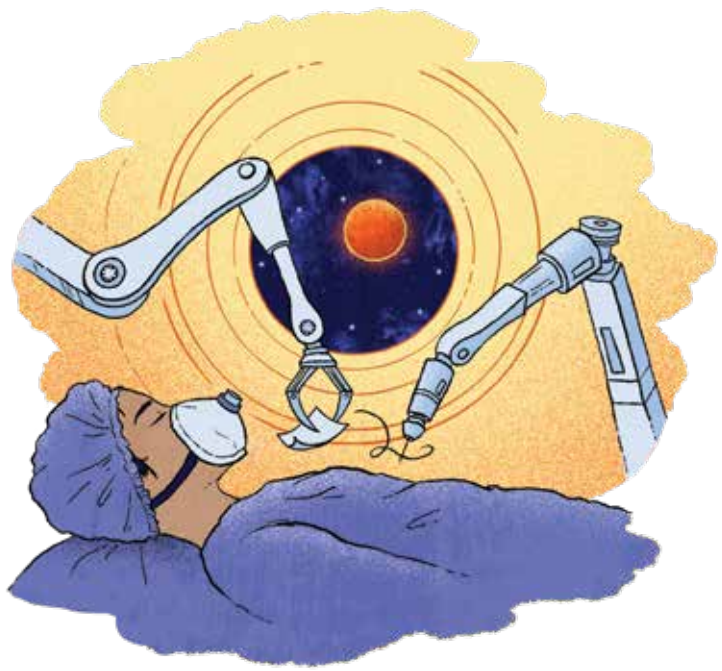
But de Ridder is open-eyed about AI's risks. When an algorithm like Sturgeon delivers an answer, it can seem black or white, with no shades of uncertainty. "It's very easy to pretend it's flawless, and it clearly is not," he says.

Those flaws are hard to pinpoint in advance, part of the problem of AI being a black box. If we don't know how a system works, it's hard to predict how it might fail, Mascagni says. Designing AI that tells us when its uncertain is one solution. Another, de Ridder says, is rigorous validation. That's needed whether the AI helps surgeons make decisions — or makes them all by itself.

Krieger has been working on one AI-enabled surgeon, the Smart Tissue Autonomous Robot, for a decade. In 2022, Krieger and colleagues reported that STAR could stitch up a wound inside living pigs, suturing together the tubular halves of the small intestines, with no human help.

Krieger's team trained STAR by breaking down surgical tasks into steps and then teaching the AI to manipulate the robot correctly in each step. But these days, he's excited about a different approach — one that combines the neural network architecture underlying ChatGPT with a type of AI training that relies on expert demonstrations. It's called imitation learning, and it lets AI models learn directly from video data. Researchers fed the model videos of the da Vinci robot lifting a piece of tissue or tying a suture knot, and the model figured out how to perform the tasks by itself, Krieger's team reported last November at the Conference on Robot Learning.

Now the team is testing its system on more complex surgical tasks. Krieger is optimistic. "I really believe it's the most promising future direction for our field," he says. Though there are already surgical procedures that have some autonomy (think LASIK for improving vision), perhaps one day Krieger's approach could enable autonomous machines that perform complicated operations — even on different planets. — *Meghan Rosen*



05

Wearables could predict imminent symptom flare-ups or heart attacks ←

Linda is in her 60s, retired and has just set out to play some morning pickleball.

As she walks to the courts, sensors woven into her clothing track body temperature, blood pressure, chemicals in her sweat and the rumblings of her stomach. The technology is nearly invisible. Linda doesn't even notice the scanner built into her bra.

Six months ago, doctors biopsied a lump in her breast. It was benign, but a subsequent scan revealed another lump nearby. Ever since, Linda has been wearing an UltraBra to monitor the new lump's growth. The bra takes regular ultrasound images of her breast and an integrated AI flags anything concerning. So far, everything has looked good. The bra has saved her time (fewer trips to the doctor's office) and given her peace of mind (if the AI spots something suspicious, she'll find out from her doctor ASAP). Now, instead of worrying about cancer, Linda can focus on her dinks.

That fictional scene (and bra) sounds like something out of a Marvel movie, like the artificial intelligence J.A.R.V.I.S. monitoring Tony Stark's vitals and diagnosing an anxiety attack. "We're nowhere near that level of technology," says Emilio Ferrara, a computer scientist at the University of Southern California in Los Angeles. But we are marching down the path to wearable devices that offer those kinds of personalized health insights.

In the not-too-distant future, AI-enabled devices could act like virtual life coaches, fishing for insights in the data flooding from a person's body and packaging them into suggestions for users, Ferrara says. One day, artificial intelligence could use an individual's real-time data to forecast how their health may change six months or a year down the road if they modify their diet, activity or sleep habits.

Scientists are experimenting with such ideas in the lab. And AI is already integrated into the Fitbits, Apple Watches and Pixel Watches that millions of people use every day. These devices can track heart rate, figure out when you're asleep or awake and recognize physical activities. "Those are all AI models," says Xin Liu, a Google research scientist based in Seattle.

AI algorithms trained on human movement data, for example, let the devices classify people's activities into categories, like running, cycling or walking. Other algorithms help separate the signal a device is trying to detect — like someone's heartbeat — from other noise that's coming in.

Liu is working on even more advanced AI-based systems. He is exploring ways to tap into the power of large language models. They "are extremely powerful architectures for learning patterns in data," Ferrara says. Liu and colleagues recently reported a version of Google's Gemini that can look through someone's wearable data and offer recommendations on sleep and fitness.

His team is also working on a system that combines Gemini with other computational tools to answer real-life open-ended queries

about health, such as, “What are my sleep patterns during different seasons?” and “Tell me about anomalies in my steps last month.” In tests with such requests, responses were accurate more than 80 percent of the time, Liu and colleagues reported last year. But the research is still in an early stage, he says.

One challenge, as with many health questions, is “there’s no single answer,” Liu says. “There are 10 different possible solutions, and they’re all reasonable.”

Other teams are exploring AI-powered wearables for medical applications. Gastroenterologist Robert Hirten is working on a model that uses data from Fitbits, Apple Watches and Oura Rings to forecast when a person’s inflammatory bowel disease may flare up. These devices collect enough data for scientists to identify inflammation in people with the disease, Hirten’s team reported at the 2024 Digestive Disease Week meeting.

An AI that monitors wearable data over time could give patients a heads-up weeks before symptoms manifest. “Instead of waiting until someone’s developing diarrhea or bleeding or pain, we can start getting ahead of it,” says Hirten, of the Icahn School of Medicine at Mount Sinai in New York City.

Hirten points out that real-world validation of any AI tool for medicine is crucial. “We need to be very certain that it’s reliable and that the information it’s going to provide to doctors or patients is accurate,” he says.

With so much health data streaming among our digital devices, privacy is another big area for caution, says Uttandaraman Sundararaj, a biomedical engineer at the University of Calgary in Canada. There’s a chance that personal health data could be hacked. It’s important to encrypt the data or otherwise protect it, Sundararaj says.

He envisions secure AI systems one day weaving together streams of wearable data to perhaps predict when a heart attack or stroke might occur. That analytical power, Sundararaj says, “gives us the ability to actually see in the future.” *—Meghan Rosen*

AI could calculate health risks from patient data ←

A retired Navy veteran caught what he thought was a cold from his great-grandson after taking the sniffling toddler to a petting zoo. The little guy bounced back, but GG-Pop kept feeling worse. He ended up in the emergency room with a cough, fever, muscle aches and difficulty breathing. A chest X-ray indicated he had pneumonia.

An AI used to analyze his blood revealed that he was at risk of developing sepsis, a life-threatening condition in which the immune system overreacts to infection. More than 1.7 million adults in the United States develop sepsis each year, and without prompt treatment, the condition can lead to tissue or organ damage, hospitalization and death. About 350,000 people who develop sepsis while hospitalized die or are sent to hospice care.

Doctors admitted GG-Pop to the hospital and gave him fluids and antibiotics. As a backup, his physicians also used another AI that sorted through his past and present electronic medical records and warned doctors that, despite treatment, the man was approaching a sepsis danger zone. The team gave him steroids to help calm his immune system. GG-Pop recovered and was soon onto other adventures with his great-grandson.

Some AI-based risk predictors for sepsis are already in clinical use or coming online soon, says Suchi Saria, an AI researcher at the Johns Hopkins Whiting School of Engineering. One, made by Chicago-based Prenosis, won authorization from the U.S. Food and Drug Administration last April. Such AI help is important because sepsis can be hard to spot. Standard tests can’t ID

the infectious microbe in most pneumonia cases. And there is no hard dividing line between sepsis and not sepsis. "Because the early signs are not as well understood, it's very easy to not notice," Saria says. "In this scenario, every hour matters."

Saria, who founded the company Bayesian Health, helped create an AI that sorts through electronic health records to detect early signs of sepsis. The AI, dubbed TREWS for Targeted Real-time Early Warning System, correctly flagged 82 percent of sepsis cases, Saria and colleagues reported in *Nature Medicine* in 2022.

Sepsis patients whose doctors promptly responded to an alert from the AI were less likely to die and had shorter hospital stays than those whose doctors took over three hours to respond.

Many sepsis predictors comb electronic health data, says Tim Sweeney, cofounder and CEO of Inflammatix. Alternatively, his company developed a machine learning blood test, under review by the FDA, that measures 29 messenger RNAs (molecules that act as blueprints to make proteins) from white blood cells to tell whether an infection is bacterial or viral and to predict whether the patient will develop sepsis in the next week.

Even if the test wins approval, the company will need to monitor its performance and update the test accordingly, Sweeney says. "It would be unethical not to have a mechanism to update the algorithm in some way with more data," he says. Government approval may depend on having the right update plan. The FDA, Health Canada and the U.K. Medicines and Healthcare products Regulatory Agency have agreed on guidelines for updating medical devices that run on machine learning or more advanced AI.

AI is not a set-it-and-forget-it proposition, says Michael Matheny, a bioinformatician at Vanderbilt University Medical Center in Nashville. Matheny and colleagues built an AI that evaluates hospitals on how well they prevent acute kidney injury — a sudden drop in the kidneys' ability to filter waste products from the blood — after cardiac catheterization, a procedure often used to find and clear blocked arteries. If U.S. hospitals consistently used good preventive strategies, about half of the 140,000 yearly acute kidney injuries could be avoided, some studies suggest.

Matheny and colleagues trained the AI and made sure it worked in various settings. But over time, "we tried to use these models, and they kept breaking," Matheny says. That's because the data AI trains on aren't always the same as the data it encounters in real life. Real-world data change, or "drift," over time, so updates are needed.

But Matheny's team wanted to avoid unnecessary overhauls. The researchers used another AI to supervise the first one and set off alarms when results seemed fishy. The value of the supervisor became obvious when the COVID-19 pandemic hit, bringing the ultimate data drift.

Before the pandemic, most cardiac catheterizations were elective outpatient procedures with lower risk of kidney injury. But then, in March 2020, "the data went crazy," Matheny says. "All elective [catheterizations] were stopped for three or four months. The patients that were brought back into the cath lab after that were very different than your typical, average patient. And so the algorithm was broken." But the supervisor flagged the issue, and the scientists corrected it.

"If we'd done a fixed strategy, we would have had a period of time where the model was just flat broken," Matheny says.

Hospitals that used the AI maintained lower than expected rates of kidney injury. But those same hospitals stopped using the system after the study. That's an indication that AI developers need to make sure their systems are useful and trustworthy and have a plan to keep them reliable, says Sharon Davis, an informatician and Matheny's colleague at Vanderbilt.

"You can make the most accurate model in the world, but if we don't deliver it well, and it doesn't provide actionable information to providers," she says, "it's not going to change anything."

— Tina Hesman Saey

Secrets of Human Navigation

Often overlooked in research studies, both environment and culture influence a person's navigation skills (nomadic Kazakhs in Mongolia are shown).

People from rural areas are better navigators than those living in cities. Scientists are just beginning to figure out why

By Sujata Gupta

On a trip to Siberia

in 2019, cognitive scientist Pablo Fernandez Velasco attended a raffle drawing with the region's Evenki reindeer herders. Prizes included a soccer ball, tea, a portable radio, a GPS navigation unit and other knickknacks. The herder who won the GPS was "crestfallen," says Velasco, of the University of York in England. "I thought [that] was one of the fancier prizes."

The herder, who had been eyeing the radio, had no use for GPS. Evenki herders navigate the vast taiga by heeding their own gait and tracking place names, paths and river flow patterns, a suite of strategies Velasco and geographer Anna Gleizer of the University of Oxford described in 2023 in the *Journal of Navigation*.

Surprisingly, how people navigate in the real world has been understudied. Instead, researchers have long devoted their time and attention to how participants, mostly from the Western world, "navigate" on a flat computer screen. Such studies scrub out the noisy environment, including tree canopies, wildlife, weather events and other occurrences, to ensure maximum control.

In treating the environment as fixed — as is common across brain and behavior research — scientists effectively operate under the assumption that humans behave the same way regardless of their cultural or environmental milieu, neuroscientist Hugo Spiers of University College London and colleagues wrote in November in *Royal Society Open Science*. Yet decades of research make clear that findings in a lab may not translate to real life.

PREVIOUS SPREAD: JEREMY WOODHOUSE/GETTY IMAGES

"You can do work in a lab in the United States and have everything go flawlessly and then take it out to the field and everything falls apart," says environmental anthropologist Helen Elizabeth Davis of Arizona State University in Tempe.

Spiers and collaborators argue that researchers should stop using reductionist approaches that eliminate environmental "noise." Adding the outside world to research is more complex. But newer tools mean researchers can bring that wider world to the lab, or vice versa, while still ensuring a high level of control.

Navigation research is moving from the 2-D world on a computer screen to a more realistic 3-D world, says Gabriella Vigliocco, a cognitive scientist at University College London and coauthor of the paper published in *Royal Society Open Science*. The work isn't just helping researchers better understand how people navigate their environment. The findings have implications for what we know about human development, public health and the human psyche.

Wilding the lab

Concerns about the pitfalls of studying human behavior in artificial lab settings date back decades. "In order to behave like scientists, [experimental psychologists] must construct situations in which our subjects are totally controlled, manipulated and measured," British psychologist Don Bannister wrote in 1966 in the *Bulletin of the British Psychological Society*. "We construct situations in which they can behave as little like human beings as possible and we do this in order to allow ourselves to make statements about the nature of their humanity."

PERKINS & WILL, UCL PEARL

Facilities such as PEARL in London (rendering shown) allow for more lifelike experimental setups.

But setting up rigorous, reproducible experiments with the messy, unpredictable environment was simply too hard, Vigliocco says. "Now the tools are there." One step in that direction is the video game *Sea Hero Quest*, in which players navigate within a boat in search of mystical sea creatures. More than 4 million people from 193 countries have played the game, which was developed for research purposes, since 2016. This trove of data has allowed researchers to study how people navigate through various environs.

Key among the findings is that people from rural areas are better at finding targets in the video game than people from urban areas, Spiers and colleagues reported in 2022. Researchers suspect that's because city dwellers would have been more likely to trek around streets laid out in a neat grid, while people in the country would have been more likely to wander and get lost along meandering rural paths.

Sea Hero Quest, though, still has participants navigate on a device, no locomotion needed, and hinges on wayfinding by sight. And the assumption that people everywhere navigate primarily by sight is simply false, Velasco and Spiers wrote last year in *Trends in Cognitive Sciences*.

Their review of the ethnographic literature unearthed myriad studies showing that navigation is multisensory. For instance, Batek people walking through the dense rainforests of Malaysia, where sight is often obscured, can navigate by birdsong. People in other parts of the world stay oriented by looking to patterns in the stars, snowdrifts, seaweed, ocean swells and numerous other cues.

Scientists are increasingly trying to bring that real-world variability to the laboratory, often with the help of virtual reality. The aim is to let participants experience sounds and smells and even walk about as they would in real life, all in a controlled environment. One such facility is the Person-Environment-Activity Research Laboratory, or PEARL, which opened at University College London in 2021 and spans 4,000 square meters. A wide variety of everyday locales, from hospital wards to transportation hubs, can be reproduced. "It's very much like a movie studio but for research," Spiers says.

Although still in their early days, facilities like PEARL could be game changers for navigation research, Spiers says. But they also come with drawbacks that could limit their widespread adoption, including a hefty price tag. "The cost to run I think is like 7,000 pounds [almost $9,000] a day," Spiers says.

Taking the lab to the wild

Work in the lab and the field each present challenges, Davis says. But in tandem, these approaches have allowed for rigorous study. "What I think has been really cool … is that there is this mash-up now between fieldwork and lab work."

Davis and colleagues have studied the daily movements and spatial cognitive ability of Tsimane people in Bolivia, ranging in age from 6 to 84, using mobile GPS units and compasses mounted on tripods. In a task measuring dead reckoning, the ability to point in the direction of a given landmark, participants aimed the compass to a distant, out-of-sight landmark. Researchers measured participants' accuracy by calculating the difference between the correct bearing and the pointed bearing.

The average error rate of Tsimane children, whose GPS units showed that they traveled an average of over 5 kilometers per day, was just over 30 degrees, Davis and anthropologist Elizabeth Cashdan of the University of Utah reported in 2019. That put their ability roughly on par with adults in Salt Lake City.

Children in the Ovatwa foraging community in Namibia, meanwhile, could point with, on average, a 20-degree error, Davis and her team reported in 2021. Most Ovatwa children attend boarding schools during the week and return home on weekends — traveling upward of 20 kilometers each way. That range seems to help Ovatwa children develop exceptional navigational skills. "Young kids were better at dead reckoning than adults in the U.S.," Davis says.

Wayfinding prowess, using environmental clues to navigate, is more than a neat trick. The comparatively poor spatial navigation abilities of people in the Western world — exacerbated, mounting research suggests, by people's deepening reliance on GPS — tend to be treated as the norm, Davis says. Yet her work with the Tsimane and other foraging communities suggests such skills are highly malleable. Tsimane children who travel more widely and along curvier routes have better dead reckoning skills than Tsimane children who explore less.

Researchers comparing older teens from the Faroe Islands of Denmark, where kids typically have the freedom to roam without adult supervision, with students in the United States, where roaming distance has declined in recent years, found a related disparity in navigation skills. People can navigate in two ways: by following a specific route, where they know when to turn left or right, or by gauging cardinal directions. U.S. participants more often relied on route strategies than the Faroese participants. Shrinking opportunity to roam may hurt people's lifelong spatial navigation abilities.

Similarly, while Western adults tend to show worsening dead reckoning ability as they age, Tsimane adults show no comparable decline, Davis and her team reported in 2022. Tsimane adults continue traveling long distances through their communities' dense forests and snaking paths well into old age, averaging over 5 kilometers per day.

Work has shown that navigation ability declines with age. Spatial disorientation is also often one of the first signs of dementia. But a gradual loss of navigation ability may not be inevitable. Instead, a sedentary lifestyle, often brought on by living in car-based communities where walking is difficult, might be partly to blame, Davis and colleagues say.

Additional support for this idea comes from a closer look at Tsimane women. They have increased errors in navigation tests in their 20s and 30s, the researchers found. The average Tsimane woman has nine children, so increased child-rearing responsibilities and thus lessened mobility probably underpins that decline, Davis' team notes. Women's pointing abilities begin to improve around age 40 and return to baseline by the time they hit 50 or so.

"Even sedentary individuals may be able to enhance their navigational abilities by increasing mobility," Davis and colleagues conclude.

The ability to roam may, in turn, impact one's outlook on life. Evenki herders and hunters detest planning routes. They see space as laden with possibility, a sweeping canvas that should not be sullied by prescribed paths. The Western fear of getting lost is incomprehensible to the Evenki hunter, Velasco and Gleizer reported in their recent study: "When we asked an Evenki hunter what he would do if lost, he looked at us confused and said, 'Well, I would just find my way.'" ✖

Is GPS destroying navigation skills?

Perhaps you've heard a story like this: A driver faithfully follows GPS directions — off a cliff, into a lake or around and around in circles. Amid a rising reliance on GPS, such anecdotes have led experts to wonder whether regular use of the technology harms people's ability to navigate. One answer comes from a group of researchers in Italy. Yes, the technology appears to impair a sense of direction and environmental knowledge, the researchers reported last year in the *Journal of Environmental Psychology*. But the correlation is weak. And in the case of wayfinding, which involves following and planning routes, performance seems unaffected. But this isn't the final answer. The conclusions come from a meta-analysis that included just 18 studies, and the researchers note the need for more standardized measurements in this area of study. And one understudied factor is what role variation in people's innate abilities plays in the link between GPS and an individual's navigation skills.
— Erin Wayman

Fill Your Vault with U.S. Silver Eagles!

Actual size is 40.6 mm

Not only are these coins one full Troy ounce of 99.9% precious silver, they're also beautiful, featuring Adolph A. Weinman's iconic "Walking Liberty" design and the fifth year of Emily Damstra's stunning Bald Eagle. These patriotic designs are pure America—matching the silver purity that makes these collectible bullion coins desired by millions of people the world over. Struck by the U.S. Mint in American silver, these one-ounce 99.9% fine silver coins are eagerly anticipated each year. Take advantage of our special offer and save $2.50 off our regular price.

American Silver Eagles Are Among the World's Most Popular Silver Coins

Established in 1986, American Silver Eagles were designed to provide collectors with a trusted source of silver and to promote the U.S. Mint's silver coinage. Over the decades, it has become one of the most popular, prized and best-selling silver coins in the world, symbolizing American craftsmanship and a backed by the United States Government.

Each year the annual limited supply has historically been met with high demand, with some back-dated Silver Eagles being scarce and hard to find.

A Special Way for You to Stock Up on Precious Silver

While no one can predict the future value of silver in an uncertain economy, many Americans are rushing to get their hands on as much silver as possible, putting it away for themselves and their loved ones. You'll enjoy owning these Silver Eagles. They're tangible. They feel good when you hold them, You'll relish the designs and thinking about all they represent. These 2025 American Silver Eagles make appreciated gifts for birthdays, anniversaries, and graduations, creating a legacy sure to be cherished for a lifetime.

Order More and SAVE

You can save $2.50 off our regular price when you buy now. There is a limit of 40 coins per customer, which means with this special offer, you can save up to $100.

Hurry. Secure Yours Now!

Call right now to secure your U.S. Mint 2025 American Silver Eagle struck in highly pure 99.9% silver. You'll be glad you did!

2025 $1 1-oz Silver Eagle
SPECIAL OFFER
Save $2.50 per coin—that's over 5% off!

BUY MORE SAVE MORE!

SAVE UP TO $100
Limit of 40 coins per customer

FREE Type I Silver Eagle with every order over $299
(A $47.95 value!)

FREE SHIPPING over $99!
Limited time only. Product total over $99 before taxes (if any). Standard domestic shipping only. Not valid on previous purchases.

For fastest service call today toll-free

1-888-201-7144

Offer Code SRE502-05
Please mention this code when you call.

SPECIAL CALL-IN ONLY OFFER

GovMint ▪ 1300 Corporate Center Curve, Dept. SRE502-05, Eagan, MN 55121

Curiosities

FPG/HULTON ARCHIVE/GETTY IMAGES

TECHNOLOGY

THE LONG, STRANGE TRIP TO MAKE CARS FLY

● The concept of the flying car dates back more than a century. Several prototypes appeared throughout the 1900s, and some even took to the skies. In 1947, the Convair Model 118 ConvAirCar (shown above) embarked on an ill-fated test flight in California. An emergency landing damaged one of the wings and demolished the car, along with any hope that this airborne automobile would revolutionize travel. Some successors, such as the Aerocar line of aircraft, had better luck. But mass-produced flying cars have yet to take off (see Page 66). — *Cassie Martin*

HOW CHILD SOLDIERS HEAL AFTER THE TRAUMA OF WAR

By Elizabeth Quill

SHADOWS INTO LIGHT | *Theresa S. Betancourt*
Harvard Univ. | $35

For more than two decades, Theresa S. Betancourt has followed the lives of children (now adults) who returned home after being forced to fight in the civil war that ravaged Sierra Leone from 1991 to 2002. Thousands of children unwillingly participated in the violent conflict as soldiers, spies and laborers. Many took part in attacks on their own neighbors and relatives, many faced sexual violence, many witnessed unspeakable atrocities. In her new book, Betancourt, director of Boston College's Research Program on Children and Adversity, shares what she has learned about the factors that have helped some of these people recover and even thrive.

Shadows into Light is both heart-wrenching and heartening. It tells the stories of the trauma these children faced, their reunion with family, their reintegration into their communities, and their ongoing struggles and healing. Sahr, for example, who was kidnapped as a toddler and spent four years with rebel fighters, returned to rejection and isolation. He was teased and criticized by community members, and his tendency to lose his temper reinforced people's suspicions that he was dangerous and perhaps permanently damaged by his experience. Then there is Isatu, age 12 when rebels attacked her village, capturing her and her sister. Isatu's experience upon her return was much different. Initial support from her family and community, combined with her own motivation, led to more help from an extended network. "Isatu's perseverance generated additional ripples of support, soon to become a self-fulfilling virtuous cycle," Betancourt writes. Isatu is now a doctor.

With great care, Betancourt weaves together portraits of the people and the country with her own backstory and research effort. One research finding is the importance of family, community, and societal and cultural influences on a person's trajectory — what psychologist Urie Bronfenbrenner described as "social ecology." Betancourt and her team were surprised that girls tended to face more stigma and have poorer mental health immediately after the conflict than boys, but the girls did better in the long-term. Some may have benefited over time from "the ties that bind women and girls to one another."

Betancourt puts her own learnings in context with the existing literature on childhood development and trauma. Readers learn about research on intergenerational trauma in Holocaust survivors, studies of children leaving Romanian orphanages and the healing power of narrative storytelling

The book avoids sentimentality. There are horrors, but the aim is never to horrify. There are triumphs, but they don't fit the superhero trope.

among the Lost Boys of Sudan. She also addresses head on the controversy around the concept of post-traumatic growth, essentially the idea that suffering can beget success.

Betancourt has a clear passion for the topic and people. Yet the book avoids sentimentality. There are horrors, but the aim is never to horrify. There are triumphs, but they don't fit the superhero trope or any other simplification. If anything, Betancourt's writing is measured and pragmatic. "Everything we have learned about resilience in the face of extreme risk," she writes, "has helped us to develop and test group mental health interventions for youth, as well as family-based preventive interventions to break cycles of violence across generations." ✖

A PODCAST REASSESSES OUR RELATIONSHIP WITH WILDFIRE

By Nikk Ogasa

UNITED BY FIRE | *Denver Museum of Nature & Science*

For hundreds of millions of years, wildfires were directed solely by the weather, vegetation and terrain. But in the last century in the United States, people have sought to suppress even those beneficial fires that would otherwise clear out dead vegetation, which can fuel wildfires, and stimulate new growth. Now, catastrophic megafires erupt each year, and in some places, climate change has extended the fire season. Clearly something has to give — our society must change its relationship with fire.

This dilemma smolders at the heart of *United by Fire* — the fourth season of the podcast series *Laws of Notion*, produced by the Denver Museum of Nature & Science's Institute for Science & Policy. A gripping and educational listening experience, *United by Fire* intertwines stories of those who lived through the 2020 Cameron Peak and East Troublesome fires — two of the largest blazes in Colorado history — with contextual threads of history and science.

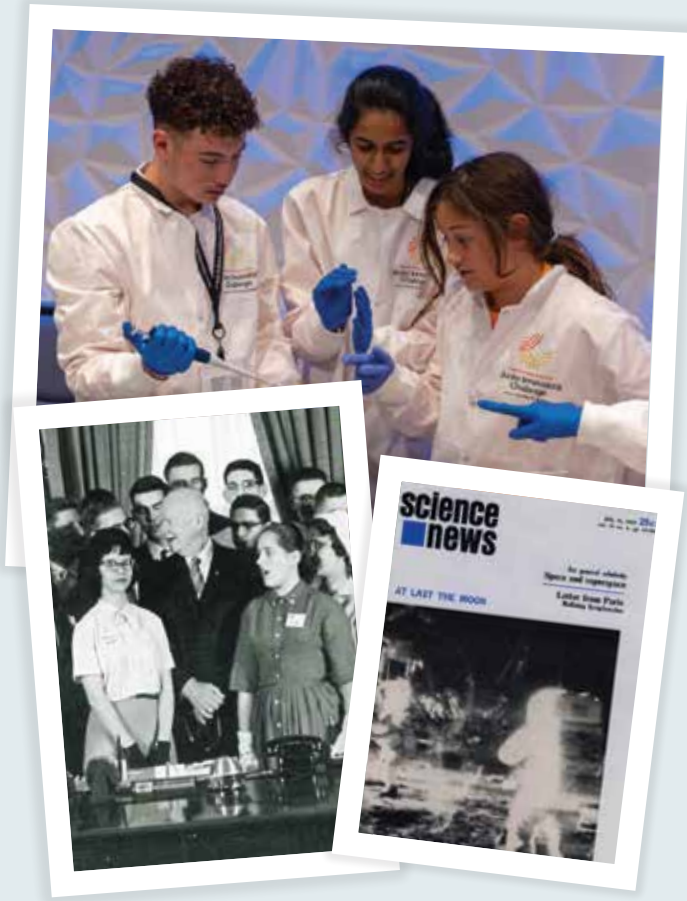
Each episode explores an aspect of the fires, from the impact on water quality to the challenges of rebuilding in the aftermath. Emotional recollections from residents, fire ecologists, firefighters and others deliver hard truths about the uncontrollable. Living in the mountains has its risks, says David Wolf, battalion chief of the City of Golden Fire Department. "I can't guarantee that your home will be safe if you build up here."

The series could have included more Indigenous voices. Having coexisted with wildfires and having also used fire to manage the land for millennia, Indigenous people have invaluable knowledge. Nonetheless, *United by Fire* is a thoroughly reported and thoughtful primer on the United States' fraught relationship with fire. As wildfires change, so must we. ✖

MILEHIGHTRAVELER/ISTOCK/GETTY IMAGES PLUS

↑ Flames devoured pines and other vegetation in the Arapaho National Forest and Rocky Mountain National Park during the East Troublesome Fire in 2020. The blaze, the subject of a new podcast, is the second largest wildfire in Colorado history.

Championing Science for More than 100 Years



From top: Students compete in the Society's middle school STEM competition in 2024; Science Talent Search Finalists meet with President Dwight Eisenhower in 1959; the July 26, 1969 issue of Science News featured the moon landing.

Publishing magnate E.W. Scripps and zoologist William Ritter founded Science Service, today called Society for Science, in 1921, believing that "a healthy democracy depended on a public understanding of science." Their aim was to fight misinformation and disinformation in science through journalism – and Science News was born. For over a century, Society for Science has published objective science journalism, advised government agencies, cultivated the nation's top STEM talent and ignited a passion for science in generations of students.

AFTER ESTABLISHING SCIENCE NEWS, the Society created its first science research competition for students in 1942, the Science Talent Search (STS), which began as an initiative to bolster national defense by identifying the nation's most promising young minds. STS was first sponsored by Westinghouse, then by Intel and today by Regeneron. In 1950, the Society launched the National Science Fair, now known as the Regeneron International Science and Engineering Fair, which has become the world's largest STEM competition for high school students.

In 1999, the Society launched what would become the nation's premier middle school STEM competition, today called the Thermo Fisher Scientific Junior Innovators Challenge. Then in 2003, the Society launched Science News Explores, our magazine for young people, to inspire the next generation through accessible journalism.

The Society's competitions have nurtured world-renowned scientists, including 15 Nobel Laureates, two Fields Medalists, 27 MacArthur Fellows and countless innovators, inventors and entrepreneurs.

The Society is also committed to making science accessible to everyone, everywhere. We support young people on their STEM journeys by distributing grants to educators and innovative community-based STEM organizations, delivering Science News to nearly 6,000 schools, providing professional development opportunities to teachers and supplying scientific equipment to classrooms.

We are proud to partner with corporate, philanthropic and public institutions, including the Department of Defense, NASA and USAID. Science is the key to unlocking solutions to our greatest challenges. Together, we will create a future defined by an informed, educated and inspired public.

SOCIETY FOR SCIENCE

LEARN MORE: WWW.SOCIETYFORSCIENCE.ORG

Society for Science is a nonprofit organization best known for our award-winning journalism, world-class STEM competitions and suite of Outreach & Equity programming activities. For more than a century, our mission has been to promote the understanding and appreciation of science and the vital role it plays in human advancement: to inform, educate, and inspire.

VOL. 207 NO. 01 | JANUARY 2025

It's all relative

● *Betelgeuse may have a sun-sized companion star that orbits it about once every 2,100 days, astronomy writer Lisa Grossman reported in "Betelgeuse's invisible buddy."*

The story describes Betelgeuse as "the red giant that marks Orion's left shoulder." Reader Chris Jespersen wrote: "I often see Betelgeuse on Orion's right shoulder.... Am I mistaken?"

This is actually a matter of perspective, Grossman says. The ancient Greeks thought the Orion constellation resembled the figure of a hunter. Many people agree that this celestial hunter faces Earth. Betelgeuse represents what's considered the hunter's right shoulder, which is on the figure's left from the perspective of Earth, she says.

Sharing reflections

● *The 2024 Nobel Prizes honored research in biology and AI, including foundational work on artificial neural networks, which enable machine learning and other tech advances,* Science News *staff reported in "2024 Nobel Prize winners announced."*

Reader Jeremy Brown pondered the rise of AI. "Artificial neural networks may scare off some people, but it captivates the rest of us who see its nearly unlimited potential for unlocking the secrets of the universe and ourselves," Brown wrote. "We have a long way to go before a neural network could surpass our own [brain]," Brown continued, but the technology could help humans meet various needs in medicine and research (see Page 42).

"Artificial neural networks may scare off some people, but it captivates the rest of us who see its nearly unlimited potential."

November 2, 2024

November 16, 2024

Brown also expressed general appreciation for *Science News*: "Thank you so very much for bringing science to us who are incarcerated. This publication aids us, and we have formed informal study groups on the sciences in general in my living quarters," Brown wrote. "I live in a dormitory setting and am a facilitator and a squad leader for our educational program called A New Direction Movement. This publication has opened new neural pathways in my dendrites and is keeping us all up-to-date on the latest physics, astronomy, biology, archaeology!"

What about waste?

● *Tech companies including Google and Amazon are investing in small nuclear reactors for their energy needs. The shift may help propel the proliferation of nuclear power, touted as a source of reliable "green" energy, senior physics writer Emily Conover reported in "Nuclear energy entices Big Tech."*

Reader Susanne Kjemtrup-Lovelace wondered how the waste produced by these small reactors will be managed.

Nuclear waste disposal is still a thorny issue. For now, spent nuclear fuel is mostly stored in dry casks on the sites of nuclear power plants. After decades of local opposition halted plans for a storage facility at Yucca Mountain in Nevada in 2010, the U.S. government made little progress toward a solution for years.

But now, the government is working toward an interim storage facility that would consolidate waste until a long-term geologic repository is established. Since 2015, the U.S. Department of Energy has been developing a "consent-based" process, focused on finding a community willing to accept a facility. "It would be very hard to start building advanced reactors in a universe where the government was still doing nothing," says nuclear engineer Kathryn Huff of the University of Illinois Urbana-Champaign.

WHERE ARE THE FLYING CARS?

BY HELEN BRADSHAW

The year is 2015. "Mad scientist" Doc Brown has just brought wide-eyed teenager Marty McFly to the future in style: aboard a flying DeLorean. Although the time travelers are out of place, their mode of transportation is not. Cars zip by in the sky. We're now 10 years past the future envisioned in *Back to the Future Part II*, and still no flying cars. But aerial automobiles, a mainstay of sci-fi and fantasy stories since the early 1900s, may soon be reality. The technology to make flying cars already exists, says Xiaosong Du, an aerospace engineer at Missouri University of Science and Technology in Rolla. And some companies have already flown prototypes.

A real-world flying car would most likely be a cross between an airplane and a helicopter. Airplanes need runways, so it would be more practical for a flying car to take off vertically like a helicopter. Rotating blades would generate lift to bring the vehicle off the ground. "Once it's completed takeoff," Du says, "you can fly like a normal airplane." Airplane wings would rotate out from the body of the craft, allowing for flight with less air resistance than a helicopter experience.

Another option is to attach propellers to a flying car's wings. At first, the wings would be tilted upward, so that the propellers could lift the vehicle. Once the car takes off, the wings would tilt to lay flat, like those on an airplane, says aerospace engineer Pat Anderson, former director of the Eagle Flight Research Center at Embry-Riddle Aeronautical University in Daytona Beach, Fla. "It's like a Transformer."

Vehicles with rotating blades and propellers don't sound much like the flying cars of science fiction. They don't even sound much like cars. Instead, these vehicles would resemble winged military choppers like those in the *Avatar* movies, Anderson says. Or real-world winged choppers like the U.S. military's V-22 Osprey.

One of the biggest barriers to people commuting in flying cars is expense. The U.S. company Alef Aeronautics, for instance, plans to sell personal cars that can drive on roads and take off into the skies.

ILLUSTRATION BY KATHLEEN FU

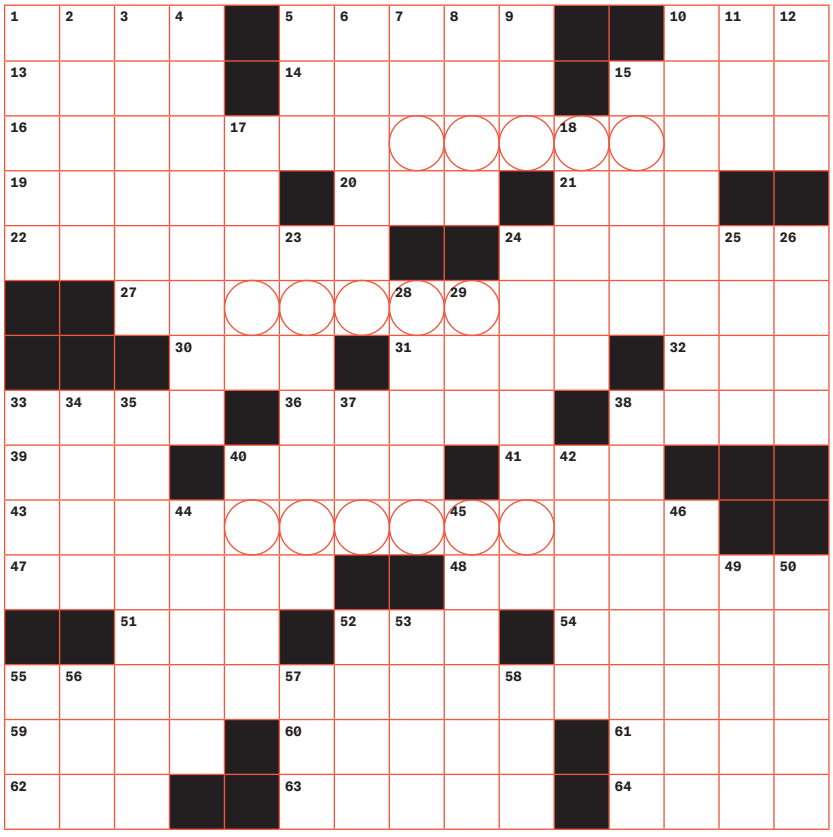
These cars look and function similarly to those in many sci-fi movies but come with a steep price tag. When they go into production sometime this year, the cars are expected to cost about $300,000 each.

For people with more modest bank accounts, a rideshare service for flying cars — something like Uber or Lyft for the skies — may be more likely, Anderson says.

Flying Ubers may become common in 10 or 20 years, Anderson predicts. First, aircraft need to be tested over and over for safety. The U.S. Federal Aviation Administration also needs to create regulations for flying cars. In October, the FAA brought the industry closer to liftoff by announcing rules on operating and piloting air taxis.

Those regulations pertain to a type of electric vehicle. Because of sustainability, "people are kind of in love with batteries," Anderson says. But batteries are heavy, and — like those in electric cars — have a limited range.

Flying takes a lot of power, especially during takeoff. Current rechargeable lithium-ion batteries would power a flying-car ride for only 20 to 30 minutes, Du says. And while a car that runs out of charge can simply pull over, a flying car would fall out of the sky. So Du and many other researchers are trying to improve battery efficiency before flying taxis take off. ✖



TWISTING WORDS

BY SHANNON RAPP

Rapp is a research administrator and former research biologist who has created puzzles for the *New York Times*, *Los Angeles Times* and other publications. This puzzle was edited by Sid Sivakumar, a puzzle constructor who is an M.D./Ph.D. student in biomedical engineering and neuroscience.

ACROSS

1 Sound of a shocked reaction
5 Hired personnel
10 "You'll ___ for this!"
13 Microbiology lab gel
14 Phone answerer's greeting
15 Lion's flowing locks
16 They make illustrations on streets (*... huh, that's not the same eye color!*)
19 Act theatrically
20 Goofy or Pluto
21 Ctrl-___-Del
22 Complex of fast-moving thunderstorms
24 Ancient Greek city-state whose military used text encryption
27 Alternative professional input (*... whoa, wasn't expecting that amino acid!*)
30 Grammy-winning rapper Lil ___ X
31 Rotten egg emanation
32 Period of time aptly hidden in "paleontology"
33 Sci-fi saucers
36 Jenga structure
38 Stop on a cruise
39 ___ center (home to an intramural sports team, maybe)
40 Scuba journey
41 Element #50
43 "The House of the Spirits" author (*... wait, those nucleotides are different!*)
47 Feature of a skunk's coat
48 Numbers to be summed
51 Oath when joining a union?
52 Succumb to gravity
54 First section of a research report, familiarly
55 Alteration in a DNA sequence ... or a hint to unscrambling each set of circled squares
59 "Taylor Swift: The ___ Tour" (2023 concert film)
60 Bugs Bunny and Dora the Explorer, for two
61 Active Italian volcano
62 "The Marvelous ___ Maisel"
63 Crossbody bag part
64 "Stranger Things" actress Natalia

DOWN

1 Hung open
2 Best-effort athletic performance
3 Takes time to enjoy
4 Many middle schoolers, agewise
5 Word on a pronoun pin
6 Muscle-to-bone connector
7 Vocal range below soprano
8 Item carried at an Olympic ceremony
9 "I'm all ___ it!"
10 Bear claws, etc.
11 Insect in the Formicidae family
12 "Sure thing!"
15 Italian city near the Alps
17 Holy city in Saudi Arabia
18 Mammal with a prehensile trunk
23 Like environments with conditions unfavorable for life
24 Wore
25 Pipette or screwdriver
26 Developmental biologist McLaren whose work paved the way for in vitro fertilization
28 Wooden part in an IKEA package
29 Dedicated poem
33 "Exodus" author Leon
34 End of Oktober?
35 Ovoid flute relatives
37 Egg cells
38 Started a new paragraph, perhaps
40 Structure in a model train set
42 Country where chess originated
44 Waits patiently
45 ___ Beach (city in Orange County, California)
46 Being
49 Bee that lacks a stinger
50 Echolocation technology
52 Resident of Glasgow or Edinburgh
53 Love, in Spanish
55 Stone that might exhibit double refraction
56 Mess up
57 "___ about time!"
58 Recipe measurement (Abbr.)

Visit **sciencenews.org/puzzle-answers** for answers. We will publish science-themed crossword puzzles and math puzzles on alternating months. We'd love to hear your thoughts at **puzzles@sciencenews.org**.

Jewelry That Dances With Her Every Step

DANIEL STEIGER

'DANCING' JEWELRY PENDANT & EARRINGS COLLECTION

'Dancing' Center Stone

Solid 925 Sterling Silver

Available in Lavish Gold or Platinum Finish

Diamondeau® - Flawless Simulated Diamonds

Carat Weight: 0.8CT

Complimentary 22" Chain

Perfect Gift for Her

*Set Also Available in Platinum

From Only

$79

With Code:

SN5KDD

Beautiful, radiant, captivating—she deserves jewelry as extraordinary as she is. Introducing the Dancing Diamonds Jewelry Collection, featuring a revolutionary design that takes elegance to a whole new level. Each piece is crafted with a patented setting that allows the center stone to move freely, creating a mesmerizing shimmer of fire and brilliance with every motion.

At the heart of each piece is the Diamondeau®, a flawless simulated diamond, meticulously handset at precise angles to ensure continuous movement and unparalleled sparkle. This innovative design brings timeless beauty to life, making every moment unforgettable. The Dancing Diamonds Jewelry Collection is the perfect way to say, "You're one of a kind."

'Dancing' Jewelry Pendant - ~~$299~~ $79 plus S&H

'Dancing' Jewelry Earrings - ~~$299~~ $79 plus S&H

Complete 'Dancing' Pendant & Earrings Collection - ~~$598~~ *Now Only $149*

(EXTRA SAVING WHEN PURCHASING THE SET)

CALL NOW TOLL FREE 24/7 ON: 1-800 733 8463

Please quote SN5KDD or order online at: www.timepiecesusa.com/SN5KDD

PAY BY CHECK: Timepieces International Inc. 10701 NW 140th Street, Suite 1, Hialeah Gardens, FL 33018

Power and protect life online

Every moment, billions of people, all over the world, are using the internet to shop, play games, look after finances, learn remotely, share videos, and so much more. They may not know it, but Akamai is there — we power and protect life online by solving the toughest challenges, together. The world's most innovative companies trust Akamai to build, secure, and accelerate their apps and digital experiences.

Learn more at **Akamai.com**