SCIENCENEWS.ORG
VOL. 207 NO. 6
JUNE 2025

ScienceNews

THE QUANTUM FUTURE

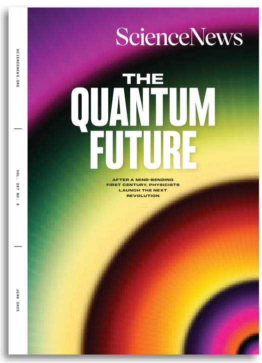
AFTER A MIND-BENDING FIRST CENTURY, PHYSICISTS LAUNCH THE NEXT REVOLUTION

Contents

VOL. 207 NO. 06 | JUNE 2025

CHRISTOPHER AUGER-DOMINGUEZ

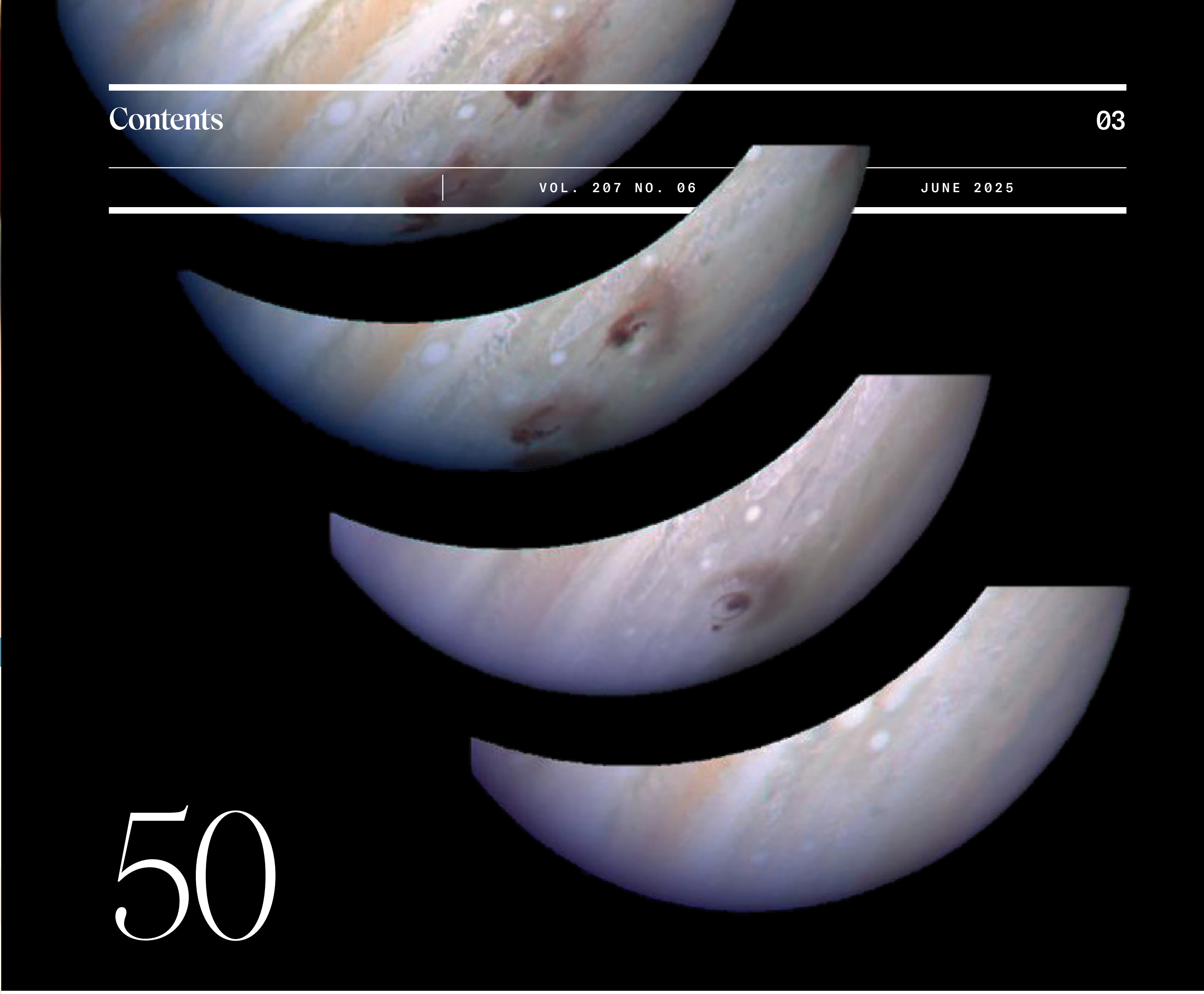
News



On the Cover

Illustration by La Boca

VOL. 207 NO. 06 | JUNE 2025


50

Features

Curiosities


64

FROM TOP: NASA, R. EVANS, J. TRAUGER, H. HAMMEL AND THE HST COMET SCIENCE TEAM; PETER CROWTHER

The long and short of science

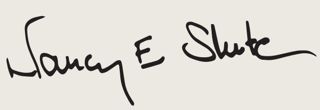
Scientists seek out what's new — discovery is at the core of science, and scientific journals and news organizations often focus on the latest breakthroughs. But getting to an innovation is usually a long game. In this issue, we note the 100th anniversary of the framework of quantum mechanics, the theory that describes how physics at very small scales behaves very differently from the classical world we live in.

The quantum world is more like a fun house with seriously warped mirrors: Quantum effects can connect two objects at great distances, or make it possible for a hypothetical cat to be both alive and dead at the same time. Over the last century, that quantum revolution has led to many innovations, including semiconductor technologies, MRIs, lasers and the atomic clocks that make GPS navigation possible.

The next quantum revolution is already under way, senior physics writer Emily Conover reports (Page 34). Physicists are developing new ways to manipulate quantum weirdness for advances in computing and timekeeping — and even to discover if birds use a quantum compass to detect magnetic fields.

We also note another significant scientific milestone: the 35th anniversary of the Hubble Space Telescope (Page 50). This spacecraft has observed more than 100 million objects since its launch, freelance journalist Katherine Kornei reports, and researchers have written more than 21,000 studies using its data. (Kornei, a former astronomer, wrote two of them.) Because Hubble captures high-resolution images in ultraviolet light, which neither terrestrial telescopes nor the James Webb Space Telescope can do, the telescope still excels at recording some of the hottest objects in space, such as massive stars.

Closer to home, we revisit the fraught history of studying whether nonhuman primates can use language, a skill long presumed to be unique to humans. March marked the passing of Kanzi, a bonobo who became famous as one of a handful of apes used in research. Kanzi mastered symbols to communicate with humans, and even learned to play a version of Minecraft. But such feats came with losses. As managing editor Erin Wayman notes in our new history column (Page 66), researchers also learned that apes have rich inner lives, and that by isolating the animals from their community, they forced these intelligent, social creatures to live in a strange limbo between the human and ape worlds.



Nancy Shute
Editor in Chief
nshute@sciencenews.org

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

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. 06 | JUNE 2025

EMILY CONOVER

SENIOR PHYSICS WRITER

● SINCE THE EMERGENCE OF QUANTUM MECHANICS a century ago, this scientific framework has revolutionized how scientists perceive matter — and the universe. In this issue, Emily Conover presents the status of modern-day quantum science, as told by five physicists working in quantum gravity, quantum thermodynamics, quantum biology and more (Page 34). “If you force me to pick a favorite, I’d say it’s quantum gravity,” Conover says, “because understanding it could transform physics.” A particle physicist by training, Conover says her favorite quantum process involves neutrinos. These subatomic particles oscillate — or change from one variety to another — as they travel due to quantum superposition that can take place over hundreds of kilometers. We don’t tend to think quantum effects are relevant at such large distances, Conover says.

Sujata Gupta
People can preserve their fertility by storing sperm, eggs and embryos in liquid nitrogen. Less known is that researchers have long sought to do something similar for plants, creating backups should species go extinct, social sciences writer Sujata Gupta reports (Page 42). Watching the cryopreservation process reminded her of cooking show contestants’ use of liquid nitrogen to flash-freeze ice cream — though the process for prepping plants is “very, very different,” she says. “The chefs have it easy.”

Katherine Kornei
The Hubble Space Telescope launched 35 years ago and has been expanding our understanding of the universe since. For this issue, freelance journalist Katherine Kornei tells the famous telescope’s history in both words and stunning images (Page 50). Kornei’s connection to Hubble runs deep: She used its data for her astronomy Ph.D. “While the James Webb Space Telescope and others are incredible, it’s Hubble that I’ll always remember for inspiring me to study science,” Kornei says.

Susan Milius
Given sharks’ villainous reputation due to movies like *Jaws*, you might assume the sound that these predators make would be an underwater version of a roar — if they were to make sounds at all. So when life sciences writer Susan Milius heard a recording of subtle clicks from a shark (Page 22), she was surprised. “Once I thought about it, though, I was glad,” Milius says. “It’s more fun that real sharks do something really different from what I as a human expect.”

Erin Wayman
Our new history column debuts with the story of Kanzi, the bonobo famous for communicating with humans by pointing at symbols (Page 66). “When I heard Kanzi had passed away, it felt like the end of an era, in terms of the classic ape-language studies,” says managing editor Erin Wayman. Thanks to *Science News*’ new monthly format, “we now have more space to delve into science history, whether that’s exploring the development of a field or how science of the past might inform us of contemporary issues.”

RIGHT, SECOND FROM THE TOP: K. KORNEI; REST: SOCIETY FOR SCIENCE

ANIMALS

A HISTORY OF A BIRD NEST, IN PLASTIC ‘FOSSILS’

By Darren Incorvaia

● **One man’s trash** is a common coot’s treasure. In Amsterdam, the birds have been constructing nests out of food wrappers, masks and other plastic waste for at least 30 years, researchers report in *Ecology*. The revelation shows not only how much plastic litters the environment but also the power of using human-made products to learn about the natural world.

PHOTOS BY AUKE-FLORIAN HIEMSTRA

Date labels on waste packaging in common coot nests let researchers build a layer-by-layer history of each nest. Here is a timeline of one of the nests (below), along with some packaging labels.

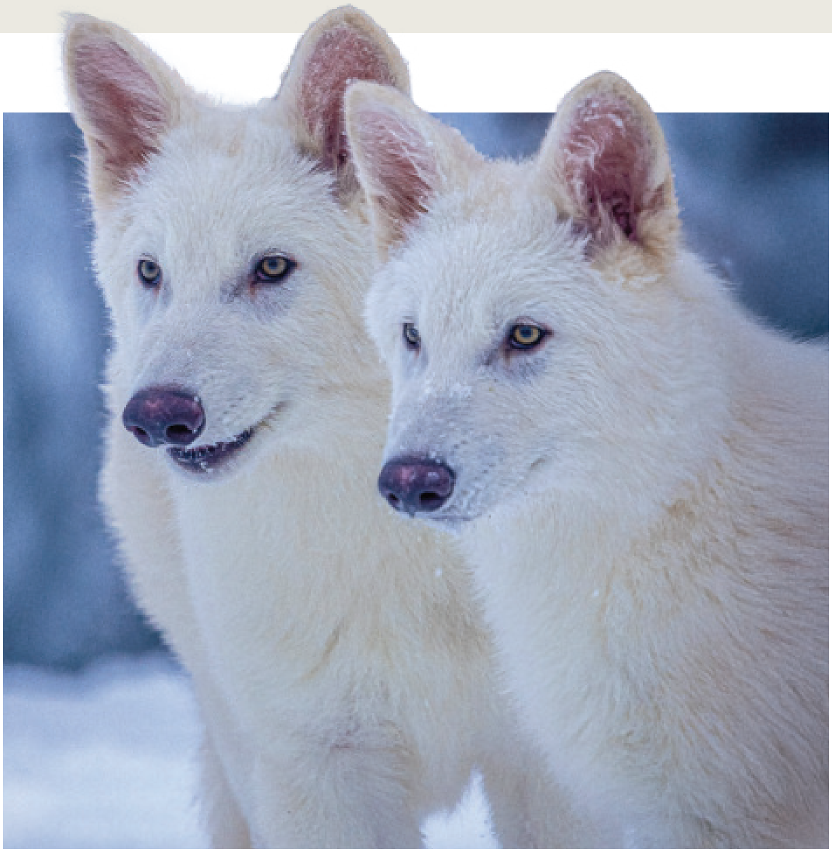
Coots added face masks to their nests during the COVID-19 pandemic. This nest had 14 masks as well as four loose elastic bands from such masks.

Coots (*Fulica atra*) reuse their nests and build on them over time. These two birds were this nest's most recent architects as of 2021.

News

What makes this shark tick—literally? Turn to Page 22 to find out.

PAUL CAIGER/UNIV. OF AUCKLAND



ANIMALS

The story of dire wolves goes beyond de-extinction

By Meghan Rosen

● **Their names are Romulus, Remus and Khaleesi**, and they're the first dire wolves to walk the Earth in over 10,000 years — or so one biotech company and a flurry of recent headlines say.

Colossal Biosciences announced in April the "world's first de-extinction": the births of three dire wolves, extinct animals that lived during the ice ages of the Pleistocene. The pups were instant icons. With snowy-white coats and muscular bodies, they looked like they could have walked straight out of the TV series *Game of Thrones*. News reports heralded the animals as "scientifically seismic" and said "the dire wolf is back."

Some scientists aren't buying it. "That is no more a dire wolf than I am Wonder Woman," says Jacquelyn Gill, a paleoecologist at the University of Maine in Orono. The issue boils down to genetics. Colossal didn't create the animals from a fully reconstructed dire wolf genome. Instead, the company relied on the genome of a gray wolf (*Canis lupus*), making changes to it based on ancient DNA recovered from specimens of two dire wolves (*Aenocyon dirus*). "For something to be a dire wolf, it should have the full genetic blueprint of a dire wolf," Gill says. Colossal has simply created a genetically modified gray wolf.

That type of thinking "misses the point," says Beth Shapiro, chief science officer of Colossal. The Dallas-based company's goal was to resurrect the animal's core attributes, like size, body type and face shape. By making a handful of genetic changes, "we've brought these extinct genes back to life in a living animal," she says. "I'm happy to call that a dire wolf."

And a new preprint counters one common critique of the work, showing that dire wolves may be more closely related to modern wolves than previously thought.

Colossal is no stranger to controversy. Earlier this year, the company garnered acclaim with its announcement of "woolly mice," luxuriously tressed mice with genetic modifications inspired by woolly mammoths. The rodents' golden-brown fluff made them internet stars, but some scientists were skeptical that such a creation brought the field any closer to bringing back woolly mammoths.

"I think they're creating interesting zoolike novelties," says wildlife geneticist Paul Wilson of Trent University Ontario in Peterborough. Even so, he finds the company's technology impressive. "There's a huge range of applications, both for medicine and conservation" of endangered species, he says.

↖ Scientists genetically engineered gray wolves to have dire wolf traits. Pups Romulus and Remus are shown at 3 months old.

COLOSSAL BIOSCIENCES

Long before Romulus, Remus and Khaleesi made their debut, dire wolves roamed the Americas during the Pleistocene Epoch, which stretched from about 2.5 million years ago to 12,000 years ago. Ancient DNA from two of these animals informed the new pups' biology. Colossal scientists extracted DNA from a 13,000-year-old fossilized tooth and a 72,000-year-old inner ear bone fossil.

It can be tough to get a clear read of an animal's genome from ancient DNA. As soon as an animal dies, its long strands of DNA start getting chopped up into tiny pieces "like confetti," Shapiro says. But by lining up billions of these snippets in a computer and comparing them with the genome of a gray wolf, scientists got an idea of what makes the animals different.

The team used this information to identify genetic tweaks that might make the gray wolf more dire wolf–like. Altogether, the team made 20 edits to the genomes of gray wolf cells in the lab. Then, it removed the DNA-packed nuclei of those cells and transferred them into denucleated dog egg cells, which developed into embryos. Researchers implanted the embryos into surrogate hounds, which gave birth via C-section: twin males, Romulus and Remus, born in October, and a female, Khaleesi, born four months later.

The gene-editing technology itself is exciting, Gill says, "but the problem now is that the public is going to believe that an animal that lived 10,000 years ago is back. And it is definitely not."

Critics of Colossal's work have been vocal about dire wolves not being wolves at all. That argument seems to be based on a 2021 *Nature* paper that reconstructed the animals' evolutionary history. Scientists analyzed the genomes of five dire wolves and concluded that though the animals looked similar to gray wolves, they forged separate evolutionary paths nearly 6 million years ago.

"There's a huge range of applications, both for medicine and conservation."

—Paul Wilson

"We thought that there was enough genetic divergence that they should not be in the genus *Canis*," says vertebrate paleontologist Julie Meachen of Des Moines University in Iowa. *Canis* is the group that includes wolves, dogs and coyotes.

But those analyses were based on low-quality DNA sequences. Colossal scientists re-extracted DNA from two of the original samples, making a more comprehensive dire wolf genome. The work suggests that dire wolves are more wolflike than once thought, though still distantly related, Shapiro's team reports in a study that has yet to be peer-reviewed.

"I am not sure if they'll be put back into the *Canis* group," says Meachen, who is listed as a coauthor.

In her opinion, the hubbub around the dire wolf project has overshadowed the importance of Colossal's technology, which could help save endangered species like the red wolf (*Canis rufus*). Fewer than 20 red wolves roam North America, and all are descended from about 12 individuals. That means the wolves lack genetic diversity, which increases the risk of health problems in descendants.

Scientists identified a group of canines on the Gulf Coast of Louisiana and Texas that are genetically similar to red wolves. These "red ghost wolves," as Colossal calls them, carry some ancestral red wolf DNA that's been lost in red wolf populations.

Colossal cloned four animals from red ghost wolf cells. Those pups could one day be added to the wild red wolf population to boost genetic diversity, says Matt James, Colossal's chief animal officer. Or scientists could edit ancestral genes into red wolves to help them be "more adaptable to climate change and disease and all the challenges that wild species face," he says. ✖

CHEMISTRY

THIS MISO OFFERS A TASTE OF SPACE

By McKenzie Prillaman

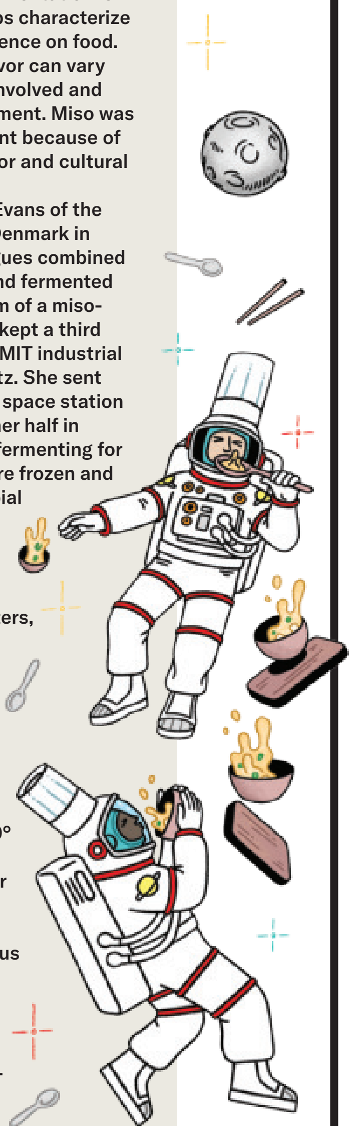
● Fermenting foods in outer space may be a new culinary frontier. Miso fermented aboard the International Space Station tasted nuttier than two earthbound versions of the Japanese condiment, researchers report in *iScience*. The result shows that fermentation is possible in orbit and helps characterize space's terroir — its influence on food.

A fermented food's flavor can vary based on the microbes involved and the surrounding environment. Miso was chosen for the experiment because of its structure, strong flavor and cultural significance.

Food researcher Josh Evans of the Technical University of Denmark in Copenhagen and colleagues combined cooked soybeans, salt and fermented rice to make one kilogram of a miso-to-be mixture. The team kept a third of it and sent the rest to MIT industrial designer Maggie Coblentz. She sent half of her portion to the space station in 2020 and kept the other half in Cambridge, Mass. After fermenting for 30 days, the batches were frozen and later analyzed for microbial and chemical composition as well as flavor.

The space miso's nuttier flavor profile, determined by 14 taste testers, is due to its high level of the compound pyrazine. That's likely because the space station's 36° Celsius average temperature sped up fermentation. Miso fermented at an average of 23° in Cambridge and 20° in Copenhagen.

All batches bore similar microbes, but the space miso had a bacterium unique to it. And its fungus had more genetic mutations, possibly due to space radiation. It's unclear how exactly these factors may have impacted the miso's flavor. ✖



COSMOLOGY

DESI DATA DEEPEN A DARK ENERGY MYSTERY

BY EMILY CONOVER

Change is in the air. New data strengthen a hint that dark energy, long thought to be a constant force in the universe, might change over time.

Dark energy explains the observation that the universe's expansion rate is accelerating. But its origins are unknown. It's typically expected to have constant density across the billions of years of the universe's history. So when researchers using the Dark Energy Spectroscopic Instrument, or DESI, reported in 2024 that dark energy might vary over time based on their first year of data, it shook cosmology to its core.

Many scientists expected that the standard picture would prevail with additional data from DESI. But that hasn't happened. Instead, with three years of DESI data, the preference for a changing, or dynamical, dark energy has grown.

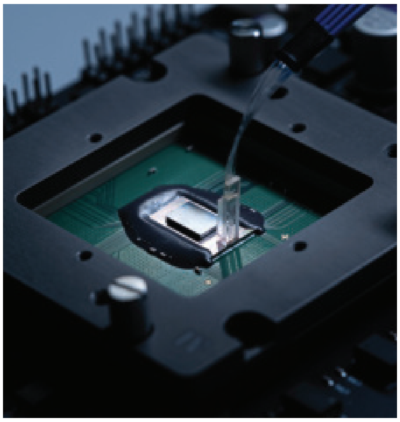
"I am shocked," says cosmologist Eleonora Di Valentino of the University of Sheffield in England, who wasn't involved with the research. "It means that really there is the possibility of new physics, and that's very exciting."

DESI mapped the locations of more than 14 million galaxies and quasars, the extremely bright cores of distant, active galaxies. The researchers measured a phenomenon called baryon acoustic oscillations, ring-shaped patterns imprinted on the cosmos in the early universe. The researchers combined their data with other datasets, including catalogs of exploding stars called supernovas and observations of ancient light called the cosmic microwave background.

Together, the data match dynamical dark energy better than the standard picture, by a statistical measure as large as 4.2 sigma, depending on which data are used, the researchers report in a paper published on DESI's website and in a talk at the American Physical Society's Global Physics Summit. That approaches the benchmark commonly required for a discovery, five sigma.

But the standard cosmological model with constant dark energy, called lambda CDM, is not ruled out. "Lambda CDM, for all of its shortcomings, really works pretty well," says cosmologist Michael Turner of the University of Chicago. DESI found that lambda CDM can explain the data, CONT. ON PAGE 16

ANDREW RAE



LIGHTELLIGENCE

↑ Lightelligence's computer component uses light to speed up calculations that are crucial for AI processing.

TECHNOLOGY

New computer chips do math with light

By Kathryn Hulick

● **It's a bright day for computing** — literally.

Two tech companies have unveiled computer components that use laser light to process information. These futuristic processors could soon solve specific real-world problems faster and with lower energy requirements than conventional computers. The announcements, published in *Nature*, mark a major leap forward for this alternative approach to computing.

Lightelligence, based in Boston, and Lightmatter, in Mountain View, Calif., have shown that light-based components "can do things that we care about, and that they can do them better than electronic chips that we already have," says photonics engineer Anthony Rizzo of Dartmouth College.

Lasers already zap data across the world through fiber-optic cables, and photonics helps move data in advanced data centers. But in both cases, light doesn't compute anything, Rizzo says. In conventional computers, light signals are transformed into slower electronic 1s and 0s that move through transistors.

Light inside the new devices "is actually doing math," Rizzo says. Both use light to perform matrix multiplication, which is essential for most AI processing and other areas of computing. All other calculations in these devices occur in electronic components.

These developments couldn't come at a better time. AI models are growing in size and complexity, while the progress of traditional chips is slowing. Historically, the number of transistors that engineers could squeeze onto chips would about double every two years, which has led to faster computing. But the physics of how electricity moves through transistors puts a limit on that progress. Photonic computing offers a solution, says Lightmatter founder and CEO Nick Harris.

Lightelligence's device is an accelerator that combines a photonic and electronic chip to speed up computation for optimization problems, which are crucial for industries such as finance, manufacturing and shipping. Lightmatter's device is a processor that integrates four light-based and two electronic chips. It can run large language models like those behind ChatGPT.

Past photonic processors could do math but never came close to a regular computer's performance on real-world problems, Harris says. One hurdle has been accuracy. A small mistake in transmitting a light signal could lead to a big error in calculations. Some randomness helps the Lightelligence device explore solutions more efficiently. Lightmatter reduces errors by using electronic chips to control data going in and out of the photonic ones.

Since these photonic components can be made in electronic chip factories, the technology will scale easily, Rizzo says. "These could be in real systems [within five years]." ✖

CONT. FROM PAGE 14 but a model with dynamical dark energy fit the data better.

"It is becoming increasingly clear that lambda CDM is struggling to fit [baryon acoustic oscillation] data in combination with other datasets, and that dynamical dark energy might offer a possible solution to this puzzle," cosmologist Enrique Paillas of the University of Arizona in Tucson said at the meeting.

The researchers performed a variety of cross-checks, including leaving out the cosmic microwave background or the supernova data. Dynamical dark energy still won.

With the first result, DESI scientists still questioned whether they'd missed some subtle effect that would account for the dark energy surprise. "We were all worried that there was something that had stayed under the rug," says physicist Nathalie Palanque-Delabrouille of Lawrence Berkeley National Lab in California. Now, "we're much more confident that we've explored all possible options, and this result ... is really what the data is telling us."

Other instruments, including the European Space Agency's Euclid space telescope, will soon add more data. "To see whether it's a simple cosmological constant or it's something more complex, we need Euclid; we need to look at all the cosmic history," says ESA astrophysicist Xavier Dupac. In the future, Euclid scientists will look at how galaxies cluster in different eras of the universe's history to tease out how the cosmos expanded.

The fate of the universe may be at stake, says DESI physicist Mustapha Ishak-Boushaki of the University of Texas at Dallas. In an extremely distant future with changing dark energy, the universe could collapse in a "Big Crunch." ✖

EMILE HOLMEWOOD

NEUROSCIENCE

Babies form memories like adults do

By Laura Sanders

● **A baby's early life** has a lot of milestones: first giggle, first tooth, first step. A brain-scanning study adds something to the list: first memory.

Infants can form memories, and they use a memory structure in the brain called the hippocampus to do it, researchers report in *Science*. The results shore up the idea that memories can be made during the earliest years of life, though what happens to these memories as the days, weeks and

years roll by remains mysterious.

"What is really new in this paper is that it implicates the hippocampus in the encoding of early memories," says cognitive scientist Vladimir Sloutsky of Ohio State University in Columbus. And that's important, Sloutsky says, because it shows the hippocampus "is mature enough to encode early memories."

Babies can be difficult research subjects. For the study, awake babies were kept calm in functional MRI scanners with a parent nearby and earphones to protect them from startling sounds. In the scanner, babies who ranged in age from 4 months to nearly 25 months saw images, one after another, of people, places or objects. All the while, scientists recorded blood flow in the brain, a proxy of neural activity.

Occasionally, the babies were tested with a pair of images, one of which they had seen before. If the babies looked longer at the previously seen image, researchers reasoned, they likely remembered it. "We can kind of quantify the strength of their memory based on how much they look at it," says study coauthor Nick Turk-Browne, a neuroscientist at Yale University. "The trick in this sort of study is to then go back and look at, when they first saw the picture, what was different in the brain for pictures that they later had a memory for, versus that they later forgot?"

The difference, it turns out, was in the hippocampus — a seahorse-shaped structure, one on each side of the brain. In the study, 13 babies were younger than a year, and 13 babies were older than a year. When the older babies remembered an image, this memory feat corresponded to brain activity in a part of the hippocampus. The effect was weaker in the younger babies, the researchers found.

The result adds to other evidence that babies can in fact form memories and starts to answer how, says neuroscientist Cristina Alberini of New York University. But it doesn't explain why we can't recall some of life's earliest moments, a phenomenon known as infantile amnesia.

It's possible that these memories aren't effectively stored elsewhere in the brain. Or it could be that neural traces persist but aren't able to be called back up.

This second idea is out there, but there's some evidence for it, Turk-Browne says. Scientists have successfully reactivated infant memories in mice by stimulating specific memory-related nerve cells. It's possible that there may be fragments of early memories still in the brain that could be reactivated later in life with the right kinds of cues. He likens the process to an unsuccessful internet search. "The search terms your brain is using to access the memory are wrong or different from what they were when you initially stored the memory." Turk-Browne and his colleagues are now studying how long babies' memories might last. ✖

↖ **Babies form memories of people, places and things, but it is still unclear why those memories can't be recalled as we age.**

CLIMATE

SPLIT SEAWATER TO MAKE 'GREEN' CEMENT

By Carolyn Gramling

● A new cement-making process could shift production from being a carbon source to a carbon sink, creating a carbon-negative version of the building material, researchers report in *Advanced Sustainable Systems*. This process might also be adaptable to producing a variety of carbon-stashing products such as paint, plaster and concrete.

Cement production is responsible for about 8 percent of total carbon dioxide emissions annually. That makes it the fourth-largest emitter in the world. The primary sources for those emissions are the chemical processes to make cement and the mining of raw materials — largely calcium carbonate — in mountains, riverbeds and the ocean floor. To develop an alternative to that mining, scientists at Northwestern University in Evanston, Ill., partnered with Cemex, a multinational cement manufacturer.

Seawater electrolysis is a technique that splits the water's molecules with electricity and generates mineral byproducts such as calcium carbonate. But making calcium carbonate via electrolysis is currently too slow to meet industrial demand, so environmental engineer Alessandro Rotta Loria and colleagues investigated in the lab how minerals form during the process and whether it's possible to scale it up.

By adjusting the applied voltage of electrodes in seawater and injecting CO_2 gas into the water at different rates, the team could control the chemical compositions, crystal structures and yields of the precipitating minerals.

The findings suggest it's possible to tailor seawater electrolysis to make a variety of minerals that the construction industry could use, the team says. If the energy source for the electricity is renewable, the cement could be carbon-negative, trapping some of the atmosphere's CO_2 for up to thousands of years. ✖

↗ In the brains of budgerigars (shown), specific nerve cells make up a "keyboard" of sounds that help the parrots talk.

CHRISTOPHER AUGER-DOMINGUEZ

ANIMALS

Budgie brains parrot human speech centers

By Laura Sanders

● **When it comes to speech,** parrots have the gift of gab. And the way the brains of some small parrots bestow this gift is remarkably similar to some of the ways human brains create speech, scientists report in *Nature*.

Budgerigars (*Melopsittacus undulatus*) are now the only animals known to have speech centers akin to those in humans, says neuroscientist Michael Long of New York University Langone Health. This "is really the first nonhuman animal in which that has been shown." Understanding how speech gets created in budgie brains could help clarify what goes wrong in certain communication disorders in people.

The parrots are smart cutie pies, their especially social and chatty nature making the birds interesting subjects for language research. Long and his Langone Health colleague Zetian Yang tracked nerve cells in four budgie brains as the birds chirruped. The activity of cells nestled in a part of the brain called the anterior arcopallium is tied to the sounds the birds make, the duo found.

The organization of these neurons' activity is like a keyboard that can produce consonants, vowels, high pitches and low pitches, Long says. A budgie can generate "arbitrary sounds in its universe by just playing this vocal keyboard." Overall, this flexible system has a humanlike organization.

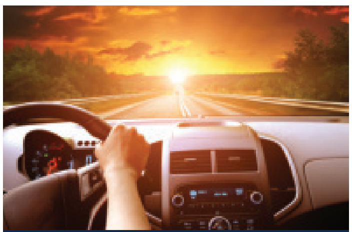
Long and colleagues are trying to decipher what warbles and chirps mean using machine learning. Perhaps some aspects of budgie vocalizations are similar to human language, he says. ✖

Quite Simply The World's Most Advanced Sunglasses May Save Your Life

The sun rises and sets at peak travel periods. During the early-morning and afternoon rush hours, many drivers find themselves temporarily blinded while driving directly into the glare of the sun. **Deadly accidents are regularly caused by such blinding glare**, with danger arising from reflected light off another vehicle, the pavement, or even oily windshields that can make matters worse. Yet motorists struggle on despite being blinded by the sun's glare that causes countless accidents every year.

NASA Technology
Eagle Eyes® has been working on perfecting these sunglasses for two decades and has finally achieved it. Many overpriced designer sunglasses can actually blur your vision by allowing harmful UV and blue light rays in, but thanks to a team of NASA physicists and scientists, **Eagle Eyes' revolutionary technology allows you to see the world like you've never seen it before**. Looking to nature for inspiration, these NASA scientists discovered how eagles can distinguish their prey from their surroundings with utmost precision while protecting their eyes from harmful UV rays and blue light. Scientists then adapted this natural process into lens technology that, in turn, led to the founding of Eagle Eyes Optics,™ the leader in stylish, high-performance eyewear that protects and enhances vision under any light condition.

Superlight, Super-Flexible, Layered-in-22K-Gold
Eagle Eyes Optics Eyewear has set these breakthrough polarized, Trilenium® lenses into the best frame material on the market. **At just over ½ ounce**, these titanium superlight frames layered in 22 karat gold are some of the strongest, lightest and most flexible frames ever designed. And of course, the aviator style is amazingly good looking.



A study by the National Highway Traffic Safety Administration showed that **74% of crashes** occurred on clear, sunny days

In a world where inferior name-brand sunglasses sell for $200 to $350, these sunglasses are made of the best materials and the most advanced optical technology for your safety. Eagle Eye provide **100% UV light protection** and blocking from harmful blue and ultraviolet light while visually enhancing the colors of your surrounding environment. **Your driving just became a lot safer.**

Specifications:
- Flexible titanium frame layered in 22k gold
- Micro-spring hinges, Silicon AirTec™ nose pads
- TriLenium® 7 polarized lenses that block scattered blue light and 99.9% UVA/UVB rays
- Case and pouch included

Memory Flex Apollo Aviator Sunglasses
22k gold-clad ~~$295~~ $99* + S&P *Save $196*
**Special price only for customers using the offer code.*

1-800-333-2045

Your Insider Offer Code: ATS163-02

Stauer®

14091 Southcross Drive W.
Dept. ATS163-02
Burnsville, Minnesota 55337
www.stauer.com

ARCHAEOLOGY

STONE AGE HUNTER-GATHERERS MAY HAVE TAKEN TO THE SEA

BY MICHAEL MARSHALL

Prehistoric hunter-gatherers were likely skilled seafarers who could make long and challenging journeys.

Stone tools, animal bones and other artifacts unearthed in Malta indicate that humans first inhabited the Mediterranean island 8,500 years ago, about a thousand years earlier than previously thought, researchers report in *Nature*. To reach Malta, these hunter-gatherers seemingly crossed at least 100 kilometers of open ocean, the team says.

The findings add to an emerging picture of systematic seafaring in the middle Stone Age. "There's this new world of Mediterranean crossings in the Mesolithic that we didn't know about," says archaeological scientist Eleanor Scerri of the Max Planck Institute of Geoanthropology in Jena, Germany.

There has been a long-held view that hunter-gatherers could not routinely and intentionally cross large bodies of water, she says. While evidence exists of earlier sea crossings elsewhere — such as humans arriving in Australia at least 40,000 years ago — those instances appear to be one-offs, possibly explainable by shorter journeys gone awry by bad weather, Scerri says. "It doesn't look like there was this sort of systematic coming and going."

But the seafaring abilities of Malta's Stone Age immigrants, she argues, indicates they were clearly capable of such journeys.

From 2021 to 2023, Scerri and colleagues excavated a sinkhole at a site in northern Malta called Latnija. They found sediment layers containing traces of human habitation: ashes from hearths, 64 stone tools and wild animal remains that bear signs of butchering.

Radiocarbon dating of 32 charcoal pieces and one animal bone suggests that hunter-gatherers occupied the site for a millennium beginning about 8,500 years ago. The stone tools were typical of those used by hunter-gatherers on the European continent around the same time, the team says, suggesting that's where they came from.

Malta's closest neighbor is Sicily, about 85 kilometers to the north. But the best route from Sicily to Malta may have been a 100-kilometer journey starting from an easterly point on Sicily, like the Gulf of Gela, to take advantage of a powerful east-west ocean current, Scerri says.

The team did not find any boat remains, leaving the type of craft used uncertain. However, five ancient canoes discovered in central Italy might offer a clue, Scerri says. Although these canoes are roughly 7,500 years old, they indicate what people could make at the time. Each vessel was hollowed out from a single tree trunk, the largest measuring 11 meters long, and designed for seagoing, Scerri says, with "these weird holes in them that might point to some sort of primitive outriggers."

Experiments with replicas of such canoes suggest travel speeds of about 4 kilometers per hour. That suggests it would have taken about 25 hours to cover 100 kilometers.

"They would have had to have navigated at least through part of

Latnija, an ancient sinkhole on Malta (shown), contains evidence of seafaring prowess by Stone Age hunter-gatherers. ↓

HUW GROUCUTT

the night," Scerri says, which would have required knowledge of the stars and currents.

Genetic evidence also lends support to the seafaring narrative. A DNA analysis of an 8,000-year-old individual from Tunisia shows European hunter-gatherer ancestry, another group of researchers reported in *Nature*. That ancestry could be from people coming west across the Mediterranean, via Malta. The implication, Scerri says, is that hunter-gatherers were "seafaring all over the place."

These findings fit with tentative evidence of connections between Mediterranean hunter-gatherer societies, says Cyprian Broodbank, an archaeologist at the University of Cambridge who peer-reviewed the study by Scerri and colleagues.

The new findings, he says, bring us "closer to potentially confirming exchanges of [hunter-gatherer] people, technologies and suchlike between the two sides of the Mediterranean, earlier than so far attested." Previous research suggested that late Stone Age farmers settled on Malta about 7,400 years ago. These people, while still using primarily stone tools, had begun cultivating crops and domesticating animals, moving away from a hunter-gatherer lifestyle.

Roughly 9,000 years ago, Stone Age farmers were moving into mainland Europe from the Fertile Crescent and Anatolia, or what is now much of Turkey. This expansion "is one of the most fundamentally transformative things that ever happened to Europe," says archaeologist Rowan McLaughlin of Maynooth University in Ireland. He speculates that disruptions brought by these farmers may have prompted some hunter-gatherers to leave for Malta. ✖

É. LÉVÊQUE, MÉDIATHÈQUE DU GRAND TROYES

ANTHROPOLOGY

Medieval monks wrapped books in pelts from afar

By Alex Viveros

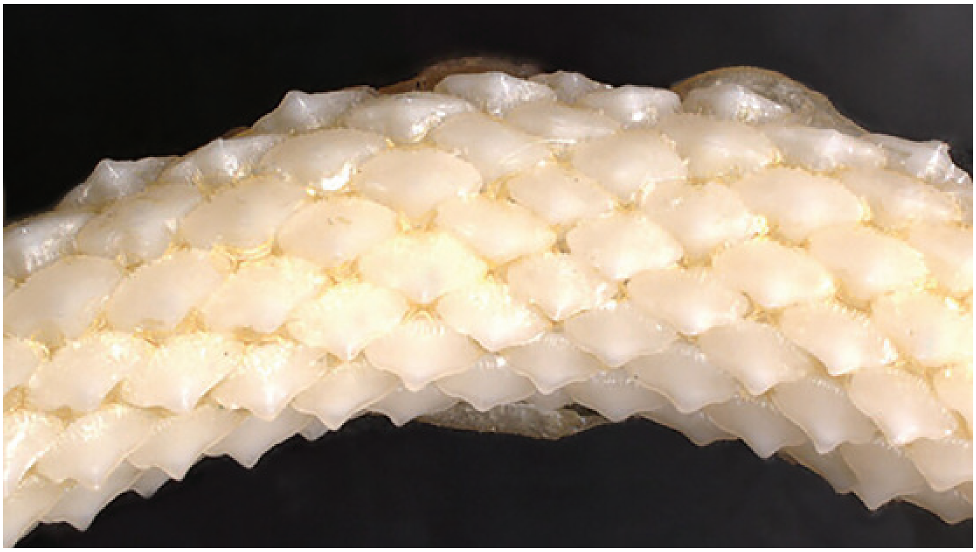
● **Science is helping** researchers judge books by their covers — and revealing surprising beneficiaries of medieval trading routes in the process.

Dozens of rare fur-covered volumes from 12th and 13th century French monasteries are wrapped with seal skins, some of which may have come from as far away as Greenland, researchers report in *Royal Society Open Science*. The findings challenge the assumption that the books' makers used only locally sourced materials and suggest that they were part of an extensive trade network.

The books hail from Clairvaux Abbey in northern France and related monasteries. Examining the tomes through a microscope, conservator Élodie Lévêque struggled to identify their furry outermost covers. So scientists compared proteins from the covers with known animal proteins, finding a match with seals. "I was like, 'That's not possible. There must be a mistake,'" says Lévêque, of Panthéon-Sorbonne University in Paris. Seals didn't frequent France's northern coast at the time. But DNA analyses confirmed the ID.

The source may have been harbor seals near Scandinavia, Denmark and Scotland, and harp seals near Greenland or Iceland. It's possible Norse hunters brought the skins to France, Lévêque says. What's more, the books were much furrier in their heyday, "like a teddy bear," she says. ✖

↑ When monks in medieval France covered this book with seal skin, it was furrier and lighter in color.



ANIMALS

'Click!' goes the shark

By Susan Milius

↑ New Zealand's rig sharks possess rows of flat, cusped teeth (shown) that are perfect for consuming crustaceans and, perhaps, making communicative sounds.

PAUL CAIGER/UNIV. OF AUCKLAND

● **Sharks may not be** the sharp-toothed silent type after all. The clicking of flattened teeth, discovered by accident, could be "the first documented case of deliberate sound production in sharks," evolutionary biologist Carolin Nieder of Woods Hole Oceanographic Institution in Massachusetts and colleagues propose in *Royal Society Open Science*.

Humankind has been slow to pick up on sounds fishes make, and many of their squeaks and rumbles have come to the attention of science in captive animals. For the many bony fishes, it's no longer a surprise to detect various chirps, hums or growls. Yet sharks and rays, built with cartilage, have been slower to get recognized for sounding off. In the 1970s, clicking was reported in a cow-nosed ray (*Rhinoptera bonasus*), and has since turned up in other rays. Sharks, however, had remained silent until recently.

Nieder was at the University of Auckland's Leigh Marine Laboratory in New Zealand, dangling an underwater microphone into a tank to explore hearing in rig sharks (*Mustelus lenticulatus*). Reaching into the tank to grasp one of these small sharks, she heard "click ... click...." After a week or so, the animal still squirmed when handled but didn't repeat the click. Perhaps the sound was an involuntary response to stress, she mused.

Nieder handled 10 sharks, recording multiple clickity bouts. On average, sharks clicked nine times during a 20-second grasp. The sounds may come from clacking together the rows of flattened teeth with cusps, great for cracking crustaceans shells, she speculates. Rows of these teeth emerge from gum tissue, reminding her of stones set in a mosaic.

Wiggling doesn't seem important: Nieder heard the sounds when a shark writhed in her grasp and when it held still. It's possible the sharks click by forceful snapping, but the idea still needs formal testing, she cautions.

Whether rigs can hear the clicks and whether they use them in communication is unclear. Rigs seem to be especially sensitive to frequencies around 150 hertz, Nieder and colleagues found, though they can hear frequencies of up to 800 Hz. But many of the recorded clicks fell well above the upper limit of that range. ✖

COLLEGE ESSAY MENTOR

An Ivy Plus Admissions Specialist

ONE-ON-ONE ESSAY ADVISING

Zoom meetings tailored to STEM students who want admissions officers to see the curiosity behind their questions, the drive behind their work.

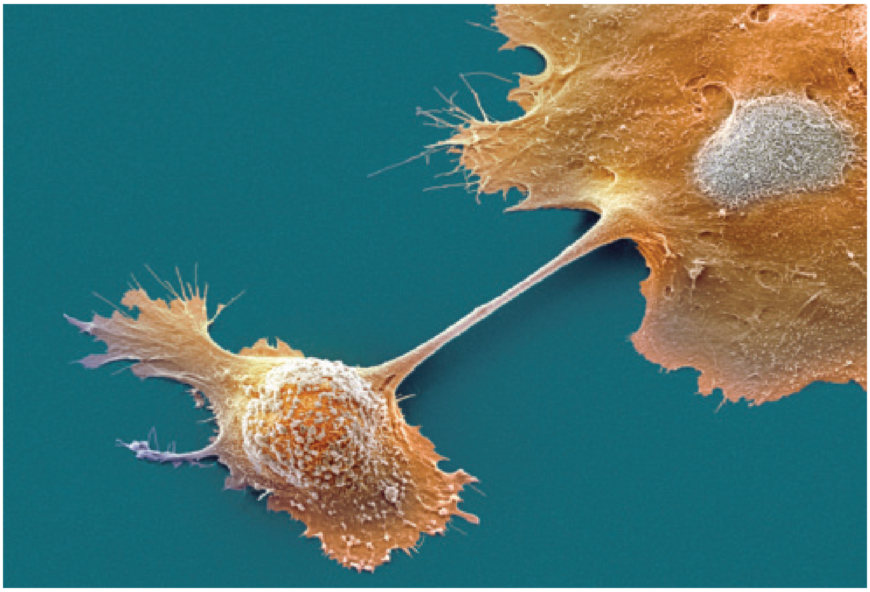
COLLEGE COUNSELING

I demystify the process, create personal application plans, and share strategies that open the doors to Stanford, MIT and the Ivy League.

COLLEGE ESSAY WEBINARS

Affordable, half-day sessions that teach students how to write poignant personal statements and unique supplement essays for Ivy Plus applications.

Get started at
CollegeEssayMentor.com



HEALTH & MEDICINE

An mRNA vaccine may fend off pancreatic cancer

By Meghan Rosen

● **A new mRNA vaccine** could prevent pancreatic cancer from returning, potentially for the long haul. In a small clinical trial, some patients who received the vaccine remained cancer-free for over three years, researchers report in *Nature*.

That is "pretty remarkable," says Aaron Sasson, director of the Pancreatic Cancer Center at Stony Brook Medicine in New York. Despite facing a notoriously lethal cancer, which kills over 450,000 people globally each year, these patients lived "a lot longer than we would have otherwise expected," he says.

The standard set of therapies for treating pancreatic cancer — surgery, chemotherapy, radiation therapy and drugs that specifically attack cancer cells — don't work very well, Sasson says. Pancreatic cancer's five-year survival rate is around 13 percent, meaning that five years after diagnosis, 87 out of 100 patients will have died. "If you're diagnosed with pancreas cancer, the odds are extremely high you're going to die [from it]," he says.

The new research is still in the proof-of-concept stage but suggests that a cancer vaccine strategy could one day offer patients a long-lasting treatment option and may extend lives.

Unlike a traditional vaccine such as the flu shot, which helps the body ready defenses for future viral encounters, this cancer vaccine acts therapeutically, after someone has already developed cancer. It teaches patients' immune cells what pancreatic cancer looks like. Those educated cells can then seek out and destroy tumors. This approach is part of a growing field of cancer immunotherapies that enlist people's own immune systems in treatment.

Dozens of similar cancer vaccines are in the works. Researchers are testing the new mRNA cancer vaccine in melanoma and colorectal cancer as well as other vaccines in different cancers. Excitement about this technology has been brewing in the cancer vaccine field, says study coauthor Vinod Balachandran, a surgical oncologist at Memorial Sloan Kettering Cancer Center in

↑ A new mRNA vaccine can teach the immune system to spot pancreatic cancer cells (shown in a false-color scanning electron micrograph).

SCIENCE PHOTO LIBRARY - STEVE GSCHMEISSNER/BRAND X PICTURES/GETTY IMAGES PLUS

New York City. The work could offer a blueprint for developing effective vaccines against even more types of cancer, he says.

However, the new results come amid recent news that the National Institutes of Health terminated a grant supporting research of an mRNA vaccine against COVID-19. Scientists are concerned that grants supporting any mRNA vaccine research could be next. It's a move that would significantly hamper advancements in cancer therapies and patient care, Sasson says.

Cancer vaccines belong to a class of therapies that harness our bodies' own defenses to fight disease. The U.S. Food and Drug Administration has already approved dozens of such immunotherapies, including checkpoint inhibitors, which rev up the immune system; therapeutic antibodies, which help the immune system spot cancer; and T-cell transfer therapy, which gives patients a fresh influx of their own (sometimes supercharged) immune cells.

The common thread is the immune system, Sasson says, which is a "very efficient killing machine."

Cancer vaccines like the one Balachandran's team is testing, which was developed by the companies BioNTech and Genentech, take a different approach. They show the body a tiny, nonfunctional piece of their tumor, serving as a Bat-Signal for the immune system. In response, the body produces immune cells called T cells that can recognize cancer as something to be destroyed.

13 percent

The five-year survival rate for pancreatic cancer

The cancer vaccine works similarly to mRNA COVID-19 vaccines, but instead contains instructions for building cancer proteins rather than coronavirus proteins and is given after the disease develops rather than before. The other major difference: The cancer vaccine is personalized for every patient.

"Each individual tumor has a unique combination of genetic mutations," Balachandran says. To create the vaccine, doctors surgically remove a patient's tumor and analyze its DNA for genetic errors. Some of these errors produce mutant tumor proteins, which the immune system can recognize like red flags warning danger. Patients receive a personalized vaccine containing RNA sequences for those red flags, Balachandran says. (It's not exactly clear why the immune system sometimes has trouble recognizing those red flags on its own, he says.)

This process teaches patients' immune systems to be on the lookout; when immune cells see the red flags, they know it's time to strike. The body makes "these cells that can recognize the cancer, kill the cancer and last in the body for long periods of time" in case the cancer comes back, Balachandran says.

In a small clinical trial involving people with pancreatic cancer, the vaccine spurred a strong immune response in eight out of 16 patients, generating a legion of red flag–targeting T cells. Balachandran's team reported those results in 2023. At the time, the prevailing wisdom was that "you could not teach the immune system to recognize pancreatic cancer," he says.

Many scientists thought pancreatic cancer did not create enough red flags to alert the immune system. The team's results challenged that view. Scientists now know that the cancer produces these red flags — and they can identify them, build a vaccine around them and use that vaccine to grow an army of T cells that hunt for pancreatic cancer.

But an effective cancer vaccine requires more, Balachandran says. "Not only do you need to make the cells, but the cells need to last and retain function long-term." His team followed the 16 patients for up to about four years; all had had surgery, an immune checkpoint inhibitor, their personalized vaccine and a standard chemotherapy regimen. Of the eight people who mounted an immune response to the vaccine, only two saw their cancers return. In contrast, seven of the eight who did not respond saw their cancer return after about a year.

The results suggest the vaccine can generate immune cells that patrol the body like guard dogs even several years later. "It's a big deal," Sasson says.

Balachandran can't say for sure why the vaccine didn't work for everybody. It's possible the spleen may be involved. The organ is part of the immune system and helps generate immune responses. Some patients had their spleens removed before vaccination. Without it, the immune response to the vaccine may be weaker. He and colleagues are now enrolling patients in a larger trial to test whether the vaccine is safe and effective. ✖

PARTICLE PHYSICS

PHYSICISTS EXPOSE RULE-BREAKING BARYONS

By Emily Conover

● There's a newfound mismatch between matter and antimatter. And that could bring physicists one step closer to understanding how everything in the universe came to be.

For the most part, particles and their oppositely charged antiparticles are like perfect mirror images of one another. But some particles disobey this symmetry, a phenomenon known as charge-parity, or CP, violation. Now, researchers at the Large Hadron Collider near Geneva have spotted CP violation in a class of particles called baryons, where it's never been confirmed before.

Baryons are particles that contain three smaller particles called quarks. The most famous examples of baryons are protons and neutrons. Previously, scientists had seen CP violation only in mesons, which are particles containing one quark and one antiquark.

For the new study, researchers with the LHCb collaboration studied particles called lambda-b baryons. The scientists looked at a decay of a lambda-b baryon into a proton and three lesser-known particles: a kaon and two pions. The rate of this decay is slightly different than that of its antimatter counterpart, the team found. This difference indicates CP violation, the researchers report in a paper posted to arXiv.org and in a talk at the Rencontres de Moriond meeting in La Thuile, Italy.

Building on previous hints of CP violation in baryons, the study is the first to cross the statistical threshold for a discovery, known as five sigma.

A better understanding of CP violation could help explain how matter came to dominate over antimatter. In the Big Bang, matter and antimatter were made in equal measure. CP violation is thought to have given matter the upper hand. But known processes don't violate CP enough to account for the matter-antimatter imbalance.

The new study doesn't solve that quandary, but it's a step in the right direction. ✖

ASTRONOMY

Cosmic reionization may have gotten an early start

By Lisa Grossman

● **The James Webb Space Telescope** has caught a distant galaxy blowing an unexpected bubble of charged gas just 330 million years after the Big Bang. The finding marks the earliest sign yet of the era of cosmic reionization, when ultraviolet radiation from the first stars and galaxies stripped electrons from most of the universe's hydrogen atoms, astronomers report in *Nature*.

The universe was completely ionized about one billion years after the Big Bang, but it's hard to tell when the process began or what produced the light. "It definitely puts a pin in the map of the first point where [reionization] very likely has already started," says astrophysicist Joris Witstok of the University of Copenhagen. "No one had predicted that it would be this early."

A clear signal of cosmic reionization is a UV wavelength called Lyman-alpha, produced by excited hydrogen atoms returning to their lowest energy states. Seeing these photons means the galaxy must have blown a bubble of ionized gas, clearing a path for the light to shine through. Witstok's team observed the galaxy JADES-GS-z13-1-LA emitting a superstrong Lyman-alpha signal, possibly due to extremely hot, massive stars or matter heating up as it fell onto the galaxy's central black hole. Whatever the cause, says cosmologist Michele Trenti of the University of Melbourne in Australia, it will affect our understanding of the early universe. ✖

↑ JADES-GS-z13-1-LA (red dot, center) emits a superstrong signal that indicates the ancient galaxy is reshaping its environment.

JWST/ESA, NASA, STSCI, CSA, JADES COLLABORATION, BRANT ROBERTSON/UC SANTA CRUZ, BEN JOHNSON/CFA, SANDRO TACCHELLA/U. OF CAMBRIDGE, PHILL CARGILE/CFA, J. WITSTOK, P. JAKOBSEN, A. PAGAN/STSCI, M. ZAMANI/JWST/ESA

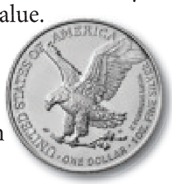
Your Silver Passport to Travel the World

The 5 Most Popular Pure Silver Coins on Earth in One Set

Travel the globe without leaving home with the world's five most popular pure silver coins. Newly struck for 2025 in one ounce of fine silver, each comes in Brilliant Uncirculated (BU) condition. Your trip includes stops in the United States, Canada, South Africa, China, and Great Britain.

We've Done the Work for You With This Extraordinary 5-Pc. World Silver Coin Set

Each of these coins is recognized for its breathtaking beauty, and for its stability even in unstable times, since each coin is backed by its government for weight, purity and legal-tender value.



2025 American Silver Eagle: The Silver Eagle is the most popular coin in the world, with its iconic Adolph Weinman Walking Liberty obverse backed by Emily Damstra's Eagle Landing reverse. Struck in 99.9% fine silver at the U.S. Mint.

2025 South African Krugerrand: The Krugerrand continues to be the best-known, most respected numismatic coin brand in the world. Struck in 99.9% fine silver at the South African Mint.

2025 Canada Maple Leaf: A highly sought-after bullion coin since 1988, this 2025 issue was struck in highly pure 99.99% silver at the Royal Canadian Mint.

2025 British Silver Britannia: One of The Royal Mint's flagship coins, this 2025 issue features Lady Britannia, defender of Britain, struck in 99.9% fine silver at The Royal Mint.

2025 China Silver Panda: China Silver Pandas have been collector favorites since their debut in 1983. They're noted for their heart-warming one-year-only designs highlighting the maturing of Panda cubs. Struck in 30 grams of 99.9% fine silver at the China Mint.

SAVE with this World Coin Set!

You'll save both time and money on this world coin set with **FREE shipping** and a **BONUS presentation case**, plus a new and informative Silver Passport! You'll also receive a **FREE mystery gift**. A $25 value, it's yours at no extra charge!

FREE Mystery Gift with every order!
(A $25 value!)

Just Released and AVAILABLE NOW!

These amazing, just released 2025 Silver Passport 5-Coin Sets featuring five popular Silver Dollars from around the world are in stock now. Don't wait. Order now and your 2025 Set will ship directly to your door. Order your Silver Passport Set right now—while they last!

2025 World Silver 5-Coin Set
Regular Price ~~$279~~ – Only $219 per set!
SAVE $60.00 ***(over 20%)*** **+ FREE SHIPPING**
AND FREE Gift! Total Value of $304 – FOR ONLY $219!
FREE SHIPPING: Standard domestic shipping. Not valid on previous purchases.

For fastest service call today toll-free

1-888-201-7070

Offer Code WRD433-14
Please mention this code when you call.

SPECIAL CALL-IN ONLY OFFER

GOVMINT • 1300 Corporate Center Curve, Dept. WRD433-14, Eagan, MN 55121

HEALTH & MEDICINE

POOP FROM ATHLETES MAY BOOST METABOLISM

BY ALEX VIVEROS

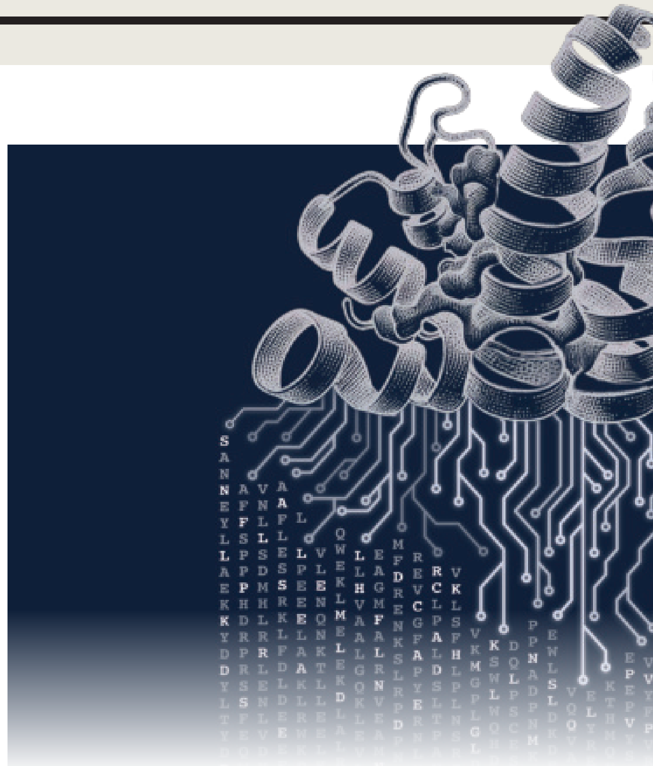
One of the keys to having the metabolism of an elite athlete may be having the gut microbes of one. Transplanting feces from top-level cyclists and soccer players into mice boosted levels of a molecule that fuels intense workouts, physiologist Frédéric Derbré and colleagues report in *Cell Reports*.

Gut bacteria play a crucial role in digestion and metabolism. Derbré, of Rennes 2 University in France, wondered how the microbes influence exercise performance. So his team analyzed the poop of athletes and nonathletes, then transplanted the poop into the digestive tracts of mice. In people, fecal transplants can treat certain gastrointestinal health issues by refreshing the gut's microbes.

Athletes with the highest exercise capacities had less diverse and less abundant gut bacteria compared with the other volunteers. The athletes also had higher levels of short-chain fatty acids, bacteria-produced molecules that the body uses for energy. Mice given feces from these athletes were more sensitive to insulin and had more glycogen — exercise fuel — compared with mice given nonathletes' poop. Despite the increased stores of complex sugar, however, the mice's running endurance did not improve.

Though fecal transplants probably won't boost athletic performance, the potential metabolic benefits hint that people who are considering a fecal transplant should also consider a donor's exercise levels, Derbré says.

But there are other, less invasive ways to possibly improve metabolism, says physiologist Edward Chambers of Imperial College London. One suggestion: Increase dietary sources of short-chain fatty acids, such as legumes, fruits and vegetables. ✖



ANNEKATRINE KIRKETERP-MØLLER

ARTIFICIAL INTELLIGENCE

New AI tools reveal 'hidden' proteins

By Lauren Leffer

● **Generative artificial intelligence** has entered a new frontier of fundamental biology: helping scientists to better understand proteins, the workhorses of living cells.

Two new AI tools, described in *Nature Machine Intelligence*, can decode protein sequences from biological samples often missed by existing detection methods, say computational bioengineer Konstantinos Kalogeropoulos of the Technical University of Denmark in Lyngby and colleagues. Uncovering these unknown proteins could be key to creating better cancer treatments, improving understanding of diseases and discovering mechanisms behind unexplained animal abilities.

If DNA represents an organism's master plan, then proteins are the final build, encapsulating what cells actually make and do. Deviations from the DNA blueprint for making proteins are common. Proteins might undergo alterations or

↖ New AI tools to detect and detail amino acid sequences (letters) of previously undiscovered proteins have the potential to improve disease treatments and boost basic biological knowledge.

cuts postproduction, and there are many instances where something goes awry in the pipeline, leading to proteins that differ from the initial schematic. These unexpected, "hidden" proteins have been difficult for scientists to identify and analyze. That's where the new machine learning tools come in.

The team's AI tools are a step toward sequencing previously unidentified proteins en masse, the holy grail of protein research, says Benjamin Neely, a chemist at the National Institute of Standards and Technology in Gaithersburg, Md. With continued testing, such tools are "going to let me see things that I can't normally see," he says, like the proteins that let stingrays move between brackish water and the ocean.

AI has already transformed how scientists predict protein folding with the machine learning tool AlphaFold. And machine learning–powered protein design and structure prediction earned a Nobel Prize in 2024. Filling gaps in protein sequencing is poised to be the field's next AI leap, Neely says.

One of the new AIs, InstaNovo, or IN, is structured similarly to the large language models underlying ChatGPT. It associates the peaks and valleys of a protein's "fingerprint," plotted through mass spectroscopy, with a string of likely amino acids. These amino acid sequences can then be used to reconstruct and identify the hidden protein. The other, InstaNovo+, or IN+, is more like an AI image generator. It progressively removes noise from the same initial information to produce a clear protein picture.

IN and IN+ demonstrate how far AI protein sequencing has come, edging closer to real-world utility. That's largely due to expanding protein analysis databases that IN, IN+ and other tools are trained on. But IN and IN+ extend beyond their training materials. They can identify sequences and suggest candidate protein segments that haven't yet been cataloged in any database.

In straightforward protein sequencing tests, IN and IN+ didn't outperform database search, yet they seemed to excel in more complicated trials. For instance, one challenging task is sequencing human immune proteins, which are uniquely tough to analyze with standard methods due to their small size and amino acid composition. IN found about three times as many candidate protein segments as classic database searching, going from about 10,000 identified peptides to more than 35,000, the team reports. And IN+ found about six times as many. The tools' combined performance offered an even larger boost.

Chemist Amanda Smythers of the Dana-Farber Cancer Institute in Boston is eager to try the tools. She imagines using them to investigate why pancreatic cancer often triggers muscle wasting and fatigue. Proteins made by cancer cells or that disrupt normal function in noncancer cells could be at fault. "It's a really important piece of biology that we don't understand yet," Smythers says.

IN and IN+ have limitations. For example, the estimated 5 percent false-positive rate means outputs need extra verification, Kalogeropoulos says.

AI sequencing isn't a replacement for database searching, Smythers says. It's a supplement. "There's never one single tool that's good for every job," she says. "However, it's tools like this that really help us keep progressing." ✖

THE HEALTH CHECKUP

SKELETONS BELONG ON THE HEALTH TO-DO LIST

BY AIMEE CUNNINGHAM

I confess: If I think about skeletons, it's around Halloween. I especially enjoy the yard displays of larger-than-life skeletons engaging in mundane activities, like walking skeleton dogs. But our own skeletons are something we should be thinking about year-round, especially as we age. Heading into midlife and beyond, bones can lose their heft. A drop below a certain bone density leads to a diagnosis of osteoporosis and bones that are weak and fragile.

Osteoporosis can happen to all adults, but it's more common in women — about 27 percent of U.S. women age 65 and older have the disorder compared with close to 6 percent of men the same age, according to the latest available data from the U.S. Centers for Disease Control and Prevention.

Bones weakened by osteoporosis are more likely to fracture, which can be debilitating and even deadly. Hip fractures are especially devastating. Around 20 percent of people die within one year of fracturing a hip. Only 40 to 60 percent of survivors are likely to regain their prefracture mobility.

In January, the U.S. Preventive Services Task Force reaffirmed its recommendation that women 65 and older should be screened for osteoporosis. That's done with a bone density test.

"A lot of emphasis on the postmenopausal, 65-plus population is warranted because we know that fractures happen at a higher incidence," says Nicole Wright, an osteoporosis epidemiologist at Tulane University in New Orleans. "But it doesn't necessarily mean that younger women should not be concerned about their bone health." Bone loss really gets going right around menopause. Starting the year before the last menstrual period and for about two years after, bone density drops about 2 percent per year on average due to the decline in estrogen. Bone loss continues more slowly after that.

However, there isn't a blanket screening recommendation for postmenopausal women age 50 to 64. Women at higher risk of developing osteoporosis might be screened. Smoking or a history of fracture are among the risk factors that could warrant screening. Women with conditions that can cause osteoporosis, such as rheumatoid arthritis, diabetes and celiac disease, or who take certain drugs that raise the risk, should already be closely watched.

For younger postmenopausal women, it's challenging to predict future fracture risk. Osteoporosis risk prediction tools don't work well, scientists report in *JAMA Network Open*. Nor does the tool for fracture risk prediction, past work has found.

Bone density tests help determine whether a person needs osteoporosis drugs, says Kristine Ensrud, a general internist and epidemiologist at the University of Minnesota in Minneapolis. Yet there isn't "good evidence on the benefits versus the harms of beginning treatment in younger postmenopausal women."

So these younger women can be in limbo, with bone loss under way but perhaps no cause to screen early and scant evidence on how to proceed. However, there are ways to minimize the rate of decline in bone density. It's not "here comes menopause and now we all have osteoporosis," Wright says.

To preserve bone health, the go-tos are exercise and nutrition. Weight-bearing exercises — like walking and running — are key, Ensrud says. "And remember, a lot of fractures ... are related to falls, so work on your balance." It's also important to get enough calcium and vitamin D and to avoid smoking and excess alcohol, she says.

If a woman is taking hormone therapy to treat menopause symptoms like hot flashes, there's the added bonus that the estrogen boost prevents bone loss.

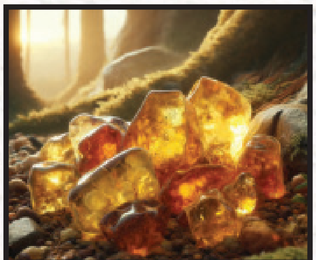
Wright wants to see more appreciation for the skeleton. While there's been a greater awareness about other health issues that affect women, such as breast cancer and heart disease, it's not there yet for osteoporosis and fractures, she says. "We need to be thinking about it because there are things we can do." ✖

Wings of Wonder

Where Nature's Beauty Takes Flight...

Over 44 million years ago, in the ancient forests of the Baltic region, nature began crafting one of its most precious treasures. Golden resin dripped from towering trees, slowly fossilizing over time into what we now know as **Baltic Amber** — a gemstone rich with history, warmth, and meaning. Often called the **"Gold of the North,"** it has long been cherished for its natural beauty and spiritual energy.

Now, we invite you to experience that timeless wonder with **The Amber Wings Collection** — a stunning jewelry set that celebrates the delicate **dragonfly**, a powerful **symbol of transformation, renewal, and light**.



Cognac Baltic Amber

Each pendant and matching earring is expertly inlaid with genuine Baltic Amber, capturing the essence of this graceful creature in exquisite detail. The dragonfly's wings shimmer with natural golden tones, reflecting the ancient energy of the earth and the elegance of nature in every curve.

Whether as a gift or a meaningful keepsake for yourself, this collection is designed to inspire and enchant. Let the **spirit of the dragonfly** lift your look — and your soul.

Yours today for **just $79** plus S&H with promo code: **SN4NAB**. Order now and step into a world of beauty, transformation, and timeless style.

DANIEL STEIGER

A. ***Baltic Amber Dragonfly Pendant & 18k Gold Plated Chain***

~~$149~~ **$79** - *Save $70*

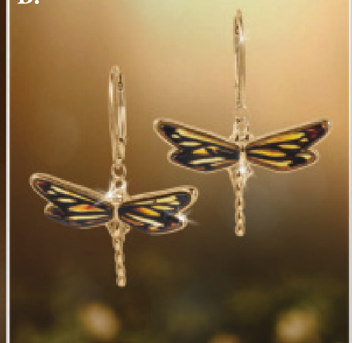
B. ***Baltic Amber Dragonfly Earrings***

~~$149~~ **$79** - *Save $70*

** Exclusive Offer Price Using Discount Code*

C. ***Baltic Amber Dragonfly Pendant & Earrings Collection***

~~$298~~ **$149** - *Save $149 (additional discount)*



B.

Matching Dragonfly Earrings

BALTIC AMBER
DESIGNED BY NATURE OVER
44 MILLION YEARS

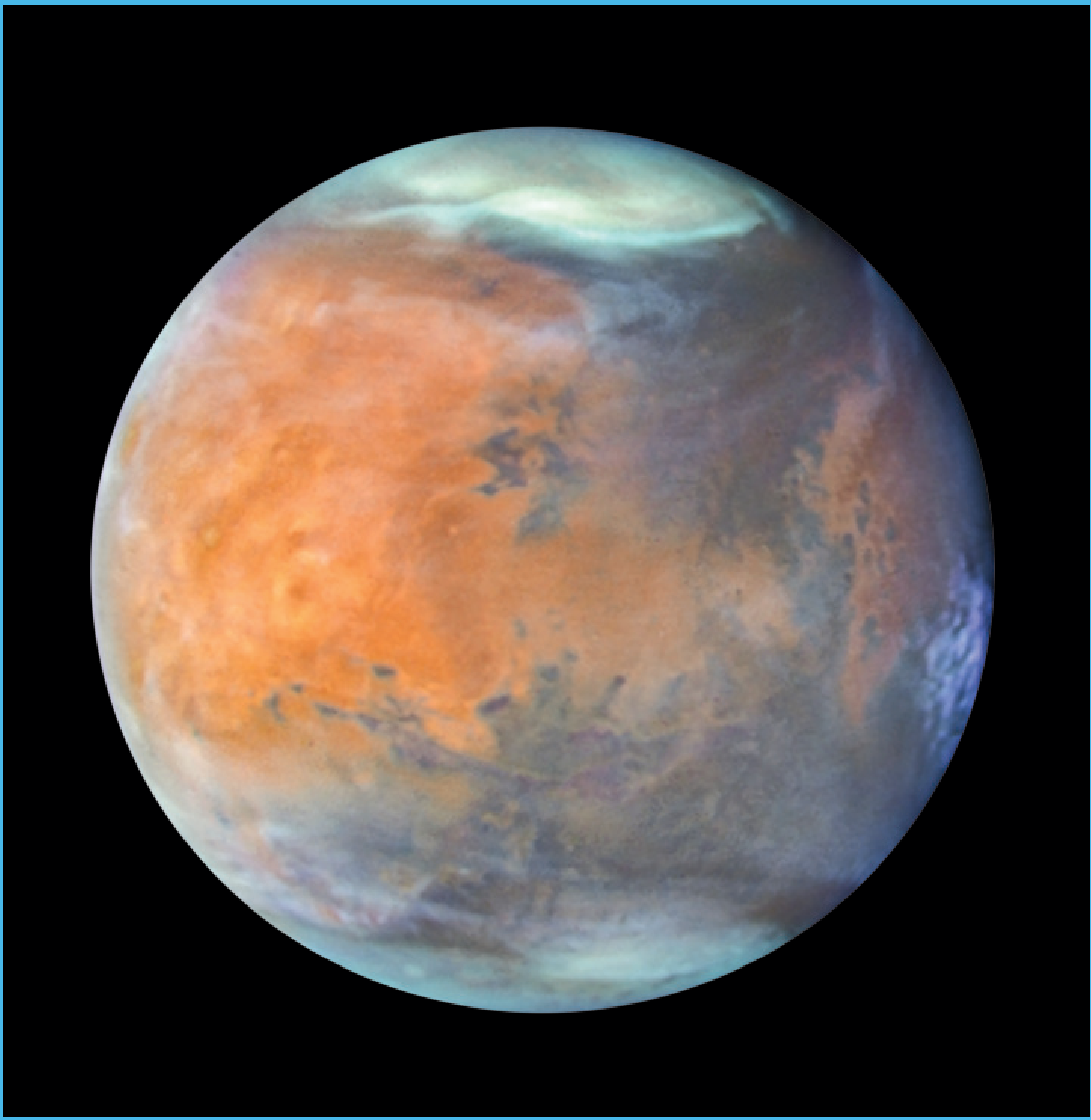
ORDER NOW TOLL FREE 24/7 ON:
1-800 733 8463

OR ORDER ONLINE AT: timepiecesusa.com
AND ENTER PROMO: SN4LAW

Pay By Check: Timepieces International Inc. 10701 NW 140th Street, Suite 1, Hialeah Gardens, FL 33018

• LUXURIOUS COGNAC BALTIC AMBER • EXQUISITE 18K GOLD PLATED STERLING SILVER • PENDANT & EARRINGS SET • 18" + 2" ADJUSTABLE 18K GOLD PLATED STERLING SILVER

Features



NASA, ESA, STSCI, IMAGE PROCESSING: JOSEPH DEPASQUALE/STSCI

ASTRONOMY

AFTER 35 YEARS, A STAR TELESCOPE SHINES ON

● The Hubble Space Telescope is often lauded for its ability to see in ultraviolet wavelengths, which for 35 years has helped astronomers unravel secrets of far-flung stellar nurseries, ancient galaxies, the chaotic environs around black holes and more (see Page 50). This UV vision also reveals interesting quirks about objects closer to home. Hubble's observation of Mars (composite UV and visible light image shown) in December unveiled a shroud of water-ice clouds that gave the Red Planet a wintry look. *— Cassie Martin*

The Next Quantum Frontier

The development of quantum mechanics a century ago was transformative. Now physicists are taking quantum technologies to new, wild heights

BY EMILY CONOVER
ILLUSTRATIONS BY LA BOCA

ONE HUNDRED YEARS AGO

on a quiet, rocky island, German physicist Werner Heisenberg helped set in motion a series of scientific developments that would touch nearly all of physics. There, Heisenberg developed the framework of quantum mechanics. At the time, quantum theory was just a loose collection of ideas about the quirks of physics on the scale of atoms.

In June 1925, the 23-year-old Heisenberg cloistered himself on the island of Helgoland, in search of relief from a nasty attack of hay fever. With pollen scant in the sea breezes, the island, 60 kilometers off the coast of Germany, was a healing refuge. It also happened to be a distraction-free place to ponder the mysteries of atoms.

Early one morning, Heisenberg had a breakthrough. “I had the feeling that, through the surface of atomic phenomena, I was looking at a strangely beautiful interior, and felt almost giddy at the thought that I now had to probe this wealth of mathematical structures nature had so generously spread out before me,” he later recounted. “I was far too excited to sleep, and so, as a new day dawned, I made for the southern tip of the island, where I had been longing to climb a rock jutting out into the sea. I now did so without too much trouble, and waited for the sun to rise.”

Physicists are now gazing upon the dawn of a new quantum era. The work of Heisenberg and his contemporaries transformed how scientists understood matter and led to new technologies based on that understanding. Current research — what some call the second quantum revolution — involves a new level of precision control over quantum systems, including building them from scratch and wielding them as needed. Scientists are bending quantum systems to their will to push technology further and unlock secrets of the universe.

This revolution is a collective effort of physicists around the world, chipping away at different quantum frontiers. Likewise, the first quantum revolution was no one-man show (see Page 60). Heisenberg’s romantic and perhaps embellished narrative was only a sliver of the tale of the birth of quantum mechanics.

Upon his return from Helgoland, Heisenberg discussed his ideas with other physicists before publishing a famously inscrutable paper that July. Later, physicists Max Born and Pascual Jordan crystallized the mathematics in a paper submitted in September and in another, in collaboration with Heisenberg, in November. And physicist Erwin Schrödinger published his own influential quantum framework in 1926, which would prove mathematically equivalent to Heisenberg’s. These and many other hands turned a confusing muddle of quantum effects into a cohesive mathematical framework.

The impact quantum mechanics has had on physics is difficult to overstate.

“The theory has ... been explored, developed and applied to a spectacular variety of phenomena and represents our basic current understanding of the nature of physical reality,” says physicist Carlo Rovelli of the Centre de Physique Théorique of Aix-Marseille Université in France. “It has explained phenomena ranging from the basis of chemistry to the color of objects, from the processes that give rise to the light of the sun to the formation of galaxies.”

Quantum mechanics also underlies innumerable technologies, including lasers, the transistors that are integral to smartphones and other miniaturized electronics, solar panels, LEDs, MRIs and the atomic clocks that make GPS navigation possible.

To kick-start that second quantum revolution, scientists must now harness some of the most beguiling aspects of the theory: superposition and entanglement.

Scientists are bending quantum systems to their will to push technology further and unlock the secrets of the universe.

In quantum mechanics, particles' positions, velocities and other qualities are described by probabilities, not certainties. That means particles can be suspended in a weird purgatory known as a superposition. For example, a particle can have a chance of being found in one place or in another location entirely — a situation often colloquially described as being in two places at once. A hypothetical feline in a superposition of alive and dead, known as Schrödinger's cat, highlights the utter peculiarity of this concept. Entanglement is another mind-boggler, in which the fates of two particles are intertwined, their properties correlated in a manner impossible in classical physics. Measuring one particle in an entangled pair instantaneously reveals the state of another, even if they're separated by a large distance.

By improving their ability to precisely manipulate superposition and entanglement, physicists are building the techniques needed to construct intricate devices such as quantum computers, which could allow for new types of calculations that are impossible with standard classical computers. Similarly, quantum sensors are beginning to enable new types of measurements, and quantum communication networks promise more secure ways to transmit information.

This revolution also has scientists closing in on some of the big mysteries of quantum physics, like whether there's a fundamental limit to how much quantum effects can scale up, and if so, where that dividing line between quantum and classical lies. And they're investigating how quantum mechanics can be melded with the general theory of relativity — Einstein's theory of gravity.

Science News spoke with five physicists pushing the quantum envelope to get their takes on the state of quantum science. These interviews have been edited and condensed for clarity.

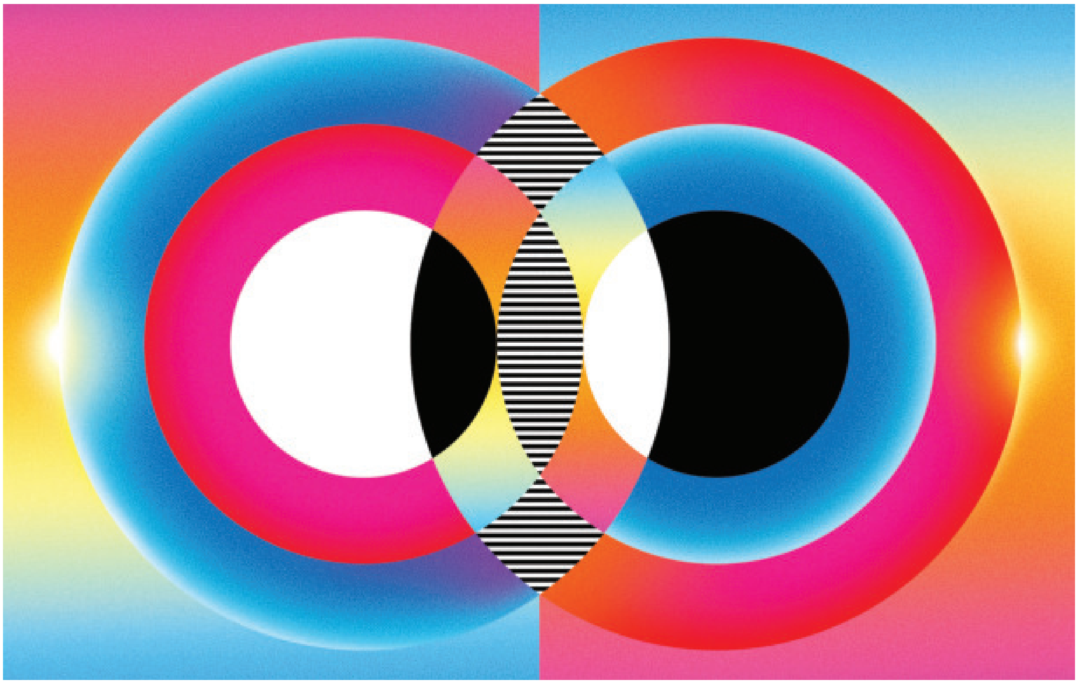
Supersizing superposition

The larger an object is, the more difficult it is for it to retain quantum properties. Interactions with the surroundings can wrench away its fragile quantumness and thrust it back into the everyday realm. Improved techniques for isolating larger objects have allowed researchers to scale up — even to borderline macroscopic objects. Some physicists believe there is a hard limit to how far that enlargement can go; others believe it can continue indefinitely.

Physicist Yiwen Chu of ETH Zurich is going big. In 2023, Chu and colleagues placed a vibrating sapphire crystal, with the mass of about half an eyelash, in a "cat state," a superposition akin to Schrödinger's cat. It's the most massive cat state ever made. Here, the superposition is in the motion of the crystals' atoms; it's as if they're moving in two directions simultaneously.

What are you excited about now?

Chu: We're looking into new physical platforms for making



quantum sensors and quantum processors. I'm getting excited about using these systems to test some fundamental physics. Quantum mechanics works really well for a lot of things, but there's still so much that we don't understand.

What are some of those questions?
Chu: Does quantum mechanics apply to macroscopic objects in our everyday world? This question has been around since the early days of quantum mechanics. We showed that these—you could call them macroscopic—crystals can, in fact, behave quantum mechanically. So the question is, just how far can we push that? I don't know if we'll ever get to the level of "cat" in my career. (And maybe it shouldn't be a cat—that probably is not very ethical.) But something really complex and macroscopic, if we can see the quantum mechanical behavior of that, I think that would be superexciting and would answer this question that's been around for such a long time.

What else are you planning to do with these devices?
Chu: We're moving toward using these systems as detectors in measurements of gravity or other forces. If you had a very weak gravitational wave that hits this object, it would excite vibrations. And then if we could detect that, then we could say, "Oh, something came by, maybe a gravitational wave." These devices would be used to detect gravitational waves at much higher frequencies than, say, the Laser Interferometer Gravitational-Wave Observatory.

Testing quantum gravity

Scaled-up quantum devices like Chu's also provide the opportunity to test how quantum mechanics interacts with general relativity. The two theories are incompatible with one another and resolving that clash tops many physicists' list of pressing problems. Vlatko Vedral of the University of Oxford is one of the physicists behind a proposal to test gravity for quantum effects. The test requires creating a superposition with an object with enough mass that its gravity will tug on another object in a superposition. That could cause the two objects to become entangled, solely due to their gravitational interaction. Confirming or refuting this effect would reveal whether gravity is quantum.

What's so fascinating about testing quantum gravity?
Vedral: Testing the quantum nature of gravity is a completely open problem. My guess is, within the next five to 10 years at most, we are going to violate general relativity. Gravity will prove to be quantum mechanical—that's my bet. But I know that there are some formidable opponents to that view. That already tells you that this is an extremely interesting experiment to do because there is a huge disagreement about what to expect.

How would you perform this test?
Vedral: You take two massive objects

and put each in a superposition of being in two different states, in two places at the same time. If gravity is quantum mechanical, each of these states will gravitationally couple to each of the other states. You are basically going to have four interactions happening simultaneously. That would be my prediction and that would be the prediction of quantum gravity. However, some people believe that gravity will force these superpositions to collapse and to go into one definitive state. And that's what the experiment is meant to test.

To me, this is possibly the most exciting experiment in physics because we've had a hundred years of huge successes, both quantum mechanically and in general relativity. But now we are able to test whether there will be a deviation in the domain where both really matter.

What's needed to perform it?

Vedral: There is a race going on; I think there are three or four teams trying to implement this proposal. You need a massive enough object. Rough calculations suggest a nanogram. It's a very challenging experiment.

Thermodynamics goes quantum

It's not just gravity that's being mashed together with quantum physics. So too is thermodynamics, the discipline that governs engines, heat and entropy, a measure of disorder. The study of quantum thermodynamics could suggest ways of making machines with increased efficiency by harnessing quantum principles. Physicist Marcus Huber of the Institute for Quantum Optics and Quantum Information in Vienna works in this field, as well as on quantum communication. That's a technique that uses quantum rules to send information securely, and it's already being demonstrated outside of laboratories.

What's the current state of quantum physics?

Huber: I am super-enthusiastic about the questions that we can more and more experimentally access. I am worried, though. People have recognized the massive commercial potential of quantum technologies. And with this recognition come the grifters and oversellers and the hype machine, which is doing a disservice to basic science and research. And with that recognition comes a geopolitical aspect, where suddenly quantum technologies and research are deemed in the interest of national security. Instead of scientists unimpededly exploring the universe together, it starts casting all of these basic science questions in terms of geopolitical advantage.

What are some of the more legitimate applications on the horizon?

Huber: There are many legitimate applications being drowned out by the noise. For one, precision measurements will be useful: We're on the verge of building more accurate clocks, more sensitive sensors. These things don't receive as much hype. Then of course, in quantum communication, in terms of data privacy and security, the applications are far advanced. We have the technological capabilities to have encrypted and secure communication between any two points. Granted, a lot of that is already possible with classical means. This extra bit of security is against very targeted attacks or against future quantum computing devices.

What quantum experiments are you excited to see in the future?

Huber: One of the big questions we had is about the fundamental limits of timekeeping. There's this old idea of the thermodynamic arrow of time, basically telling you, the way I can make a clock tick is by increasing the entropy of the universe. From a classical perspective, there's a very precise relation showing that the more precise or the more accurate you want to make a clock, the more entropy you have to dissipate. We did a bit of theory showing that quantum clocks could be exponentially more efficient. We investigated this as a fundamental question: What is the fundamental cost of letting a clock tick? But the answer also makes me excited for

The study of quantum thermodynamics could suggest ways of making machines with increased efficiency by harnessing quantum principles.

possible experiments, because that could be useful if we can create insanely energy-efficient clocks.

Putting quantum biology on the map

Physicist Clarice Aiello is on a mission to get scientists to take quantum biology seriously. The idea that quantum effects are important in living things has been proposed in a few specific areas: Quantum mechanics might play a role in photosynthesis, and birds might use a quantum compass to sense magnetic fields. But Aiello, of the Quantum Biology Institute in Los Angeles, wants to push beyond those examples. She's seized on impacts of weak magnetic fields such as Earth's. Because that field is so weak, its effect on living things can be difficult to explain via classical means. But there's potential for those effects to be explained by a concept called an electron spin superposition. The quantum property of spin makes an electron act like a tiny magnet. If that magnet's orientation is in a superposition of directions, it could result in certain chemical reactions that are sensitive to tiny magnetic fields.

Aiello is starting from the basics, aiming to show the importance of Earth's magnetic field on life before determining the cause. One of her team's recent experiments suggested that tadpoles shielded from Earth's magnetic field developed more quickly.

What could cause magnetic field effects in biology?

Aiello: The most likely explanation is a chemical reaction that depends on electron spin superpositions. If magnetic field effects in biology are explained by this type of phenomenon, the implication is that electron spin superpositions survive inside cells for long enough to be functional. The tinier the field that you want to sense, the longer those electron spin superpositions should survive with their quantumness. For example, to sense the magnetic field of the Earth, this is about 750 nanoseconds.

What's the killer experiment you hope to do?

Aiello: We want to take a cell at room temperature, learn how to "talk" to the spins of relevance inside the relevant proteins, and measure how long those spin superpositions last. If we take a tadpole cell and find that the electron spin superpositions are only alive inside the cells for 100 nanoseconds, then it's probably not what's mediating the tadpoles sensing the Earth's magnetic field. On the other hand, if you find that the quantumness of the superposition is alive for two microseconds, then all of a sudden you give credence to the idea that it is possible that the electron spin superposition mediates the sensitivity of the tadpoles to the shift in the magnetic field of the Earth.

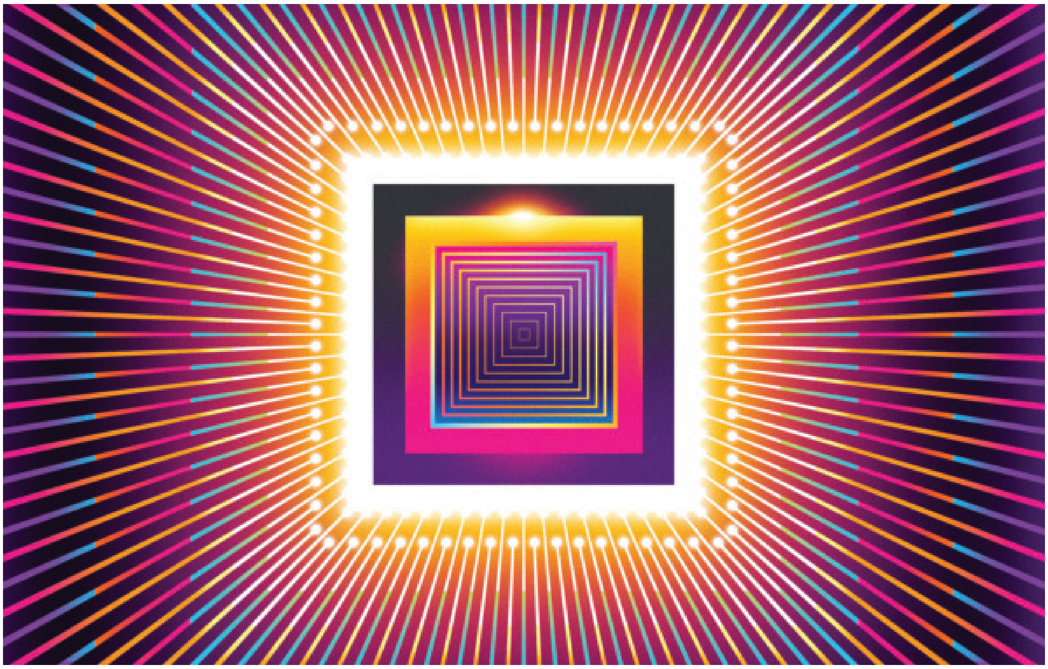
What's been the reception so far to your work?

Aiello: There is a communication problem. We try to tell people that it's not only about frogs; there's evidence that this is correct in flies, worms, bacteria. I don't think the biology community gets that. This is why I advocate for quantum literacy, because if everyone with a high school degree had a little bit of quantum, we might have more people with training in biology who might be able to make the connection between biology and quantum, or materials science and quantum. We need to have people to realize how quantum interlaces with many other disciplines.

> Quantum mechanics might play a role in photosynthesis, and birds might use a quantum compass to sense magnetic fields.

Making quantum computing work

Quantum computers garner perhaps the most hype of any quantum technology. They function based on quantum bits, or qubits. These sensitive units can be made of a variety of materials, from tiny bits of silicon to individual atoms. They perform computations like the standard bits do in classical computers, but they are designed to use the rules of quantum mechanics to calculate. Qubits are so sensitive that they're prone to errors. The promise of quantum computes rests on scientists devising ways to fix those



errors, says Barbara Terhal, a physicist at QuTech in Delft, Netherlands. A technique called quantum error correction combines multiple error-prone qubits to create a more reliable, "logical" qubit. Scientists have recently demonstrated a variety of milestones toward error-corrected quantum computers.

Why do we need quantum error correction?

Terhal: Without error correction, we can't build a quantum computer. I wouldn't say that the experiments that are being done in labs right now are quantum computers. What I call a computer is a reliable machine that can add large numbers and so on. Error correction enables the building of reliable computers which may be of interest for applications in the long term.

But it's more than that. It's also just a fundamental addition to our understanding of physics. What quantum error correction tells us is, if we very carefully control these quantum systems, we can have macroscopic quantum behavior, because these are logical qubits and they work according to the laws of quantum mechanics.

In what sense are logical qubits macroscopic?

Terhal: The traditional difficulty with creating a superposition of a cat being dead and alive has little to do with the precise size of the cat. Rather due to its size, the cat consists of many "degrees of freedom." That's a feature of many macroscopic systems comprised of many atoms. We are trying to build something which has many degrees of freedom, but each physical qubit is quite well controlled and monitored for errors. So in this sense, we get quantum behavior at a macroscopic scale. It's not literally about size.

Are there still skeptics who are not convinced that reliable quantum computers are possible?

Terhal: There will always be naysayers. It's a funny thing in quantum computing because it's a mix of complete overhype, of people who know absolutely nothing, and then there are skeptical people. It's good to be skeptical. It's not like there's one team that did error correction, and now we're there. Because at every scale-up, there may be new problems that pop up. But there's no theorem that says it's not going to be possible, and because that doesn't exist you have to try. You'll bump into the limits when they arrive, and those will be interesting challenges to overcome.

What do you think is coming in the next 100 years of quantum physics?

Terhal: Maybe the quantum ideas will have spread further, in terms of being a common language. Or maybe we'll have built a quantum computer or quantumlike computers. There will probably be new theories that don't make other theories completely wrong but widen the applicability of what we have right now. If you had asked people before the invention of quantum mechanics, they thought physics was almost done. And now we feel like maybe we have to unify quantum mechanics and gravitational forces, but other than that it's kind of done. That might very well not be correct. That's a bit too naïve. ✖

Frozen Garden

Putting plants in cold storage could protect them from extinction. But can they ever go back to life in the wild?

By Sujata Gupta

EARLY ONE MORNING IN 1985, a pair of researchers trekked into a spit of Colombian rainforest surrounded by coffee plantations. Their task was to identify all the epiphytes — plants that grow on other plants — in the forest canopy.

As Jan Wolf, a botanist now at the University of Amsterdam, measured tree trunk girth from the ground, volunteer field assistant Jan Klomp, an economist by training, clipped into a harness and climbed

up a tall tree. From his high perch, Klomp called down to say he had discovered something more familiar in the Netherlands than in the rainforest: tulips. Perplexed, Wolf scoured the forest floor for fallen flowers.

"I found a large wooden fruit with some remnant red seeds that unmistakably belonged to the Magnoliaceae, whose flowers may resemble tulips for the non-botanist," Wolf later wrote.

The seeds belonged to a previously unidentified species of magnolia tree, today fittingly named *Magnolia wolfii*. Wolf hoped that others would discover more of the same species. But in the 40 years since he and Klomp made their discovery, just six adult trees have been found, and *M. wolfii* is considered critically endangered. About half of the roughly 300 other known magnolia species are also under threat of extinction.

Scientists are now fighting to increase the plants' odds of survival. Thousands of kilometers northwest of the Colombian rainforest, cryobiologist Raquel Folgado of the Huntington Botanical Gardens in San Marino, Calif., has spent years sorting out how to deep-freeze magnolias using a technique called cryopreservation. The hope is that, if magnolias ever go extinct, the cryopreserved plants can be thawed out and reestablished in the wild.

"It's a garden on standby for things that can be lost," Folgado says, "a frozen garden."

Cryopreservation is an alternative to storing seeds in a facility known as a seed bank. Not all plants, magnolias included, are suitable for such preservation, either because they lack seeds or their seeds can't withstand conventional storage. By some estimates, more than a third of critically endangered plants fall into that second category. But to date, only about 1 percent of plants ill-suited for seed banks have been cryopreserved. Challenges to scaling up include species needing tailor-made deep-freezing recipes and high initial costs.

The need is urgent, Folgado says. "Cryopreservation gives us the possibility of storing the plant … until you need it back. That can be [in] one year, two years, 50 years or a hundred years."

But some experts caution that the time and resources spent on biobanking divert attention from preserving and restoring whole ecosystems.

↑ When scientists first identified the critically endangered *Magnolia wolfii*, the tree's flowers (one shown) were mistaken for tulips.

1 percent

The portion of plants ill-suited to seed banking that have been cryopreserved

Just as a thawed-out Captain America must live in a radically different world from the one he left behind, a cryopreserved plant may not be suited to a future environment — it may survive only if its habitat does too.

"What is it that brought us to this situation where our only solution is to strip something of all of its context and stick it in a freezer and hope for the best?" asks Hannah Landecker, a sociologist and life sciences historian at UCLA. "There is no suspension of time."

SAVE THE PLANTS

In his 1703 book, *Nova Plantarum Americanarum Genera*, Charles Plumier, a French monk and botanist for the royal court of King Louis XIV, renders in vivid detail the flowers, seeds and fruits of a plant on the Caribbean island of Martinique. Plumier named that plant "magnolia" after Pierre Magnol, a French botanist famous for systematically grouping plants into families.

PREVIOUS SPREAD: TED VANCLEAVE (MAGNOLIA) AND THE VOORHES (ICE)/GALLERY STOCK; ABOVE: M. SERNA-GONZÁLEZ

Plumier's account is among the first detailed European references to magnolias. As explorers brought those trees home with them, magnolias became a mainstay in European botanical gardens. The confines of these carefully manicured gardens demonstrated that plants could grow, and even thrive, far from home.

These gardens initially had little to do with conservation, says Xan Chacko, a feminist science studies scholar at Brown University in Providence, R.I., and an expert on the history of biodiversity conservation. Rather, the aim was to preserve the flavor of spices gleaned from distant locales or to cultivate wild plants, such as magnolias, for greater splendor.

Plant conservation became more important in the 20th century. The first seed bank, a repository of wild plant varieties related to food crops, appeared in the Soviet Union in the 1920s. Efforts to bank seeds intensified with the Green Revolution of the mid-20th century, when farmers increasingly switched to single, high-yield crops. With those monocultures imperiling wild crop varieties, scientists raced to collect the seeds of native plants.

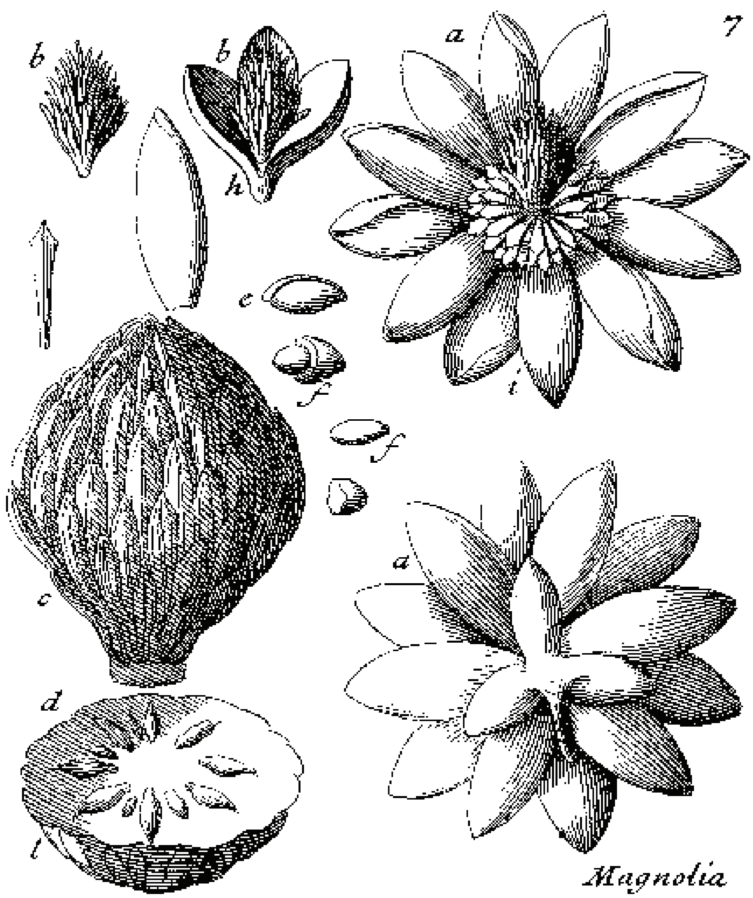
Before the 1970s, most banks stored seeds at room temperature, sociologist Leon Wolff of the University of Marburg in Germany wrote last year in *BioSocieties*. But advances in refrigeration enabled banks to keep seeds just below freezing, thus extending their shelf life. Banks gave scientists the power to bring seeds out of cold storage for planting in fields; they could also hybridize plants in myriad ways to enhance genetic biodiversity and the plants' ability to withstand changing climate conditions or disease outbreaks.

"The idea is you store possibilities for breeding," Wolff says.

Those possibilities, for instance, inspired a committee of corn breeders, geneticists, botanists and administrators to travel across Latin America in the 1950s and collect thousands of maize seeds for storage in distant banks. Today, seed banks are a pillar of plant conservation, and food plants remain the focus. The poster child for the movement is the Svalbard Global Seed Vault in Norway, home to more than 1.3 million seeds from almost 6,300 botanical species.

But seed banks were never a panacea, Wolff says. Many plants lack seeds, including species that lost them during the domestication process. Estimates vary, but some suggest roughly 8 percent of plants worldwide have "recalcitrant" seeds that retain water. Many are concentrated in tropical areas. When the seeds are frozen, the water freezes and expands, rendering them sterile.

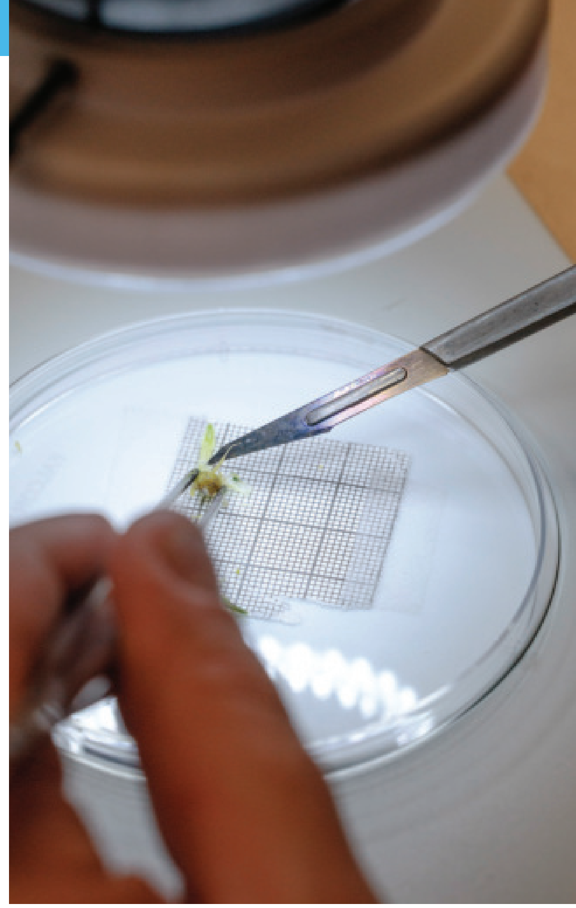
So alongside efforts to develop seed banks, scientists began experimenting with cryopreservation. Those efforts resulted in



↑ French monk and botanist Charles Plumier gave the magnolia tree its name. Plumier recorded the plant in exquisite detail in his 18th century drawings. Europeans brought magnolias and other trees back home to display in botanical gardens.

C. PLUMIER/WIKIMEDIA COMMONS

↑ At the Huntington, cryobiologist Raquel Folgado develops protocols to deep-freeze plants. For many species, she must carefully isolate a shoot tip, which can regenerate an entire plant. "This is kind of like a surgery," she says.



successfully freezing and thawing flax and carrot tissues in the late 1960s and early 1970s. But cryopreservation remained limited until the 1990s, when scientists worked out how to vitrify plant tissue, cooling it fast enough to prevent ice from forming — a process that puts the tissue in a glassy state.

Today, scientists have cryopreserved everything from apples and wasabi to ferns and willow trees. As with seed banks, cryobanks remain largely devoted to food. For example, a bank in Belgium houses 1,258 banana varieties, a bank in South Korea contains 1,158 garlic varieties and a bank in Peru stores 4,086 potato varieties.

At the Huntington, Folgado and her team have been studying how to deep-freeze avocados. The majority of commercial avocados derive from just one strain, which means a single pest could wipe out the world's supply. If that happens, Folgado says, "we will not have guacamole."

HOW TO DEEP-FREEZE LIFE

In early March, the Huntington's magnolia trees blaze fuchsia, yellow, white and orange. These vivid blossoms attract beetles for pollination.

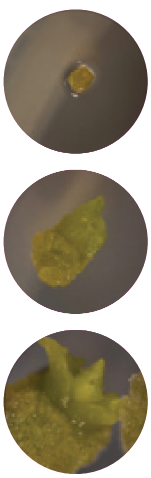
Magnolias, among the earliest flowering plants, once spread across much of the world. But the Ice Age wiped out magnolias in extreme northern regions, and the plants' range shrunk to include primarily eastern North America, Japan and China, areas where they have long been revered for their beauty and medicinal properties. Across the ages, people in China have used the bark of the *Magnolia officinalis* to treat everything from mood to stomach disorders. According to folklore, President Andrew Jackson planted *Magnolia grandiflora* seeds from his native Tennessee on White House grounds in memory of his late wife, Rachel.

Such beauty and a rich history may be reason enough to fight for magnolias. But saving plants that people don't eat, or saving biodiversity for biodiversity's sake, can be a tougher sell than saving food crops.

That mind-set irks many scientists. Plants are important for many reasons. In addition to food, for instance, a rainforest can provide medicines, raw materials and greenhouse gas mitigation as the plants inhale vast quantities of carbon dioxide. "My argument would be that there are all kinds of really important things that the rainforest does. Some of them serve humanity.... Some are important for the

Growth spurt

This once-frozen shoot tip from a magnolia tree, shown under a microscope, resumed normal growth after being thawed out.



WEEK 1

WEEK 3

WEEK 5

maintenance of life on Earth," Chacko says.

Botanical gardens, with their centuries-old collections of noncommercial but charismatic plants, are well positioned to lead efforts to maintain wild ecosystems, Folgado says. "If I didn't have magnolias at the Huntington, I could not work in helping to cryopreserve them."

Instead of traveling widely to locate specimens, all Folgado has to do is walk about 20 meters outside of her research building and snip a twig from a stubby magnolia. She can be back in her lab within five minutes — so quick that she doesn't have to worry about the sample getting contaminated or oxidizing.

In a seed bank, keeping seeds at temps slightly below a kitchen freezer, about –18° Celsius, slows the molecular movement associated with aging. But the extreme cold of cryopreservation halts the aging process altogether. Cryopreserved tissue is, from a biological standpoint at least, suspended in time.

Yet deep-freezing life is incredibly finicky. Each species's unique set of genes can react differently to the nutrients and hormones used for prepping the plant. And the scientific literature is littered with hundreds of unique deep-freezing protocols.

In her lab, Folgado demonstrates one such protocol, placing a magnolia snippet under a microscope. She painstakingly trims away the minuscule leaves furled around the shoot tip, which, like stem cells, can regenerate the whole plant. "This is kind of like a surgery," Folgado says.

Next, she bathes the shoot tip in a cocktail of minerals, vitamins, hormones and antifreeze agents. That solution is hydrophilic, or water-loving, and thus draws water out of the shoot tip. In turn, the tip absorbs other substances in the solution that are less prone than water to crystallizing when frozen.

Now the plant sample is ready for the final step, vitrification. Folgado places the shoot tip in a droplet of solution on a strip of aluminum foil and rapidly cools it. She places the now-glassy tip inside a special vial and enshrouds it with liquid nitrogen so that it can live on at –196° C. Once inside a holding tank, the deep-frozen magnolia can, in theory, persist in a suspended state forever.

As a proof of concept, Folgado has removed cryopreserved shoot tips from storage, thawed them out and grown them into little plants. When they're tall enough, she'll replant them on the Huntington's grounds.

> "Cryopreservation gives us the possibility of storing the plant … until you need it back. That can be [in] one year, two years, 50 years or a hundred years."
>
> — RAQUEL FOLGADO

A PLANT IN ISOLATION

The Huntington is just eight kilometers south of Altadena, a neighborhood leveled by the wildfires that raged through parts of Los Angeles earlier this year. With climate change making such fires exponentially worse, single catastrophes can now wipe out entire ecosystems, making recovery nearly impossible.

Such risks point to the need for biobanks, proponents argue. Keeping seeds and tissues in cold storage can be an economical way to preserve botanical biodiversity.

Cryobanking has high upfront costs; deep-freezing a single plant variety ranges from $42 to $1,500 depending on tissue type and local labor costs, researchers estimated

↓ The Svalbard Global Seed Vault in Norway is a secure backup facility to protect crop diversity. But not all plants can be seed banked.

LISE ASERUD/NTB SCANPIX/AFP/GETTY IMAGES last year in the *Annual Review of Plant Biology*. Once frozen, though, maintenance costs drop to just $1 to $2 per year. Researchers estimate that the investment it takes to cryopreserve a single species should pay off within 10 to 15 years.

But cost is only one consideration. What happens when a plant has been isolated from the natural world for years, decades, centuries or more?

"What happens if you grow a magnolia tree in 250 years and there are [no] beetles?" Landecker asks. "You have a plant that will grow once and cannot reproduce."

That concern isn't totally hypothetical, says botanist Marcela Serna-González of Tecnológico de Antioquia in Medellín, Colombia. In 2006, one of Serna-González's students helped transplant *Magnolia silvioi* trees to Medellín from elsewhere in Colombia. One of those trees wound up at the city's botanical garden. The tree appears healthy. "It produces beautiful flowers, beautiful fruits," Serna-González says, but "not a single seed."

The large beetles that naturally pollinate the trees aren't present. And though bees have taken up magnolia pollination in some other parts of the world, including at the Huntington, pollination is more specialized in the tropics. Bees in Medellín have not shown interest in the isolated magnolias.

"It's easy to forget that [conservation] is not just about preservation of certain plants but their entire life worlds," Wolff says.

Specimens in cryobanks are genetically frozen in time. Given the rapid pace of climate change, banked plants and their life worlds can start getting out of sync within years, research suggests. For instance, over the last 20 years, the mountainous Apennines region of Italy has grown drier and warmed by 0.6 degrees C. Scientists simulated those new climate conditions in a lab and compared the growth of alpine plants germinated from ancestral seeds collected in the early 2000s with that of seeds from the same type of plant collected in the last couple years.

Plants grown from the recent seeds were smaller than the ancestral plants — a size reduction that may enable the plants to conserve more water and reduce evapotranspiration, the team reported in 2023 in *Biological Conservation*. In other words, the plants that stayed on the mountain had adapted to a more arid life.

Both seed banks and cryobanks shift people's focus from saving ecosystems in the present to preserving bits and pieces of those systems for an unknowable future, Chacko says.

Those concerns have prompted some scientists, farmers and activists to turn to alternative ways of preserving diversity, such

36 percent

The portion of critically endangered plants with seeds that can't be banked

↓ **The narrow-leafed campion (shown) lives in Siberia. Scientists grew an ancient version of the plant from fruits buried in permafrost.**

PIEMAGS/NATURE/ALAMY STOCK PHOTO

as living seed banks. Unlike large seed banks, where access is often limited to scientists, living seed banks encourage, or even require, growers to regularly deposit and take out seeds. Farmers then grow crops under varying conditions and select for those that fare the best. That keeps the diversity alive.

For example, as part of Brazil's conservation strategy, the government collaborates with small-scale farmers, who get seeds from a handful of related and under-utilized crops. The farmers experiment to see which varieties, or combinations of those varieties, grow best. Those seeds then go to other farmers and the plants to markets and restaurants.

Adherents of saving biodiversity in the field tend to dispute the idea that a plant can be isolated from its ecological and cultural context and stored in a museum for later use, Chacko says. The belief that plants can thrive without their surroundings, she adds, "is the science fictional element of the seed bank."

LONG ODDS

But sometimes science fiction can have some bearing in reality. Research hints at the possibility that scientists generations from now might be able to thaw out cryopreserved plants and reestablish them in the wild.

On occasion, scientists have discovered ancient plants or seeds frozen in nature and then grown them. In one case, squirrels buried the fruits of a small Arctic plant known as the narrow-leafed campion (*Silene stenophylla*) in burrows in Siberia some 32,000 years ago. Russian scientists found some of those fruits, which had been encased in permafrost. They extracted tissue and successfully coaxed the ancient plant into flowering, the researchers reported in 2012.

The feat demonstrated that long-frozen plants can be thawed and regenerated.

In another instance, reported last year, a team of Italian scientists collected some 20,000 seeds from 26 species stored in herbarium collections in Italy and Belgium. Some of those seeds, such as those from the *Silene flos-cuculi*, a wildflower with ragged white or purplish petals, were over a century old. The team helped those seeds germinate using a variety of techniques known to help plants grow. Roughly 1 percent of seeds, drawn from 10 species, germinated, the team reported in *Taxon*.

Many of these plants are related to now-extinct species, so it's another hint that seed banking or cryopreservation might work to bring back long-lost plants, says Giulia Rocchetti, a botanist at Roma Tre University in Italy. The fact that seeds stored in such poor conditions still grew is amazing, she adds. Imagine what that means for resurrecting plants stored in optimal conditions.

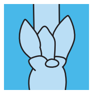
Despite the long odds of successfully transplanting and maintaining a thawed-out plant in some future ecosystem, cryopreservation and seed banking research is worthwhile, Folgado argues. Even if the whole plant never winds up back in the wild, the genes that have been saved may one day prove crucial for medicines. Or, she adds, perhaps the hormones used to cryopreserve plants could point to ways for scientists to encourage plants to grow outside their normal ecological range — think warm-weather-loving avocado trees thriving in drizzly, cold Seattle — no genetic modification required.

"I always question myself whether this can have a real value or not," Folgado says. "What I know is that there will be some things that will have a big value. If we don't preserve them, we will not know."

Reflecting on the Italian experiment, she says: "Even if you have 1 percent germination, that's more than 0." ✖

Plant parts

When seeds aren't viable for banking, scientists look to other plant tissues to cryopreserve.



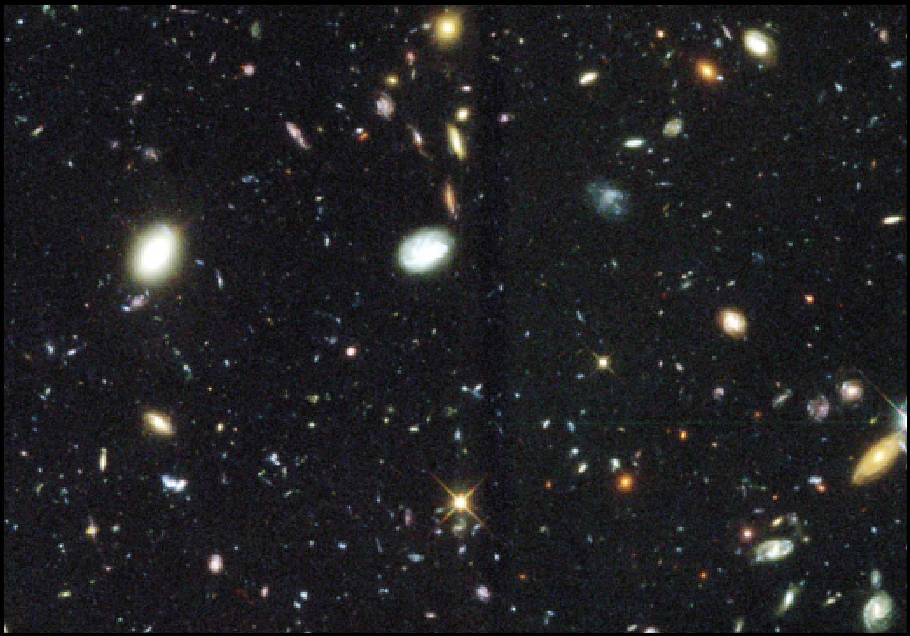
DORMANT BUD
Many woody species in temperate locales send their buds — which can develop into a shoot, leaf or flower — into a dormant state in winter. Dormant buds are a suitable target for cryopreservation because of their natural resistance to cold, and scientists have succeeded with a range of species, from raspberry bushes to mulberry trees.

SHOOT TIP
The small growing points in plants, shoot tips consist of tissue that, like stem cells, can regenerate the entire plant. Scientists have cryopreserved a variety of species using shoot tips, including those that reproduce asexually, like tubers and bulbs.

EMBRYO
Even if a plant's entire seed isn't amenable to seed banking, part of it may be stored through cryopreservation. For citrus fruits, coffee plants and some other species, scientists have removed the embryonic axis, which contains the rudimentary root and shoot, from the seed and frozen it.

B. PRICE

The longevity of the Hubble Space Telescope is thanks in large part to a series of five missions to repair and update components from 1993 to 2009. Here, astronauts replace sensors during a spacewalk in 1999.



↑ In 1995, Hubble took this composite picture of what, until then, looked like mostly empty space. Scientists were astounded to discover thousands of previously unseen galaxies in different stages of evolution.

HEROIC HUBBLE

The space telescope has been observing the universe for 35 years. It's still revolutionizing astronomy

By Katherine Kornei

OPPOSITE: NASA; THIS PAGE: R. WILLIAMS/STSCI, THE HUBBLE DEEP FIELD TEAM, NASA, ESA

After 35 years, the Hubble Space Telescope is still churning out hits. In just the last year or so, scientists have used the school bus–sized observatory to confirm the first lone black hole, reveal space rocks created by a NASA asteroid-impact mission and pinpoint the origin of a particularly intense, mysterious burst of radio waves.

These findings are a testament to the fact that there's still plenty of science for the telescope to do. And there are some observations that simply can't be done with any other telescope, including Hubble's younger sibling, the James Webb Space Telescope.

To date, Hubble has observed more than 100 million objects ranging from comets in our solar system to dying stars in the Milky Way to faraway galaxies. Researchers have collectively written more than 21,000 peer-reviewed publications using Hubble data (this astronomer–turned–science journalist wrote two of them).

Simply put, "it's been a huge asset," says Peter Senchyna, an astronomer at Carnegie Science Observatories in Pasadena, Calif.

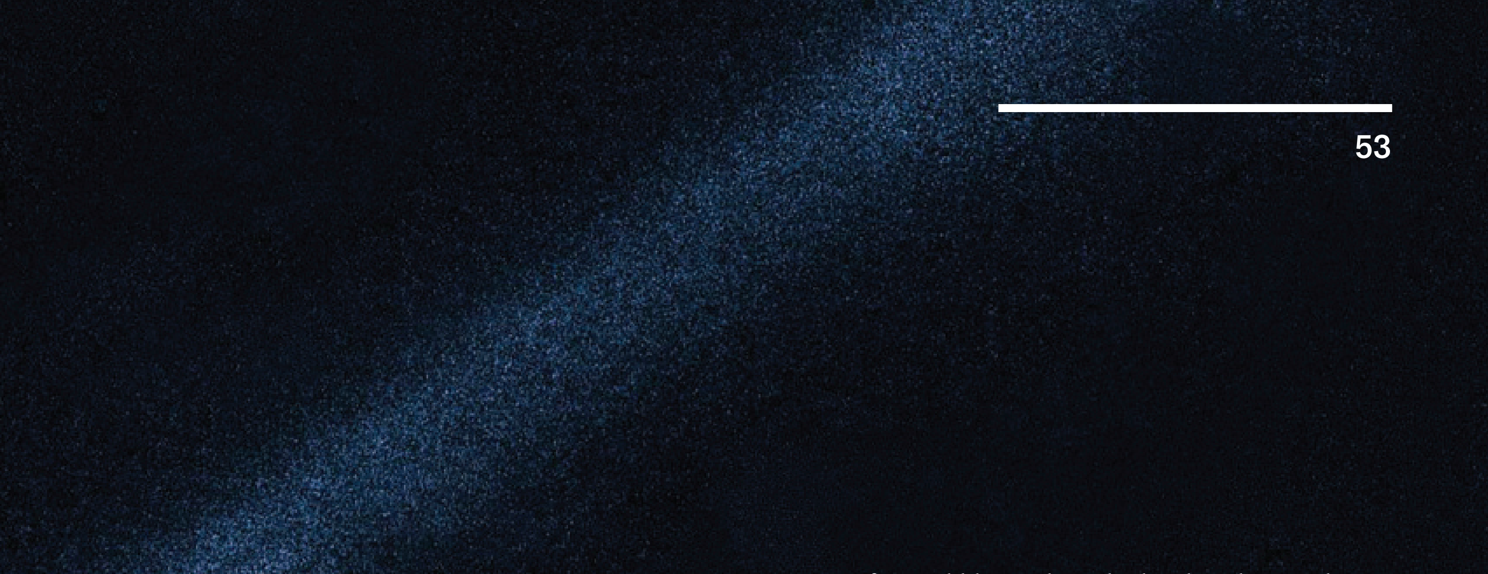
Astronauts aboard the space shuttle *Discovery* shepherded Hubble into low Earth orbit in 1990. It's been there ever since, at an altitude of roughly 515 kilometers above Earth's surface. From that vantage point, Hubble has a nearly unobstructed view of the cosmos, largely free of the absorbing and blurring effects of our planet's atmosphere.

A key attribute that differentiates Hubble from other telescopes is that it can collect high-resolution data in the ultraviolet part of the electromagnetic spectrum. That's crucial for understanding celestial objects that have temperatures measuring tens of thousands of degrees Celsius or more, such as massive stars and the chaotic regions near black holes.

UV light is "telling us something about the hottest objects," Senchyna says.

Telescopes on the ground cannot observe

↑ In 2010, astronomers discovered something puzzling in the solar system's asteroid belt: an asteroid with a cometlike tail of dust. Hubble data revealed that this object, called P/2010 A2, probably formed during the collision of two asteroids. It was the first time scientists had observed the aftermath of such a crash.



NASA, ESA AND D. JEWITT/UCLA

UV light from space because our planet's atmosphere blocks most of it. (That's a good thing, given that UV rays can cause cells to mutate and trigger cancer.) While some other space-based telescopes are sensitive to UV light, their images are much fuzzier; Hubble can resolve objects one-tenth the size of what these other UV telescopes can. And the James Webb Space Telescope, also renowned for spectacular images, isn't sensitive to UV light at all. (It excels at observing in infrared, which allows it to probe dust-enshrouded objects and particularly distant galaxies that formed not long after the Big Bang.)

"At shorter UV and optical wavelengths, [Hubble] is still the best thing we've ever done as a species in terms of sensitivity and resolution," says Kevin Hainline, an astronomer at the University of Arizona's Steward Observatory in Tucson.

Every year, hundreds of scientists propose new observations using Hubble, but only about 20 percent of those proposals are approved. Aoife Brennan, an astronomer at Trinity College Dublin, is among the lucky few. She studies debris disks, amalgams of rock and dust akin to our solar system's Kuiper Belt, in other planetary systems. And on April 24 — exactly 35 years after Hubble was launched — the telescope began observing one of Brennan's targets: a debris disk roughly 200 light-years from Earth. Brennan hopes that the new data will help reveal the prevalence of gas in debris disks, which may hold clues as to how planets form.

Even people who don't study the sky for a living appreciate Hubble, Brennan says. "When I say that I work with Hubble data, all of my friends and family immediately know what that is," she says. "We're very used to seeing Hubble images."

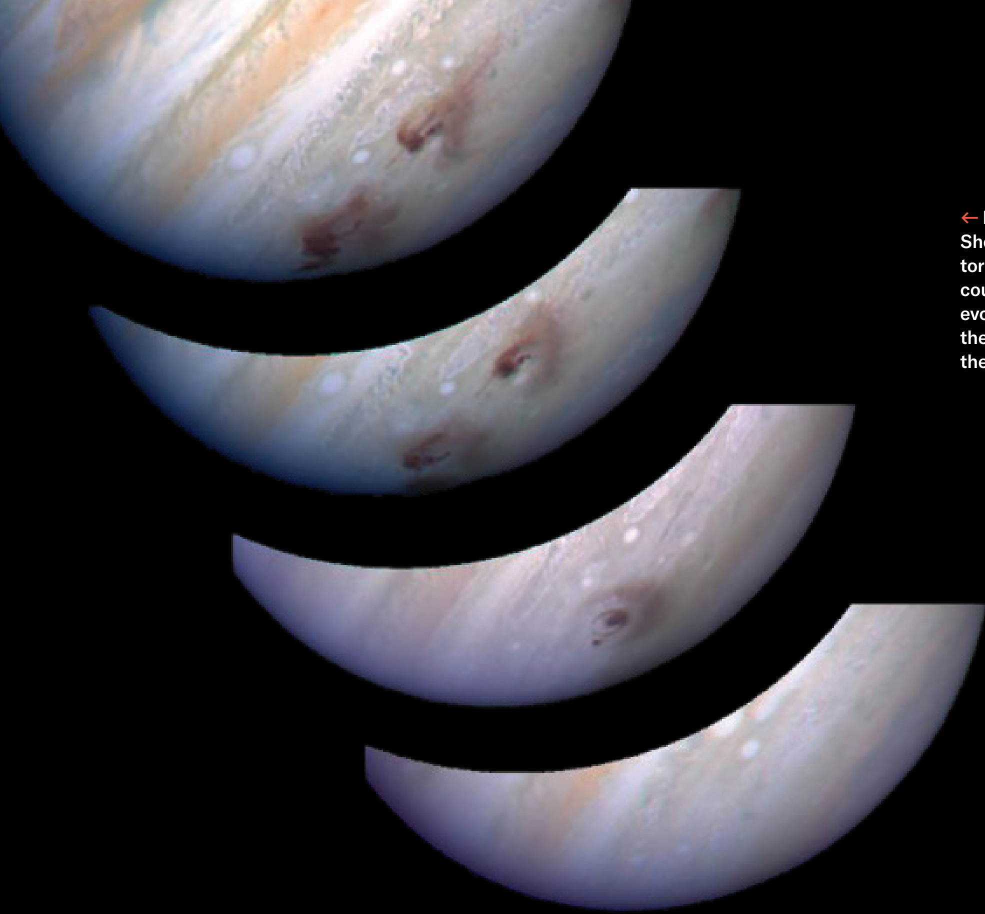
Joe DePasquale helps to create some of those images. DePasquale is the principal science visuals developer at the Space Telescope Science Institute, the Baltimore-based organization that coordinates Hubble's science operations. He and colleagues select, process and colorize Hubble observations for release to the press and the general public.

Raw data are collected at UV, visible and near-infrared wavelengths and must be corrected to account for artifacts caused by, for instance, cosmic rays, DePasquale says. "I take data from the telescope and turn it into beautiful color images."

Those images tend to stick in one's brain. Senchyna remembers seeing Hubble pictures of comet Shoemaker-Levy 9 crashing into Jupiter as a child in 1994. "That was the sort of thing that got me hooked on astronomy," he says. Hubble can inspire a sense of curiosity and wonder about the universe, he adds, and that's a powerful thing: "That's a huge part of why we need to be funding these flagship observatories."

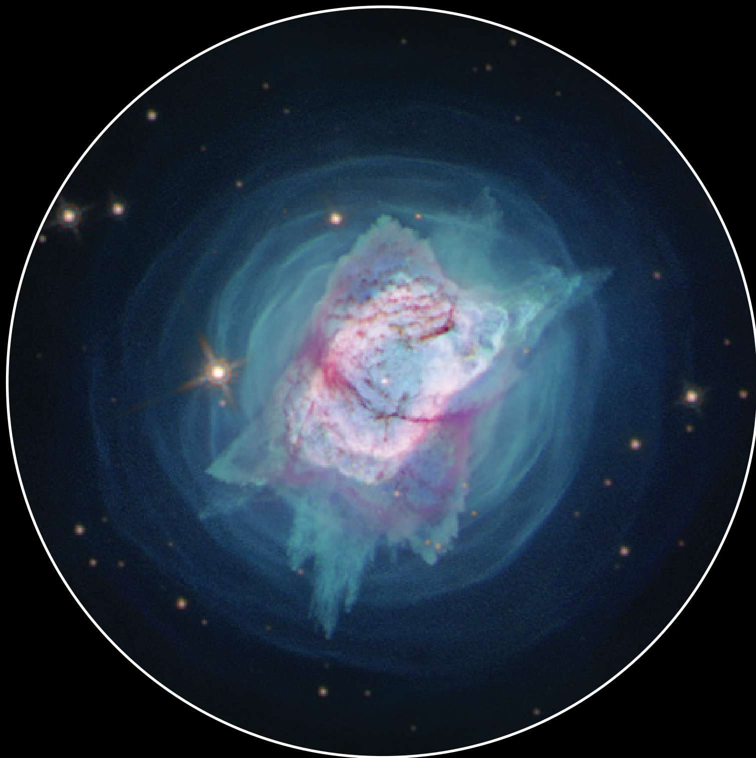
On the pages that follow are a few of the many astounding Hubble images from the last 35 years that have informed and inspired both scientists and the general public alike. ✖

Katherine Kornei is a freelance science journalist based in Portland, Ore.



← In 1994, more than 20 fragments of comet Shoemaker-Levy 9, which Jupiter's gravity had torn apart, collided with the planet. Over the course of several days, Hubble revealed the evolution of this titanic collision, starting with the bottom right image. The darkened swirls in the top three images mark impact sites.

In a series of observations, Hubble captured auroras near Jupiter's north pole, which glow brightly at ultraviolet wavelengths in this composite image. Hubble revealed that Jupiter's strong magnetic field makes auroras on the gas giant particularly intense and long-lasting, unlike those on Earth. →



↑ A dying star in the Milky Way, nicknamed the Jewel Bug nebula for its resemblance to the vivid insect, sloughs off layers of gas and dust. Researchers think that the intricate shapes seen in this image may be due to the presence of a stellar companion merging with the dying star.

FROM LEFT: NASA, R. EVANS, J. TRAUGER, H. HAMMEL AND THE HST COMET SCIENCE TEAM; NASA, ESA AND J. NICHOLS/UNIV. OF LEICESTER (ACKNOWLEDGMENT: A. SIMON/GSFC/NASA AND THE OPAL TEAM); NASA, ESA AND J. KASTNER/RIT

↑ NGC1850 is an agglomeration of stars held together by the stars' mutual gravity. This globular cluster resides in the Large Magellanic Cloud, a galaxy neighboring the Milky Way. Unlike typical globular clusters, this grouping contains relatively young stars, creating a cache of stars born across two generations. Hubble observed NGC1850 over a range of wavelengths of light, but ultraviolet observations were especially useful in detecting the youngest, hottest stars, which appear blue in this image.

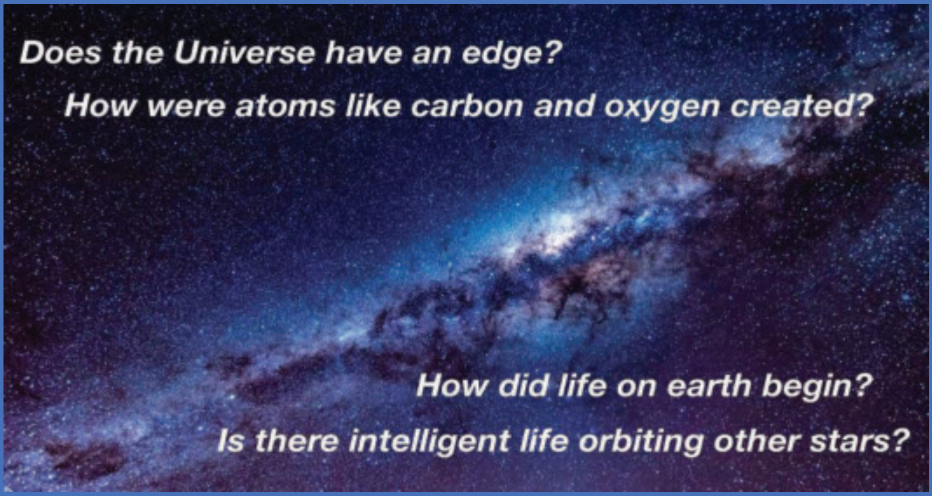
Known officially as NGC4826, this spiral galaxy is also dubbed the Black Eye galaxy due to the dark band of dust covering part of it. Turbulent motions of gas within this galaxy are responsible for the birth of new stars (blue) that are visible in this image. →

FROM TOP: NASA, ESA AND N. BASTIAN/DONOSTIA INTERNATIONAL PHYSICS CENTER, GLADYS KOBER/NASA AND CATHOLIC UNIVERSITY OF AMERICA (PROCESSING); HUBBLE/ESA AND NASA, J. LEE AND THE PHANGS-HST TEAM (ACKNOWLEDGMENT: JUDY SCHMIDT)

Adventures in Astronomy: Approaching Infinity

Tuesdays, 7:30 PM-9:00 PM, Eastern Time, over Zoom

June 10, 2025 thru September 30, 2025



Dr. George Roush will explore

1. Geo-centrism & the Copernican Revolution
2. Our sun & its planets
3. The birth, evolution & death of stars
4. Telescopes
5. Our Milky Way Galaxy
6. Other galaxies & their evolution
7. Dark matter: What is it?
8. Dark energy & the expanding universe
9. Relativity & black holes
10. The Big Bang: The beginning of spacetime
11. Is intelligent life orbiting other stars?

Email: astronomy.teacher0@gmail.com; Telephone: (203) 536-0006

To learn more and to register visit astronomyteacher.net.

Adventures in Astronomy is a non-profit 501(c)(3) organization.

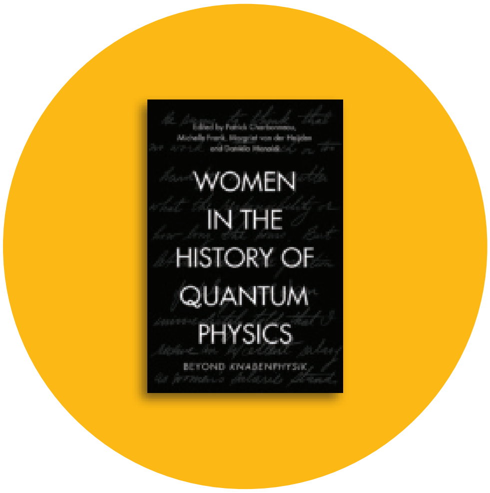
Curiosities

RICHARD MASCHMEYER/ALAMY STOCK PHOTO

ARCHAEOLOGY

IF THESE WALLS COULD TALK

● Tourists flock to Utah's San Rafael Swell each year to gander at the Head of Sinbad (one panel shown), cliffside pictographs painted by Indigenous people thousands of years ago. But at this and other rock art sites across the western United States, there's more than meets the eye. Some walls naturally focus sound waves so that a person speaking at a normal volume near one panel can be heard clear as a bell at another a ways away. Inspired by this "whisper gallery" phenomenon, scientists are crafting new modes of private communication (see Page 64). *— Cassie Martin*



THE UNSUNG WOMEN OF QUANTUM PHYSICS

By Emily Conover

WOMEN IN THE HISTORY OF QUANTUM PHYSICS |
Edited by Patrick Charbonneau, Michelle Frank, Margriet van der Heijden and Daniela Monaldi
Cambridge Univ. | $49.99

In the 1920s, when quantum mechanics was young, physicists Jane Dewey and Laura Chalk performed some of the first experimental tests of the theory, based on a phenomenon called the Stark effect. Later, famed quantum physicist Werner Heisenberg gushed over the beauty of a Stark effect measurement by a male colleague, physicist John Stuart Foster. In doing so, Heisenberg neglected the contributions of both women.

That obscuring of women's contributions is common in the history of quantum mechanics, the theory that describes the physics of atoms and other small-scale phenomena. As scientists mark 100 years since the development of the theory's foundations, a new book, *Women in the History of Quantum Physics*, provides a crucial accounting of the lives of those unsung trailblazers. With nuance and care, the book delves into the oft-forgotten stories of 16 female quantum physicists, each one thoroughly researched by a different author or authors.

In its early years, quantum mechanics was known as *Knabenphysik*, German for "boys' physics." Women's contributions were often attributed to their male supervisors or otherwise erased. And women were cut out of the old boys' clubs through which male physicists championed one another's work. For instance, Dewey's and Chalk's measurements of the Stark effect — in which the wavelengths of light an atom absorbs and emits are altered by an external electric field — came to similar conclusions as Foster's. But while Foster went on to a lengthy career as an esteemed physicist, Chalk — who was Foster's Ph.D. student — and Dewey eventually left academic research. Rampant discrimination often impeded or cut women's careers short. Dewey struggled to secure a permanent position because few wanted a woman on staff. Chalk was denied a scholarship based on a false rumor that she was engaged to be married. At the time, many wedded women were expected to give up their jobs.

Women are still woefully underrepresented in quantum physics. Conventional narratives of the field's history, which champion mostly male "geniuses," may have something to do with it, the book's editors suggest. But regardless of sex, it's not necessary to be an exceptional genius to contribute to the field. The book intentionally skips over legendary women scientists, such as Marie Curie. Celebrating them may paradoxically reinforce the harmful lone genius trope that keeps women out of

Regardless of sex, it's not necessary to be an exceptional genius to contribute to quantum physics.

the field, the editors write. Instead, the book highlights those who have remained in the shadows, including American physicist Katharine Way, creator of a crucial database of atomic and nuclear data, and Carolyn Parker, a Black American physicist who worked in military research and at Fisk University in Nashville during the oppressive Jim Crow era.

Scientific concepts in the book are probably most suited to an audience with a physics background. Equations pepper the text, and important concepts, such as the Bohr model of the atom, are often not explained. Still, the compelling life stories of the women can be understood by anyone. ✖

WHY 'SILLY' SCIENCE IS VALUABLE

By Karen Kwon

THE SALMON CANNON AND THE LEVITATING FROG |
Carly Anne York
Basic Books | $30

What's the purpose of your study? It's the question many basic-science researchers dread. And it's one that Carly Anne York received about 10 years ago as a Ph.D. student studying squid biomechanics. When a fellow Virginia Zoo volunteer, a retired army officer, probed why taxpayer dollars should be spent on "silly science," all York could do was mutter about the inherent value of knowledge.

Today, York, an animal physiologist at Lenoir-Rhyne University in Hickory, N.C., recognizes that immediate application is not the goal of basic science. Rather, it seeks to fundamentally understand natural phenomena. That doesn't mean the research is worthless. As York details in *The Salmon Cannon and the Levitating Frog*, projects that could seem silly or useless can unwittingly lead to scientific advances that better our lives.

Take sea fireflies. Studying the tiny crustaceans' mysterious glow had been considered difficult and unpredictable. But in 1956, Japanese chemist Osamu Shimomura isolated a molecule behind the phenomenon. That feat attracted the attention of a U.S. researcher, who recruited Shimomura to help study luminescent jellyfish. The team uncovered two proteins responsible for the jellyfish's glow—aequorin and green fluorescent protein. The groundbreaking work revolutionized biological research and medicine. Doctors now use green fluorescent protein to better visualize and avoid nerves during surgery, as well as to track the spread of cancer cells in the body. The discovery earned Shimomura the 2008 Nobel Prize in chemistry.

The book reminds us that it's impossible to predict the path and outcome of basic-science projects. It is an especially timely reminder as the U.S. government cuts science funding today. ✖

Innovators of Tomorrow

On March 11, Society for Science and Regeneron announced the top winners of the Regeneron Science Talent Search (STS), the nation's oldest and most prestigious science and math competition for high school seniors. Now in its 84th year, the competition celebrates and rewards young STEM innovators whose research is pushing the boundaries of discovery and addressing today's most pressing challenges.

Matteo Paz (center), 18, of Pasadena, Calif., won first place and $250,000 for designing a machine learning algorithm to efficiently comb through 200 billion entries of raw data from NASA's NEOWISE, an infrared telescope that hunted asteroids and comets. By analyzing tiny changes in infrared radiation, the AI sorted the celestial objects into 10 classes. Paz found 1.5 million potential new objects, including supermassive black holes, newborn stars and supernovas.

Second place and $175,000 went to **Ava Grace Cummings** (left), 18, of Smithfield, N.C., for her research on STAC3 disorder, a muscle condition that predominantly affects the Lumbee Native American Tribe. Third place and $150,000 went to **Owen Jianwen Zhang** (right), 18, of Bellevue, Wash., who solved a long-standing math problem about objects called 3-uniform hypergraphs. These students, along with 37 other finalists spent a week competing in Washington, D.C., They met with top scientists, presented their research to the public and visited Capitol Hill, where they met with lawmakers and their staff, including Sen. Ted Cruz (Texas), Sen. David McCormick (Pa.), Sen. Patty Murray (Wash.), Sen. Adam Schiff (Calif.), Rep. Vern Buchanan (Fla.) and Rep. Deborah Ross (N.C.).

The winning students were selected from nearly 2,500 entrants from 795 high schools across 48 states, Washington, D.C., American Samoa, Guam, Puerto Rico, and 14 other countries. U.S. citizens living abroad are eligible to apply.

Each year, Regeneron STS identifies future leaders in science and distributes $3.1 million in total awards to students and their schools. On January 8, the Society and Regeneron announced the top 300 scholars. Each student received $2,000, and their schools also received $2,000 each for their support. On January 23, the top 40 finalists were named and collectively awarded $1.8 million.

With projects spanning artificial intelligence, health and space exploration, the 2025 scholars, finalists and winners reflect the best young scientists in the nation.

SOCIETY FOR SCIENCE

WWW.SOCIETYFORSCIENCE.ORG

Society for Science is a nonprofit organization best known for our award-winning journalism, world-class STEM competitions and STEM Outreach 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.

It's a matter of size

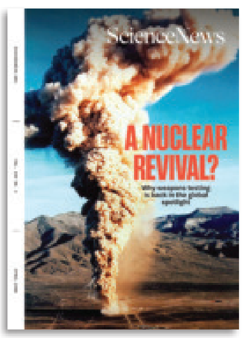
● *A January executive order by President Donald Trump designates people as female if they make the "large" reproductive cell (the egg) and male if they make the "small" one (the sperm). But the human sexes don't fit neatly into a male–female binary due to factors such as genetics and hormones, senior molecular biology writer Tina Hesman Saey reported in "The real biology of sex."*

Reader Root Gorelick, a biologist at Carleton University in Ottawa, appreciated the feature and wrote in to add some nuanced points.

Reproductive cells change throughout development, so a sex definition based on size is tricky. For instance, in developing embryos, the progenitors of eggs and sperm, known as primordial germ cells, typically form before ovaries and testes do. PGCs migrate to the gonads later in development. These cells are huge, and they start off roughly the same size, regardless of the type of gonad an embryo forms, Gorelick notes.

Reproductive cells change throughout development, so a sex definition based on size is tricky.

April 2025



After gonads form, meiosis, the process of cell division that produces sperm and eggs, further complicates things. In human females, meiosis produces one large egg cell and two small infertile cells called polar bodies. "Things are weirder in males," Gorelick continues. Before meiosis in males, a PGC replicates its genome several times without splitting up into product cells. So one huge cell with multiple nuclei is produced, Gorelick says. That huge cell then jettisons multiple tiny sperm cells, and the remaining cytoplasm is left as a large "residual body" cell without nuclei.

Roughly speaking

● *A study of nearly 100 human brain samples shows that micro- and nanoplastics, or MNPs, in the brain have increased substantially over time, senior neuroscience writer Laura Sanders reported in "Plastic shards permeate human brains."*

The story stated: "From 2016 to 2024, the median concentration of MNPs increased by about 50 percent, from 3,345 micrograms per gram to 4,917 micrograms per gram — roughly three bottle caps worth of plastic."

A couple of readers were confused about what the bottle cap comparison referred to.

The "roughly three bottle caps worth of plastic" refers to the total amount of plastic estimated to be present in an entire human brain. That's about 4,917 micrograms multiplied by the average weight of a brain in grams, Sanders says.

But this comparison comes with caveats. Brains vary in weight, as do bottle caps. Also, the study measured MNPs in samples from the brain's frontal cortex, Sanders says. It's not clear whether plastic loads differ depending on brain region.

Tip of the hat

● Reader Diana Lutz greatly enjoyed the April issue's three features, which covered the debate around the revival of nuclear weapon testing, the complexity of biological sex and the uncertain promises of the carbon credit market. "All three articles are on important topics that are rarely examined at such depth," Lutz wrote. "In each case, I had lingering questions the articles resolved. Kudos!"

Correction

✖ April's "Spooky lights could be earthquake farts" mistakenly described radon as a flammable gas. Indeed, it is an inert gas.

AUDIO ENCLAVES COULD DELIVER PRIVATE MESSAGES OUT IN THE OPEN

BY ANANYA PALIVELA

Controlling sound has long been a staple of science fiction and fantasy. In *Dune*, the cone of silence allows characters to converse privately, even in open spaces. The eerie billboards of *Blade Runner 2049* whisper advertisements into the ears of those passing by. In the real world, quirks of architecture, intentional or not, can direct where sound goes. In the U.S. Capitol's hall of statues, for example, a whisper can travel silently across the room from one spot to another. The sound waves interact with curved surfaces to focus the audio. Now, scientists are looking to precisely control sound, perhaps one day resulting in a world without earbuds, but directing sound waves is a challenge.

The frequencies that humans can hear, 20 to 20,000 hertz, tend to diffuse more easily than higher-frequency ultrasound, which is why conversations can be overheard.

In 2019, researchers directed sound using lasers that convert light into sound when absorbed by water vapor in the air. When the laser beam was stationary, precise localization was difficult; the sound could be heard anywhere along the beam. Adding a rotating mirror localized sound more, but the method couldn't transmit detailed audio.

Another approach relies on ultrasonic waves. Though inaudible, they can help target audio thanks to an effect known as nonlinear interactions. When two ultrasonic waves meet, they "add" together to create a higher-frequency wave. The converging waves also "subtract" each other to create a lower-frequency wave that's the difference between the two, which can fall within the range of human hearing.

This is what happens when water hits hot oil in a frying pan; tiny steam explosions generate ultrasonic waves, which mix in the air to create the sizzle we hear.

In the 20th century, the U.S. military took advantage of the effect to develop speakers that can direct sound along a path. Eventually, companies like Holosonics commercialized directional speakers. As with the laser, however, the audio isn't fully private because it can be

PETER CROWTHER

heard along the sound beam's path.

But recently, researchers developed private "audio enclaves." "It is like wearing an invisible headset," says Yun Jing, an acoustics researcher at Penn State. If you stand in the right place, you can hear a voice or music, while someone nearby hears nothing at all, Jing and colleagues reported in the *Proceedings of the National Academy of Sciences*.

They achieved this marvel using acoustic metasurfaces, materials engineered to have tiny repeating structures to manipulate sound in ways that natural materials can't. "A metasurface is a lens that's thinner than the wavelength of the sound waves it manipulates," says Michael Haberman, a mechanical engineer at the University of Texas at Austin. Like lenses for light, acoustic metasurfaces can bend, shape and direct sound by changing the wave's shape.

Jing's team 3-D printed acoustic panels with zigzag air channels. Adjusting the path length of each channel let the team steer ultrasonic waves into curved paths. The team then covered two speakers with thin sheets of this metasurface to bend the ultrasonic beams toward each other as they propagated through the air. At the point of intersection, nonlinear interactions transformed the waves into audible sound that could be heard at only this spot.

"The sound quality isn't great; we used a $4 transducer," Jing says. "But this is only a proof of concept. And it works."

This tech can't create a cone of silence just yet, but the researchers envision a future in which private conversations can happen in open spaces — no earbuds or wires required. Libraries, offices and other public places could host numerous audio enclaves to allow for private audio streams simultaneously. ✖

ANTHROPOLOGY

KANZI'S DEATH ISN'T THE END FOR APE-LANGUAGE RESEARCH

BY ERIN WAYMAN

Barbara J. King remembers the first time she met Kanzi the bonobo. It was the late 1990s, and the ape was living in a research center in Georgia. King walked in and told Kanzi she had a present. A small, round object created a visible outline in the front pocket of her jeans. Kanzi picked up a board checkered with colorful symbols and pointed to the one meaning "egg" and then to "question." An egg?

No, not an egg. A ball. But "he asked an on-point question, and even an extremely simple conversation was just amazing," says King, a biological anthropologist at William & Mary in Williamsburg, Va.

Born in 1980, Kanzi began learning to communicate with symbols as an infant. He ultimately mastered more than 300 symbols, combined them in novel ways and understood spoken English.

Kanzi was arguably the most accomplished among a cohort of "talking" apes that scientists intensely studied to understand the origins of language and to probe the ape mind. He was also the last of his kind. In March, Kanzi died.

"It's not just Kanzi that is gone; it's this whole field of inquiry," says comparative psychologist Heidi Lyn of the University of South Alabama in Mobile. Lyn had worked with Kanzi on and off for 30 years.

Kanzi's death offers an opportunity to reflect on what decades of ape-language experiments taught us — and at what cost.

Language — communication marked by using symbols, grammar and syntax — has long been considered among the abilities that make humans unique. And when it comes to delineating the exact boundary separating us from other animals, scientists often turn to our closest living relatives, the great apes.

In the 1940s, psychologists tried raising a baby chimp named Viki at home as a human. After seven years of speaking lessons, she could utter only four words: *mama*, *papa*, *cup* and *up*. Eventually, scientists determined that chimpanzee anatomy doesn't allow for speech, although some recent research questions that conclusion.

In the 1960s, researchers took a different approach, one suggested as early as the 17th century: Teach apes sign language.

In one famous case, psychologists Allen and Beatrix Gardner brought Washoe — a wild chimp who had been captured in Africa for NASA but never became a chimponaut — to the University of Nevada, Reno. Researchers shaped Washoe's hands to teach her signs, and she came to use over 100 of them by age 4. The experiment was apparently so successful that Washoe later taught her son sign language.

In the 1970s, sign language experiments expanded to other types of apes, including Koko the gorilla and Chantek the orangutan.

Skepticism also crept in. Psychologist Herbert Terrace of Columbia University concluded that his study subject, Nim Chimpsky, a chimp named for linguist Noam Chomsky, failed to pick up language. Nim simply learned to produce signs to get food and other rewards. It was like a dog associating commands with a treat. Nim's teachers, Terrace said, also unintentionally cued the chimp to get their desired responses.

Once again, researchers switched tactics. At Georgia State University, psychologists developed a system of visual symbols that each represented a word or phrase. These "lexigrams" were abstract and thus not a clue to what the symbol meant. *Go*, for example, was a triangle with squiggly lines above it.

Researcher Sue Savage-Rumbaugh tried teaching the system to a bonobo named Matata. She didn't catch on, but her adoptive son, Kanzi, who was present at her lessons, did. And that was a big deal.

The work "was incredibly important for clarifying the nature of language development," King says. Kanzi wasn't taught language — he absorbed it the way a human infant does.

Work with Kanzi and other "talking" apes showed that our simian relatives do have some capacity for language, and caused scientists to rethink human uniqueness, Lyn says.

Of course, there are differences. In Kanzi's case, "there seems to be a lot more imperative usage, like he just want[ed] things," says evolutionary anthropologist Simon Townsend of the University of Zurich. His conversations may have been more transactional than our own. "Much of our communication is very much declarative," Townsend says, "with this prosocial drive to inform other individuals about things in the world."

Still, these experiments demonstrated that apes have complex interior lives, King says. "The ability for people to have a direct conversation with an ape who was expressing that interiority was really mind-blowing."

Kanzi the bonobo, shown here in 2006 with psychologist Sue Savage-Rumbaugh, used symbols on a board to communicate with humans. ↓

But that recognition may have doomed ape-language studies. In recent decades, scientists have questioned whether it's ethical to conduct experiments on these intelligent, highly social creatures. What happens when a study ends or loses funding? What happens if the ape is no longer around familiar faces or has no one to "talk" to?

After Terrace's study, Nim Chimpsky bounced around biomedical labs before ending up at an animal sanctuary in Texas, where he died of a heart attack at age 26 — young for an animal that can live 40 to 45 years in the wild.

In 2012, staff at the Great Ape Trust in Iowa, where Kanzi spent his later years, raised concerns about ape health, safety and injuries at the research center. Though cleared in an internal investigation, Savage-Rumbaugh, executive director at the time, parted ways with the facility, which got new management and a new name, the Ape Initiative.

"In retrospect, I think there was absolutely no intention to harm these apes at all, but I do think they were harmed," King says. "These apes were asked to transition from their world to a weird kind of mash-up of their world/our world.... Do we have the right to do that to another being?"

And so, ape-language research has evolved. Today, scientists hike into the wild to study natural ape communication, looking to see what aspects of language are present. Townsend and colleagues, for example, recently compiled a "lexicon" of bonobo calls, discovering that the apes combine calls in complex ways. Some calls modify other calls.

It might be a stretch to call that true syntax, but it's another linguistic feat once thought to be unique to humans. ✖

THE CONUNDRUM OF SHARING

BY BEN ORLIN

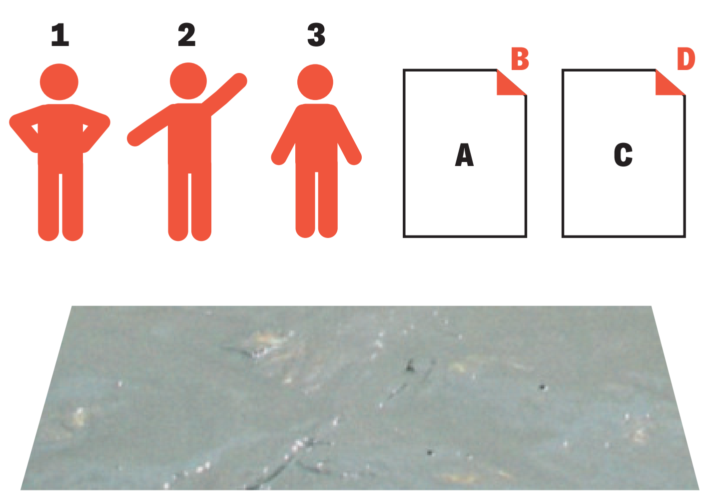
This month, we visit a trendy (but fictional) spa with an unusual feature: hot mud beds. You lay a plastic sheet on the mud. Then you lay your body upon the sheet. Without any direct contact between mud and body, you spend several minutes enjoying the soft and saunalike heat, sweating all over the plastic. Even though the spa session doesn't last long, it is said to be wonderfully restorative.

One day, three friends arrive. Unfortunately, only two plastic sheets are available. No one wants to miss out; then again, no one wants to lie on someone else's sweat.

"Wait!" says one. "It's simple! I'll use one side of the sheet, and you can use the other."

"Are you kidding?" another replies. "That side will be covered in mud."

The first friend smiles. "Not if we plan ahead."



1. How can all three friends partake in the spa using just two sheets?
2. The next day, five friends visit the spa, and only three sheets are available. Can they all partake? (Let's assume the spa now forbids laying an already-sweaty side of a sheet directly on its precious mud.)
3. Soon, 10 friends visit the spa. Only five sheets are available. "Someone will have to miss out," one of them declares. "There's no way to know that," says another, "until we at least look for a solution." Who's right?
4. Later, the spa introduces a second kind of mud, which must not be mixed with the first. If three friends want to try both muds, how many sheets do they need at minimum? (Let's assume each person is begrudgingly willing to lie twice on the same sheet.)
5. Lurking here is a fully general question, one that mathematical researchers have yet to solve: What's the minimum number of sheets that allows N friends to experience M kinds of mud if each side of a sheet may touch only a single person or a single kind of mud? (You might begin by assuming M = 1.)

While trying these puzzles, I recommend grabbing some index cards or sheets of paper to manipulate. Or if you're feeling ambitious, grab some plastic sheets, some sweaty friends and a convenient mud patch. ✖

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**.

MAKE A DIFFERENCE
BENNET YEE DOES

According to Bennet, in lieu of becoming a science teacher, donating to Society for Science is one of the best ways to help cultivate scientific thinking in future generations. Through science, we can understand the world and improve lives. That is why Bennet gives to the Society through his donor advised fund at Vanguard Charitable.

> "Science News is wonderful because it allows me to stay broadly informed about advances in many scientific fields."

BENNET YEE

Join Bennet in supporting Science News

You can make a gift to the Society that will support Science News, our STEM competitions for young people around the world and our growing outreach programs.

Ways to give

- Contribute through your donor-advised fund
- Make a distribution from your Individual Retirement Account (IRA)
- Give appreciated securities
- Leave Society for Science in your will or estate plans

For more information on giving, visit www.societyforscience.org/waystogive or email us at give@societyforscience.org

SOCIETY FOR SCIENCE

Society for Science is a 501(c)(3) nonprofit organization. Our Federal Tax ID is 53-0196483. Your contribution is tax-deductible as allowed by law.

intel

Congratulations to all ISEF Finalists

Intel Foundation is proud to sponsor the Society for Science and support how it fosters the advancement of science and builds an innovative workforce of the future.