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DECEMBER 2025

ScienceNews

THE FUTURE OF SCIENCE

Federal support built the US into a global leader in science and medicine. Is that era over?

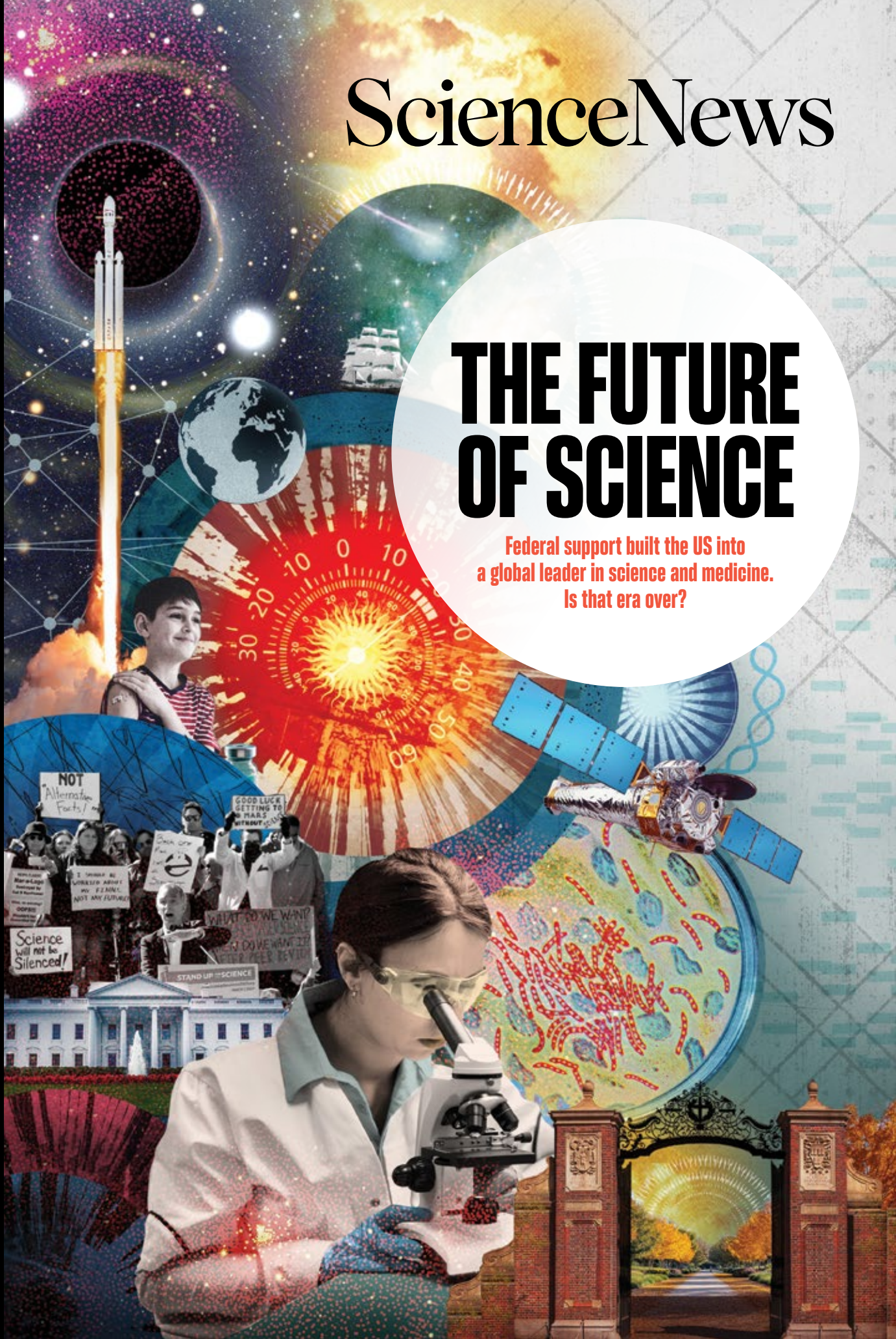

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Illustration by Martin O'Neill

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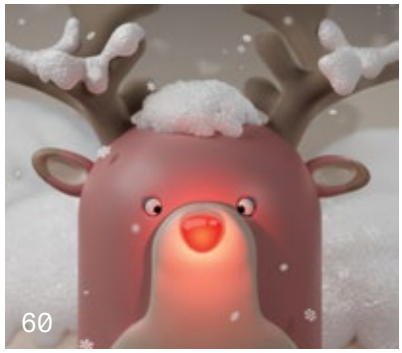

A historic year for U.S. science

This year as usual, *Science News* covered the big advances across science, medicine and technology, including the next quantum revolution, soaring rates of cancer in young people, the addictive lure of ultraprocessed foods, the debut of the Vera C. Rubin Observatory and how science-based strategies can protect communities from wildfires. But the most consequential news of the year has been the assault on science by the Trump administration.

We started alerting readers to potential impacts of Trump's second term on science immediately after the election, and have reported extensively on actions to overhaul the nation's science priorities and impose major funding cuts, including on fields such as astronomy and health that have historically enjoyed strong bipartisan support.

We also went deep on the science behind hot button topics that surfaced, including the complexity of biological sex beyond male and female; the safety of antidepressants; the health effects of removing fluoride from drinking water; and the reasons for rising rates of autism, as well as the support that people with autism and their families say they need to thrive.

In this issue, we provide perspective on this consequential year by zeroing in on four areas of science, asking researchers how their work has been impacted, what they're doing to carry on and how they envision where their fields are headed next (Page 36).

We also analyzed data from more than 5,300 National Institutes of Health and National Science Foundation grants terminated or frozen by the Trump administration in 2025 and captured that analysis in a data visualization (Page 8).

Associate news editor Christopher Crockett, who is also our resident data expert, collaborated with assistant art director Brody Price to create a sunburst graphic that conveys a large amount of information in two pages. Freelance data journalist Cam Rodriguez did a second analysis of the data, using different tools and a different programming language, to confirm the accuracy of our analysis.

And to end the year with a ray of hope, we introduce the five researchers we're honoring as our 2025 Scientists to Watch (Page 50). Each of these remarkable young researchers is clear-eyed about the challenges they face, and each is exhilarated by seeking answers to the big questions that their research poses. They are the future of science.

Nancy E. Shute

Nancy Shute
Editor in Chief
nshute@sciencenews.org

SOCIETY FOR SCIENCE

1920s Style for a 1920s Price

It was a warm summer afternoon and my wife and I were mingling with the best of them. The occasion was a 1920s-themed party, and everyone was dressed to the nines. Parked on the manse's circular driveway was a beautiful classic convertible. It was here that I got the idea for our new 1920s Retrograde Watch.

Never ones to miss an opportunity, we carefully steadied our glasses of bubbly and climbed into the car's long front seat. Among the many opulent features on display was a series of dashboard dials that accentuated the car's lavish aura. One of those dials inspired our 1920s Retrograde Watch, a genuinely unique timepiece that marries timeless style with modern technology.

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MCKENZIE PRILLAMAN

JOURNALIST

● SCIENCE JOURNALIST MCKENZIE PRILLAMAN has played a key role in our coverage of the Trump administration's policies that have touched practically every field of science. In this issue, she zeroes in on NASA funding cuts and how budget uncertainties are affecting the future of space research (Page 47). "I talked to so many passionate people. They felt a responsibility to speak up against the attacks on science," she says. Many researchers said they were disheartened by the events of this year, but a few have told her that they found hope in the ways that people have been coming together to stand up for science. "I think that people — especially scientists — are very resilient," Prillaman says. "I'm hopeful for our future in space science in the long run."

Christopher Crockett
When brainstorming ideas for how to visualize the state of U.S. science in 2025, an infographic about funding cuts was the obvious choice, says associate news editor Christopher Crockett. But how do you succinctly display cuts to more than 5,300 grants in just two pages? Categorize them by area of science. Looking at the final product (Page 8), the sheer variety of the cuts stood out the most to Crockett. All of the research areas covered by the National Institutes of Health and the National Science Foundation were impacted. "It just speaks to the sledgehammer approach that the current administration takes," he says.

Aaron Brooks
Science News works with a cadre of freelance fact-checkers to ensure that all stories in the magazine are accurate. Aaron Brooks has been verifying news items in almost every issue for the last six years. To fact-check a news story, Brooks reads the related research papers and then combs through every last detail in the story. The work is crucial: "A magazine that gets a lot of facts wrong is going to lose credibility," he says. "As a reader, I would quickly abandon any publication that appeared to play fast and loose with facts."

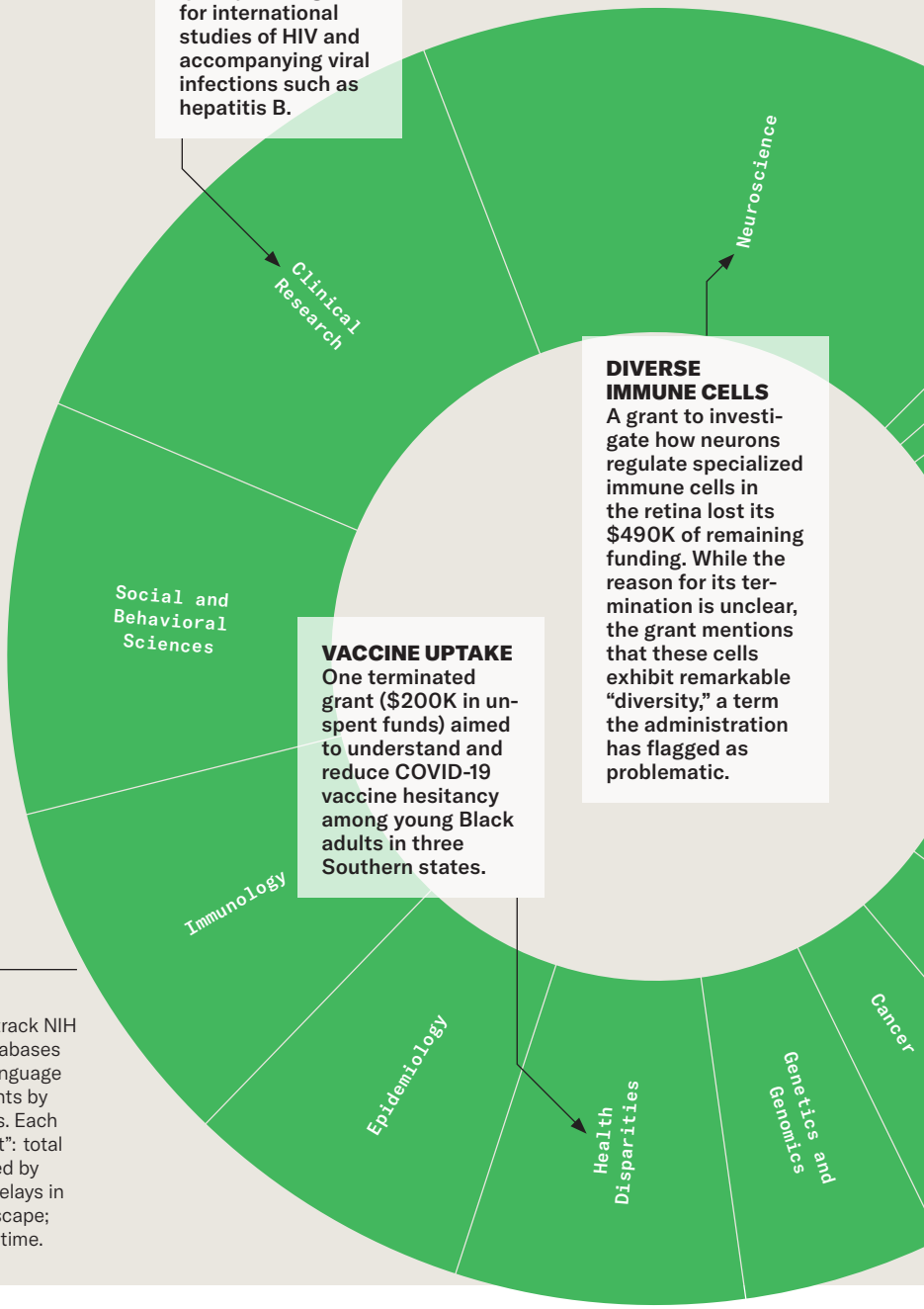
Mandana Tadayon
For the first time, *Science News*' Scientists to Watch (Page 50) is showcasing five up-and-coming researchers by letting them tell their own stories on camera. Senior producer Mandana Tadayon created the videos, which she says could be challenging because the storytelling had to balance accuracy with accessibility. But the end result was worth it. "You're not just reading about what the scientists do — you're seeing who they are. Their tone, energy and expressions help bring their curiosity and passion to life and help viewers connect with them on a deeper level," Tadayon says. Watch the videos at sciencenews.org/S2W.

CLOCKWISE FROM TOP LEFT: SARAH TRAN; R. CUEVAS; A. BROOKS; M. TADAYON

In 2025, the Trump administration froze or ended about **5,300 NIH and NSF research grants** totaling over **$5 billion** in unspent funds—a decision that reshaped many fields of science.

National Institutes of Health
$4.5 billion

National Science Foundation
$0.8 billion



HIV HUB
The largest cut to any NIH grant ($163M) ended support for a key part of the AIDS Clinical Trials Group that provides management and quality oversight for international studies of HIV and accompanying viral infections such as hepatitis B.

DIVERSE IMMUNE CELLS
A grant to investigate how neurons regulate specialized immune cells in the retina lost its $490K of remaining funding. While the reason for its termination is unclear, the grant mentions that these cells exhibit remarkable "diversity," a term the administration has flagged as problematic.

VACCINE UPTAKE
One terminated grant ($200K in unspent funds) aimed to understand and reduce COVID-19 vaccine hesitancy among young Black adults in three Southern states.

METHODOLOGY AND CAVEATS

All data come from Grant Witness, a project to track NIH and NSF grant terminations via government databases and researcher submissions. We used a large language model (OpenAI's GPT-5 Nano) to categorize grants by agency research areas based on grant abstracts. Each infographic wedge shows "equivalent grants lost": total cut or frozen funds *remaining to be spent* divided by the median. There may be inaccuracies due to delays in financial reporting and the rapidly shifting landscape; some funding may have been restored by press time.

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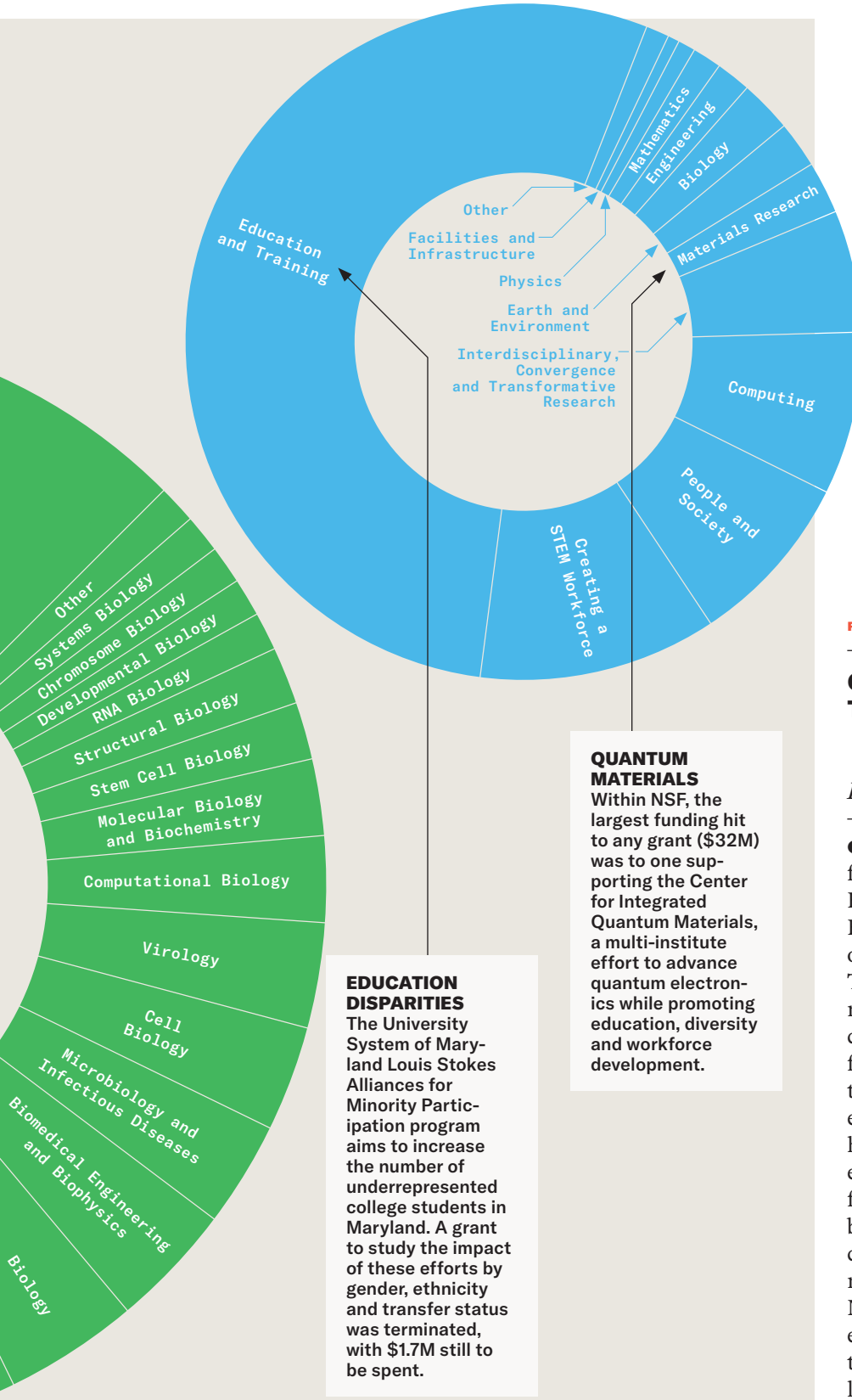

EDUCATION DISPARITIES
The University System of Maryland Louis Stokes Alliances for Minority Participation program aims to increase the number of underrepresented college students in Maryland. A grant to study the impact of these efforts by gender, ethnicity and transfer status was terminated, with $1.7M still to be spent.

QUANTUM MATERIALS
Within NSF, the largest funding hit to any grant ($32M) was to one supporting the Center for Integrated Quantum Materials, a multi-institute effort to advance quantum electronics while promoting education, diversity and workforce development.

FUTURE OF SCIENCE

CUTS THAT RIPPLED THROUGH SCIENCE

By Christopher Crockett

● **More than 5,300** research grants from the National Institutes of Health and the National Science Foundation were terminated or frozen in 2025 as part of the Trump administration's effort to realign funding priorities. The cuts — over $5 billion in unspent funds — targeted initiatives related to diversity, equity and inclusion; environmental protection; vaccine hesitancy and more. The chart at left estimates how these cuts have affected all research areas supported by NIH and NSF. While this doesn't capture the full extent of government cuts — agencies like NASA, NOAA and the EPA aren't included — it does highlight the breadth of the reductions and the ripple effects likely to be felt throughout the scientific community for years to come.

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A fluorescent protein's spin (blue arrow) can be manipulated so that the protein doubles as a quantum bit. The advance could lead to quantum sensing inside cells (see Page 20).

News

PETER ALLEN/SECOND BAY STUDIOS

HEALTH & MEDICINE

AN EARLY STAGE GENE THERAPY SLOWS HUNTINGTON'S DISEASE

BY BETHANY BROOKSHIRE

Even hearing the phrase "Huntington's disease" can make a room suddenly somber. So the joy that accompanied a recent announcement of results of an experimental gene therapy for the fatal neurodegenerative disease signaled an unfamiliar sense of hope.

In a small clinical trial, brain injections of an inactivated virus may have prevented the formation of the rogue proteins that make Huntington's so devastating. Over three years, the treatment slowed Huntington's progression by up to 75 percent, say neurologist Ed Wild and colleagues. The treatment, while not a cure, could give people with Huntington's disease the gift of many more years of life.

"We're doing science because it's interesting and important, but we're also in this game to save our friends and family from a horrible fate," says Wild, of University College London. "That's the most meaningful thing, looking my friends in the eye and [saying], 'We did it.'"

Huntington's disease is rare — affecting about 5 out of every 100,000 people globally — and has no effective treatments or cures. It is the result of one mutation in one gene, aptly called *huntingtin*, that causes the front end of its resulting protein to grow, says geneticist Russell Snell of the University of Auckland in New Zealand, who was not involved in the trial. Huntington's is passed down from parent to offspring, and it takes only one copy of the defective gene to cause the disease. That means a patient's child has a 50 percent chance of inheriting it.

The expanded huntingtin protein is toxic. It collects in the brain and kills cells largely in areas crucial for voluntary movements. Symptoms, which usually appear by the time an affected person is in their 30s to 50s, include involuntary movements, stiffness, difficulties speaking and swallowing and cognitive decline. Eventually, patients may be paralyzed and can die from complications such as pneumonia.

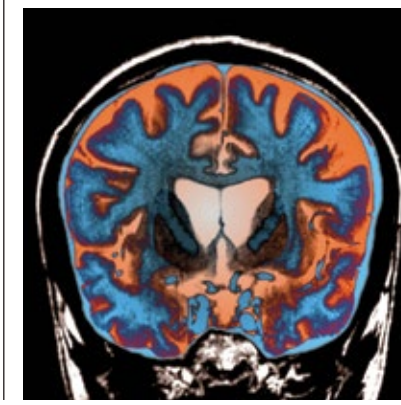
Wild and colleagues, working with the Dutch pharmaceutical company uniQure, used microRNA to trigger the breakdown of *huntingtin* RNA before it gets made into protein. Previous trials injected microRNA into patients' cerebrospinal fluid. But those trials failed, possibly because the microRNA couldn't infiltrate the targeted brain areas, Wild says.

This time, scientists injected the microRNA — packaged inside a well-studied virus — directly into the brain. The virus would deposit RNA into neurons, which would then reprogram the cells "to become a factory for a molecule that tells it not to make huntingtin protein," Wild says.

In a surgery lasting eight to 10 hours, 17 patients with early Huntington's symptoms received injections of viral payload into three spots on each side of the relevant brain areas. The team assessed 12 of those patients for 36 months, testing their motor scores, attention, working memory and how well they could go about their daily lives. "It was heroic, really, on behalf of the patients and on behalf of the doctors," Snell says.

The treatment didn't stop disease progression. But compared with patients who did not receive injections, those that got the highest dose averaged 75 percent less of a decline in their cognitive and motor

In this MRI image of the brain of a person with Huntington's disease, open cavities for circulating cerebrospinal fluid (center) are far larger than normal, a sign of degeneration. ↓



ZEPHYR/SCIENCE SOURCE

symptoms over 36 months.

One patient is a former information technology professional who had to stop work due to his symptoms. About a year after receiving the gene therapy, he had stabilized enough to go back to work. In Wild's 20 years of research, he says, this is the only patient he's seen who could do that. Other patients who expected to be in a wheelchair by now "are still walking."

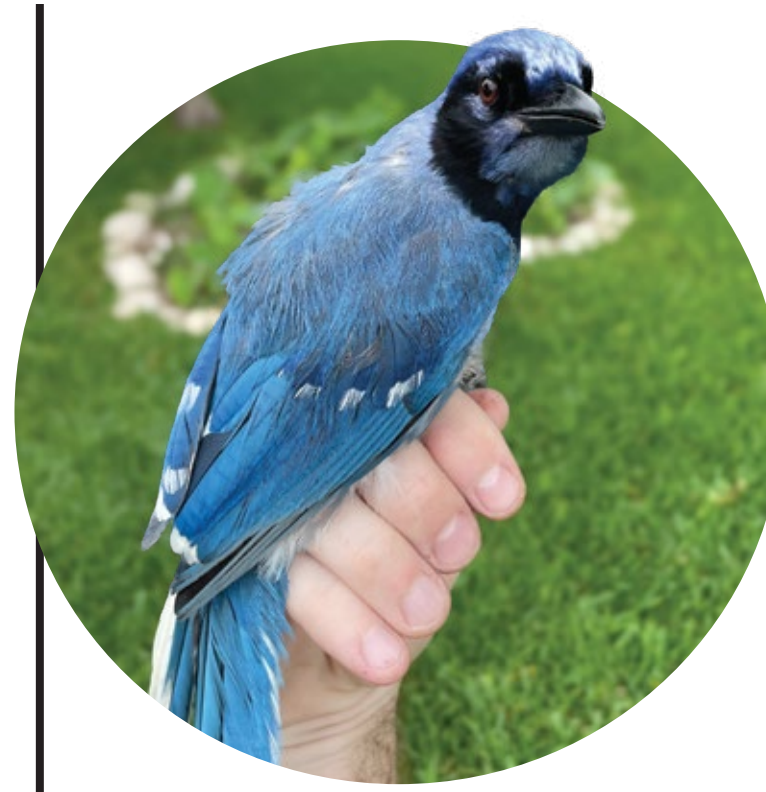
Their symptoms almost appear to stabilize, says David Rubinsztein, a neuroscientist at the University of Cambridge in England who was not involved in the trial. Though the trial was small, "at face value, I think that's quite promising."

Wild and colleagues also tracked levels of a protein called neurofilament light chain in patients' cerebrospinal fluid, a measure of nerve cell damage. The numbers spiked immediately after surgery, which was expected, but then dropped. While patients' ratings of their symptoms could be subject to a placebo effect, Wild says, the neurofilaments are not. "By year three, that drop from baseline has been maintained, which is great."

The next step is ongoing: recruiting more patients for multicenter trials, and working to reduce the neurofilament spike after surgery.

Those larger trials are necessary, Rubinsztein says, and while the current data will be sent to the U.S. Food and Drug Administration in hope of approval, they haven't been published or peer reviewed. If the treatment is approved, it will be expensive, since every dose must be made in the lab.

"One's got to steer a middle line," Rubinsztein says, between enthusiasm and caution. But "if this was my experiment, I'd be over the moon." ✖



BRIAN STOKES/UNIV. OF TEXAS AT AUSTIN

ANIMALS

Meet the 'grue jay,' a rare hybrid songbird

By Sarah Boden

● **There was something strange** about the turquoise-colored songbird flying near San Antonio in 2023. With black-and-white tail bands and a jeering honk, it somewhat resembled and sounded like a blue jay. But the bird had the face and low, two-tone rattling call of a green jay.

The bird turned out to be an extremely rare hybrid that some call a "grue jay." Genetic testing showed the hybrid bird had a green jay mother and a blue jay father, scientists report in *Ecology and Evolution*.

Though bird hybrids are not uncommon, a pairing of these two jay species is remarkable, as their ranges only recently began to overlap due to human activity, says study coauthor Timothy Keitt, an ecologist and evolutionary biologist at the University of Texas at Austin.

CONT. ON PAGE 14

CONT. FROM PAGE 13 The green jay (*Cyanocorax yncas*) is a tropical bird typically found in Mexico and parts of Central America. Due to the warming climate, green jays have spread north over the last 20 years or so. Their range now extends into Texas' side of the Rio Grande Valley.

Meanwhile, the range of the blue jay (*Cyanocitta cristata*) is reaching farther west across North America, including into south central Texas. Blue jays may be following humans into new areas, seeking food sources in suburban environments.

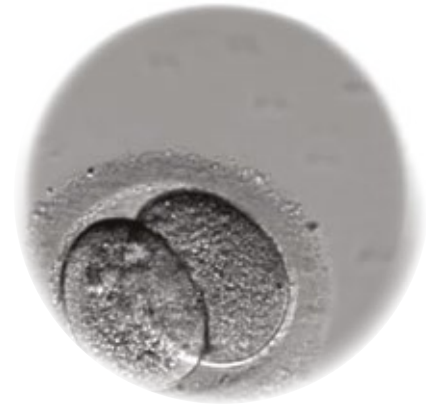
Hybridization in the wild usually occurs between species that share a recent common ancestor. However, the evolutionary split between blue jays and green jays was at least 7 million years ago.

The fact that organisms from two species, which have been evolving independently for so long, came together to produce offspring is amazing, says evolutionary biologist Jamie Alfieri of the University of Iowa in Iowa City.

Why the jays crossed the species divide to mate is a mystery. Perhaps they were attracted to novelty. Or perhaps the birds, which were at the far edges of their ranges, paired up after being unable to find a mate among their own species.

Both strategies are risky: Hybrids are sometimes sterile. In birds, however, hybrid males are more likely to be able to reproduce than females. The grue jay is male, so it's possible that it will have offspring.

Keitt doubts the grue jay will become a new species. But the bird highlights the unusual and rapid ecological changes due to human activity. "Buckle in, folks. We're going to see very different outcomes," he says, including unusual weather and new plant and animal hybrids. ✖



HEALTH & MEDICINE

Lab-made human eggs can produce embryos

By Tina Hesman Saey

● **Creating human eggs** from adult cells is one step closer to reality. A technique used in cloning combined with fertilization and a bit of chemical coaxing caused human skin cells to produce eggs able to give rise to early human embryos, researchers report in *Nature Communications*.

The effort is the latest attempt to make eggs and sperm from human nonreproductive cells. Researchers have already succeeded in making eggs and sperm of other animals, including pandas. But producing human eggs and sperm has proven elusive.

Such technology may one day treat female infertility or give same-sex male couples the ability "to have, potentially, a child that's genetically related to both partners," says reproductive endocrinologist Paula Amato of Oregon Health & Science University in Portland.

For now, the technique "is too inefficient and high-risk to apply immediately to clinical application," says stem cell researcher Katsuhiko Hayashi of the University of Osaka

↑ This two-cell human embryo was created from an egg that was derived from skin cells.

N. M. GUTIERREZ ET AL/NATURE COMMUNICATIONS 2025 (CC BY-NC-ND 4.0)

in Japan. Hayashi has reprogrammed tail cells from two adult male mice into eggs and sperm. Those reprogrammed cells gave rise to healthy mice that had two biological fathers.

A version of the new technique also works in mice, Amato says. "Usually, things that we can get to work in mice eventually work in humans." At least, in making stem cells it does.

Amato and colleagues removed the nucleus from a human egg cell and replaced it with the nucleus of a type of skin cell called a fibroblast. That step, called somatic cell nuclear transfer, is the same first step used in cloning Dolly the Sheep and many other species.

But the researchers weren't trying to make a human clone. They wanted to make an egg cell, which has 23 chromosomes. That's half the number of chromosomes as most other cells in the body, which carry a set of 46 chromosomes — 23 inherited from the mother and 23 from the father.

Cells that will give rise to eggs and sperm go through a type of cell division called meiosis, which halves the number of chromosomes. In that process, each chromosome pairs with its counterpart from the other parent and swaps some DNA. The cell then divides, pulling one half of each pair into daughter cells. Then, when eggs and sperm get together, they produce a zygote with 46 chromosomes that will divide and make every cell in the body.

But the cloned egg already had 46 chromosomes. With mice, Amato and colleagues fertilized the cloned egg with sperm. That caused the egg to jettison half its chromosomes, producing an embryo with the correct number of chromosomes.

The human eggs didn't extrude half their chromosomes when fertilized, so the team persuaded the eggs to start winnowing chromosomes by adding a chemical called roscovitine.

Some fertilized eggs made early human embryos, but many did not — probably because they had abnormal numbers of chromosomes, Amato says. These failed would-be eggs kicked out roughly half their chromosomes, but not the right half.

The embryos that did arise were allowed to grow only for about six days to the blastocyst stage. Many stopped developing at earlier stages. None of the embryos had the correct sets of chromosomes so were not viable. For instance, one embryo had 48 chromosomes instead of 46. It had all 23 chromosomes from the sperm but a mishmash of 25 chromosomes from the skin cell. Some chromosomes were present in a single copy while others had two copies, and other chromosomes were missing entirely. The unequal divisions probably resulted from chromosomes pairing randomly.

The team is working to get the chromosomes to divvy up properly. It will be at least a decade before the technique makes it to clinical trials, Amato estimates. Such trials would probably not take place in the United States, which prohibits genetic modification of human embryos. ✖

ANIMALS

SOME DOGS SHOW SIGNS OF TOY ADDICTION

By Laura Sanders

● If you've ever had a slobbery ball at your feet and a dog's hopeful eyes asking for yet another throw, then you know that some dogs *really* love to play. Now, scientists back that up by finding that some pups' behaviors share features with human addictions.

Behavioral biologist Stefanie Riemer of Vetmeduni Vienna and colleagues studied 105 pet dogs, all of whom relished a good play session. The team tested the dogs in a variety of potentially challenging scenarios for a canine that loves to play. In one test, scientists put a preferred toy on a high shelf. In another, dogs were offered a choice between a toy and a puzzle filled with dry food. Scientists also measured how long it took the dogs to calm down after a toy was gone. According to a scoring system, 33 dogs exhibited signs of addiction-like behavior, the team reports in *Scientific Reports*.

Riemer suspects play, not toys, is behind the drive. Mirroring some features of human addictions, dogs at play may be chasing good feelings. Because behavioral addictions in people and these intense behaviors in dogs aren't well understood, she cautions against equating the two. ✖

BILEVICHOLGA/GETTY IMAGES

PLANETARY SCIENCE

THIS SMALL WORLD HAS GAS AFTER ALL

By Ken Croswell

● A frigid world named Makemake sports the most distant gas ever seen in the solar system, hinting that it has an atmosphere.

Previous observations had shown no trace of gas on Makemake when the small world (illustrated above with its moon MK2) passed in front of a background star. Yet in 2023, observations from the James Webb Space Telescope discerned a hint of methane, planetary scientist Silvia Protopapa of the Southwest Research Institute in Boulder, Colo., and colleagues report in the *Astrophysical Journal Letters*.

If the barely there gas constitutes an atmosphere, its surface pressure is roughly 100 billionth that of Earth.

Orbiting 53 times as far from the sun as Earth does, Makemake is so cold that methane freezes to its surface. The methane gas may come from sunlight vaporizing some of the ice.

Or plumes of gas may erupt from Makemake's interior, similar to the geysers that shoot water into space from Saturn's moon Enceladus.

It raises the question: If Makemake can have gas, might even more remote worlds in the solar system harbor it — and their own atmospheres — too? ✖

PARTICLE PHYSICS

A RECORD-BREAKING NEUTRINO MAY HAVE PRIMORDIAL ORIGINS

BY MCKENZIE PRILLAMAN

The highest energy cosmic neutrino ever detected may have come from a theoretical object known as a primordial black hole, researchers report in *Physical Review Letters*. Thought to have emerged right after the Big Bang, primordial black holes could reveal the origin of superenergetic neutrinos and answer queries about black holes and dark matter.

"This is not proof, but it's incredibly exciting," says MIT physicist David Kaiser.

Neutrinos are lightweight, electrically neutral particles that zip through space and don't interact much with ordinary matter. Most that reach Earth have low energies and come from common reactions.

But in February 2023, an underwater neutrino detector near Sicily, Italy, picked up signals linked to a neutrino with an estimated energy of 220 million billion electron volts, about 35 times as energetic as the previous record holder.

Kaiser and MIT physicist Alexandra Klipfel suspected an exploding primordial black hole could have blasted the high energy particles toward Earth. Physicist Stephen Hawking proposed some 50 years ago that black holes leak energy, lose mass, grow hotter and emit increasingly higher energy particles until they explode. Some primordial black holes might be bursting today, 13.8 billion years after their births.

Klipfel and Kaiser calculated how many high energy neutrinos such an explosion would release, then used that number to estimate that one bursting black hole could have been close enough to Earth in the last 14 years to spit out a record-breaking neutrino that hits a detector. Superenergetic neutrinos disperse in all directions, growing farther apart as they travel.

"Only a small fraction [of neutrinos from an explosion] would ever happen to be heading toward the Earth," Kaiser says. "A small fraction of those would really hit a detector."

Dozens of studies have tried to identify the source of the record-smashing neutrino, says physicist Luigi Fusco of the University of Salerno in Fisciano, Italy, who is part of the team that detected the particle. A primordial black hole is an intriguing, exotic proposition, he says, though it's too soon to declare it the origin. ✖

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↑ Neuroscientist Anne-Laure Le Cunff's experience with ADHD has fueled her research.

BRETT AFFRUNTI

PSYCHOLOGY

A possible upside of ADHD: Hypercuriosity

By Sujata Gupta

● **Anne-Laure Le Cunff** was something of a wild child. As a teen, she repeatedly disabled the school fire alarm to sneak smoke breaks and helped launch a magazine filled with her teachers' fictional love lives. Later, as a young adult studying neuroscience, Le Cunff would spend hours researching complex topics but struggled to complete simple administrative tasks. And she often obsessed over random projects before abruptly abandoning them.

Three years ago, a colleague asked Le Cunff if she might have attention-deficit/hyperactivity disorder, or ADHD, a condition marked by distractibility, hyperactivity and impulsivity. Doctors confirmed her colleague's suspicions. But fearing professional stigma, Le Cunff — by then a postdoctoral fellow in the ADHD lab at King's College London — kept her diagnosis secret until this year.

Le Cunff knew all too well about the deficits associated with ADHD. But her research and personal experience hinted at an underappreciated upside. "I started seeing ... breadcrumbs pointing at a potential association between curiosity and ADHD," she says.

People within the ADHD community have long recognized that the condition, which affects some 5 percent of children and 2.5 percent of adults worldwide, can be both harmful and helpful. Researchers, though, have largely focused on the harms. Those studying treatments tend to define success as a reduction in ADHD symptoms, with little regard to the symptoms' possible benefits.

That's starting to change. In a 2023 study of positive experiences with ADHD, participants cited their creativity, energy, adaptability, resilience and curiosity.

"People [were] talking about how navigating the challenges of ADHD had actually made them more empathetic, more accepting of others [and] better at handling adversity," says study coauthor Astri Lundervold, a clinical neuropsychologist at the University of Bergen in Norway.

As Le Cunff dug deeper, she began to suspect that the pros and cons of ADHD might share a neurological link. She was drawn to a 2020 paper by Columbia University cognitive neuroscientist Caroline Marvin and colleagues that suggested impulsivity and curiosity light up similar reward pathways in the brain. Le Cunff began to wonder if that curiosity–impulsivity link — what she coined "hypercuriosity" — might be dialed

up in people with ADHD.

Now, with a $220,000 grant from U.K. Research and Innovation, she's putting that idea to the test.

Through interviews, eye-tracking and measurements of electrical activity in the brain, Le Cunff hopes to challenge the deficits-based narrative around ADHD by exploring how curiosity operates in university students with the condition. Eventually, she wants to create practical strategies for how educators can guide students with ADHD.

Building on previous theories about the evolutionary basis of ADHD, Le Cunff's work suggests that traits associated with ADHD might have been advantageous in ancestral environments. In a world of resource scarcity and unpredictability, people curious enough to explore unknown or dangerous situations would have helped their group's survival, Le Cunff suggested in 2024 in *Evolutionary Psychological Science*.

Modern environments, though, are rich in resources and information. So a person prone to jumping headfirst into the unknown may appear impulsive or even reckless, rather than curious.

How people balance curiosity with information overload is a rapidly growing area of inquiry in the social sciences. Some researchers, including Le Cunff, suspect that dysregulated curiosity in people with ADHD could lead to unusual, and potentially maladaptive, ways of seeking information.

For example, epistemologist Asbjørn Steglich-Petersen and philosopher of science Somogy Varga of Aarhus University in Denmark theorize that people with ADHD often cannot rein in their curiosity even when the costs of exploration are high. For instance, they may flit around for long stretches of time as they explore topics, the duo wrote this year in *Philosophical Psychology*. The strategy might seem like wasting time, but can also lead people with ADHD to find novel or unusual solutions to problems. That's because people with ADHD are also prone to hyperfocusing. What might appear from the outside as random flitting about is, instead, a quest for a topic of interest.

Scientists aren't sure how curiosity operates in the brain. Evidence suggests, though, that satiating curiosity activates the brain's reward circuits in much the same way as satiating hunger.

One recent study enticed participants with a promise of a reward: either food or the solution to a magic trick. Participants then received their odds of winning the award versus receiving an electric shock. Surprisingly, participants took the gamble and accepted some risk of a shock for either reward. Similarly, fMRI brain scans CONT. ON PAGE 20

MATERIALS SCIENCE

FUTURE WETSUITS COULD BOAST BUILT-IN SHARK SHIELDS

By Carly Kay

● Wetsuits made from new bite-resistant materials could reduce damage from sharks' multi-rowed chompers, scientists report in *Wildlife Research*. The materials block the types of cuts that lead to fatal blood loss during shark attacks.

Marine biologist Charlie Huveneers at Flinders University in Adelaide, Australia, and colleagues tested four bite-resistant materials, including chain mail, Kevlar or polyethylene nanofibers integrated into a standard neoprene wetsuit. The researchers lured white sharks (*Carcharodon carcharias*) and tiger sharks (*Galeocerdo cuvier*) to a boat using bait, then replaced the bait with either bite-resistant or traditional wetsuit material attached to buoylike "bite packages."

All bite-resistant materials significantly reduced severe damage, even when sharks clamped down, thrashed or dragged the bite package underwater. For instance, traditional neoprene packages had deep puncture marks while the new packages had shallow indentations.

The innovation may prevent ocean recreators from bleeding out, which is the main cause of death in the rare event of a shark attack. ✖

FLINDERS UNIV.

5 percent
Children worldwide who have ADHD

2.5 percent
Adults worldwide who have ADHD

CONT. FROM PAGE 19 showed that areas involved in processing reward cues lit up as participants mulled the gamble, researchers reported in 2020 in *Nature Human Behaviour*.

"Our brains do seem to respond in similar ways when we're anticipating receiving information that we really want or when we are anticipating receiving chocolate," says Marvin, who was not involved in that study.

If people with ADHD anticipate that delicious information more than others, that could help explain their difficulties in modern schools and workplaces, say Le Cunff and others. In those sedentary, often quiet spaces, hypercurious students might disrupt the classroom, and hypercurious workers might produce less than their colleagues. Particularly in the Western world, the tendency has been to rein in such individuals, whether through behavioral modification or medication, researchers say.

But dampening impulsivity risks dampening curiosity and its associated benefits, including improved learning, information retention and well-being, Marvin says.

"When you look at the way people with ADHD learn, and especially if they are hypercurious ... it looks a lot more like a messy mind map rather than a straight [line]," Le Cunff says. "The problem is when there's no space for exploration."

In moving away from a deficits-based understanding of ADHD, though, clinicians and patients need to avoid swinging too far in the other direction, Steglich-Petersen says.

Lundervold agrees. "The goal isn't to romanticize ADHD," she says. "It's to ensure that when we're supporting people with this condition, we're seeing the whole person, not just the problems." ✖

PHYSICS

A NEW QUBIT COULD PUT QUANTUM SENSORS INSIDE CELLS

BY EMILY CONOVER

Quantum technologies might seem incompatible with life. The quantum bits, or qubits, that make them up often require ultracold temperatures, and rely on hard, orderly materials like diamond or silicon that are foreign to the squishy, wet world of biology. But a new, biological qubit is a native of that messy realm.

Made out of a fluorescent protein, the qubit is just 3 nanometers in diameter, scientists report in *Nature*. By hitting the protein with laser light, tweaking it with microwaves and observing its fluorescence, the researchers unleashed its quantum nature.

If the research pans out, such biological qubits could be used as sensors for making precisely targeted, delicate quantum measurements of conditions within cells, such as magnetic fields and temperature. Such capabilities could enable new types of medical imaging, for example.

Qubits are similar to the standard bits used in computing, in that they have two possible values when measured, like the 0s and 1s of traditional computers. But qubits can also exist as both 0 and 1 at the same time, in what's known as a quantum superposition, giving them different capabilities than standard bits.

Rather than shoehorning traditional qubits into biological systems, the researchers hit on an idea: "Maybe you should turn the problem inside out," says physicist David Awschalom of the University of Chicago. He and colleagues repurposed tools of biology to form "a quantum bit that would be very happily ensconced in another biological entity."

The qubit is made of a part of the protein called the fluorophore — the part that fluoresces when hit with light. That fluorophore has a spin, a quantum property that causes it to act like a magnet that can be pointing up, down or in a quantum superposition of the two.

The researchers demonstrated that they could manipulate that spin. They produced a quantum effect called Rabi oscillations, in which the system cycles between the two spin states when hit with electromagnetic radiation, in a way that is a hallmark of a qubit.

Using genetic engineering, the team produced the protein in

cells in the lab, demonstrating Rabi oscillations in human cells at a temperature of about –98° Celsius, and in *Escherichia coli* bacteria at room temperature.

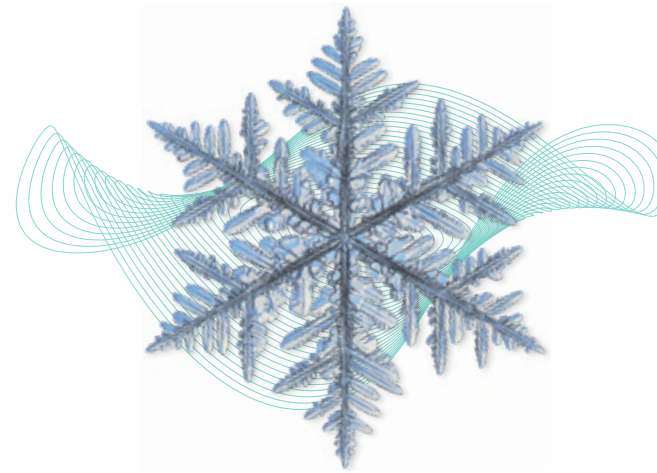
Many types of qubits won't function at such high temperatures. But the protein's structure is beneficial: "Fluorescent proteins in general have the advantage that the fluorophore … where the qubit is encoded, is in this protective shell," says study coauthor Peter Maurer, a biophysicist at the University of Chicago. That shell is key to the qubit's heat tolerance, protecting it from outside disturbances.

"It's a fancy demonstration with a lot of promise," says biophysicist Romana Schirhagl of University Medical Center Groningen in the Netherlands, who was not involved in the research. But its potential has yet to be proven outside of highly controlled labs, she says. "There's a lot of work still to be done for it to be actually useful."

The new work is part of a recent flurry of effort on quantum sensing using fluorescent proteins. For decades, these proteins have been key tools in biology labs, where their glow can help visualize other proteins of interest, locating objects such as cancer cells.

Now, researchers hope to add quantum sensing to that trusty technique. "It's really allowing us to take … what's been done with fluorescent proteins in general and use it in new ways," says physicist Harrison Steel of the University of Oxford, who reported a related quantum technique in a 2024 paper that is undergoing peer review.

Quantum effects have traditionally been considered too delicate for the wilds of biology. But now, there's new hope of breathing some life into quantum physics. ✖



↗ Solid ice can cope with internal stress, new movies show.

CHAOTICMIND75/GETTY IMAGES (SNOWFLAKE); ALEKSANDARVELASEVIC/GETTY IMAGES (BACKGROUND)

PHYSICS

Ice shows off its flexibility in molecular movies

By Rachel Berkowitz

● **As winter sets in,** watching icicles form and snow flutter may seem mundane. But at the smallest scales, we still don't know a lot about how freezing unfolds. Now, the first molecular-scale movies of ice in motion reveal that the resulting crystal is surprisingly flexible, researchers report in *Nature Communications*.

The transformation of liquid water into ice is a fundamental process on Earth and beyond. Freezing dynamics and the stability of ice are vital to atmospheric processes, transportation safety and the preservation of biological tissue. To better understand what stabilizes and what weakens ice, materials scientist Jingshan Du and colleagues investigated how well ice tolerates structural imperfections such as tiny bubbles trapped in its crystalline structure.

Watching ice at the nanoscale is incredibly hard. The weak chemical bonds between water molecules can be easily damaged by the energy sources used for atomic-scale imaging, such as X-rays and electron beams. "You need to put a lot of energy into the sample to get atomic-level signals," says Du, of Pacific Northwest National Laboratory CONT. ON PAGE 22

ASTRONOMY

A ROGUE PLANET COLLECTS GAS JUST LIKE STARS DO

By McKenzie Prillaman

● Some 600 light-years from Earth, a rogue planet has been gobbling up gas and dust at a rate of 6 billion metric tons per second, researchers report in the *Astrophysical Journal Letters*. The planet, which doesn't orbit a star, holds the record for the fastest growth observed in any planet — with or without a host star.

The planet, called Cha 1107-7626, is about five to 10 times the mass of Jupiter. It packs on the pounds by sucking up material from a surrounding disk of gas and dust, says Victor Almendros-Abad, an astronomer at the Palermo Astronomical Observatory in Italy.

He and his colleagues wondered if rogue planets form around host stars and are later flung from their homes, or form from collapsing gas clouds like stars do.

Observations with the Very Large Telescope in Chile and the James Webb Space Telescope showed that the rogue planet suddenly became gluttonous between June and August, accumulating matter up to eight times the rate it had just a few months prior. Many properties of the gluttonous period resemble a type of growth spurt previously seen only in young stars, suggesting the rogue planet had a starlike birth. ✖

CONT. FROM PAGE 21 in Richland, Wash. "It's really difficult to stabilize ice in the conditions you need for imaging."

To overcome these issues, the team developed a technique that involved sandwiching liquid water between two protective carbon membranes inside a cryogenic chamber. Slowly cooling the chamber with liquid nitrogen to –180° Celsius created an encapsulated ice film less than a few hundred nanometers thick. The researchers then watched magic unfold as they filmed the sandwiched crystal in a vacuum chamber with a transmission electron microscope.

Nanoscale air bubbles formed, moved, shrank, merged and dissolved — all within solid ice. "What's fascinating is that, throughout the entire process, ice keeps being a single solid crystal," Du says. Upon further examination, the researchers found that instead of a smooth curved surface, the bubbles had a zigzag pattern with repeated flat surfaces at the atomic level. "That's what you'd expect if you give the bubbles enough time to settle down, as the curved bubbles develop facets to stabilize," he says.

Measurements confirmed that the trapped gas bubbles did not strain the ice crystal, which would cause fracturing. Instead, the structure adapted surprisingly well to these defects, unlike other materials such as metals or ceramics. "Ice is pretty happy with the bubbles," Du says. That's because water's chemical bonds make it extremely flexible and malleable — even as a solid. Computer simulations confirmed ice's unique tolerance for defects.

"We hope this new insight can guide us in approaches to preventing ice buildup, and how it occurs," Du says. Understanding the dynamics of how ice forms, grows and recrystallizes is important for developing engineering strategies that could prevent ice buildup on airplane wings, roadways and other surfaces as well as during cryopreservation of tissues, where ice crystals could puncture cells and membranes. Finally, the results might help connect the dots in models of glacier behavior, where small-scale bubbles impact large-scale melting and movement. "What we found is that ice is not going to be less stable with bubbles in it," Du says.

Jungwon Park, a chemist at Seoul National University who studies nanoscale material dynamics, says it's exciting to see one of the earliest molecular-scale images of ice crystals, using a new method to shield the ice from the high-vacuum imaging environment.

Chemist Minyoung Lee, also of Seoul National University, notes that the findings provide "new insight and vast opportunities" for investigating effects right at the liquid-solid interface in crystallization.

Du emphasizes that his team isn't watching water freeze into ice just yet. "But this is the first step toward that." ✖

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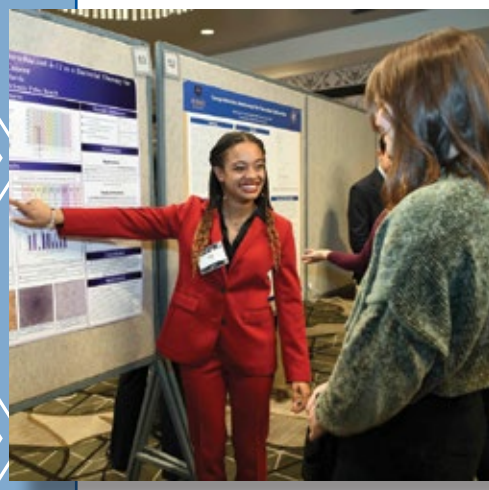

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PHYSICS

A 'ringing' black hole echoes scientists' predictions

By Emily Conover

● **Newly reported gravitational waves** rang out as clear as a bell.

Spotted in January, these spacetime ripples are the clearest yet discovered, cutting through the background noise better than any previous detection. The waves were born when two black holes merged, forming a larger black hole that reverberated like a struck bell, emitting gravitational waves as its vibrations gradually faded.

The pealing of this black hole matched predictions of black hole behavior according to physicists' theory of gravity, called general relativity, the team reports in *Physical Review Letters*.

"Just by hearing a bell, you understand it's a big bell rather than a small bell," says Caltech physicist Katerina Chatziioannou, a coauthor of the study. "The frequencies that an object makes when you strike it are unique to it, and the same thing is true with black holes."

Like actual bells, black holes ring with a fundamental pitch and other frequencies called overtones that fade away more quickly. For the newly reported merger, both the fundamental and the first overtone were detected by the Laser Interferometer Gravitational-Wave Observatory in Hanford, Wash., and Livingston, La.

The event was comparable to previous black hole mergers seen. The two initial black holes each had masses about 30 times that of the sun, similar to the first black hole merger LIGO detected, in 2015.

Improvements to LIGO's detectors in the decade since allowed this signal to come through particularly loud and clear — about 80 times as prominent as the background noise, compared with a signal-to-noise ratio of 26 for LIGO's first detection.

The measurements matched the predictions for a Kerr black hole, based on a solution to the equations of general relativity first worked out by mathematician Roy Kerr in 1963. Kerr's solution describes black holes that are spinning, as realistic black holes are expected to. Similar tests have been tried before with gravitational wave data, but this is the first time such a clear overtone has been detected, which is necessary for this type of test, Chatziioannou says.

The team also checked whether the gravitational waves were consistent with a rule called the area theorem. This theorem states that the surface area of black hole event horizons can only grow with time. The newly formed black hole had a surface area larger than the sum of the two original ones, matching Hawking's rule.

While scientists previously did this test with LIGO's first detection of a black hole merger, the improved signal-to-noise in this new event allowed for a more definitive check. ✖

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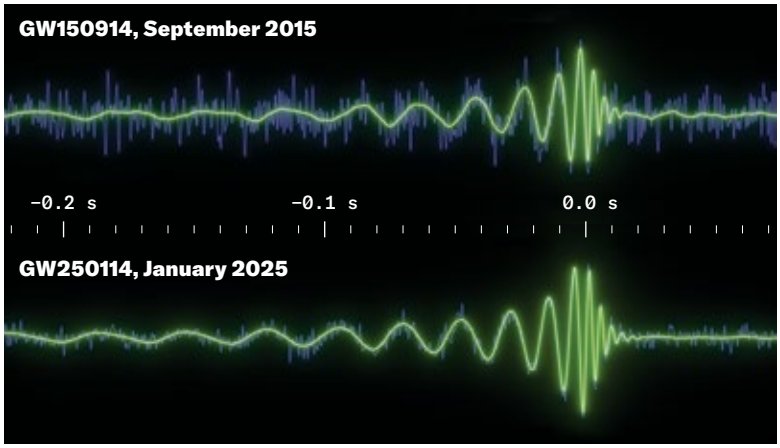

Improvements to LIGO's detectors over the last decade have reduced noise, allowing signals to pop. The amplitude of one gravitational wave signal from the LIGO Hanford detector 10 years ago (purple, top) is similar to another detected this year (bottom), but the recent detection is less jittery. The green lines are based on predictions from general relativity, fit to the data.

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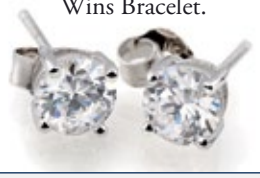

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PALEONTOLOGY

CRYSTALS PINPOINT DINOSAUR EGGS' AGE

By Carolyn Gramling

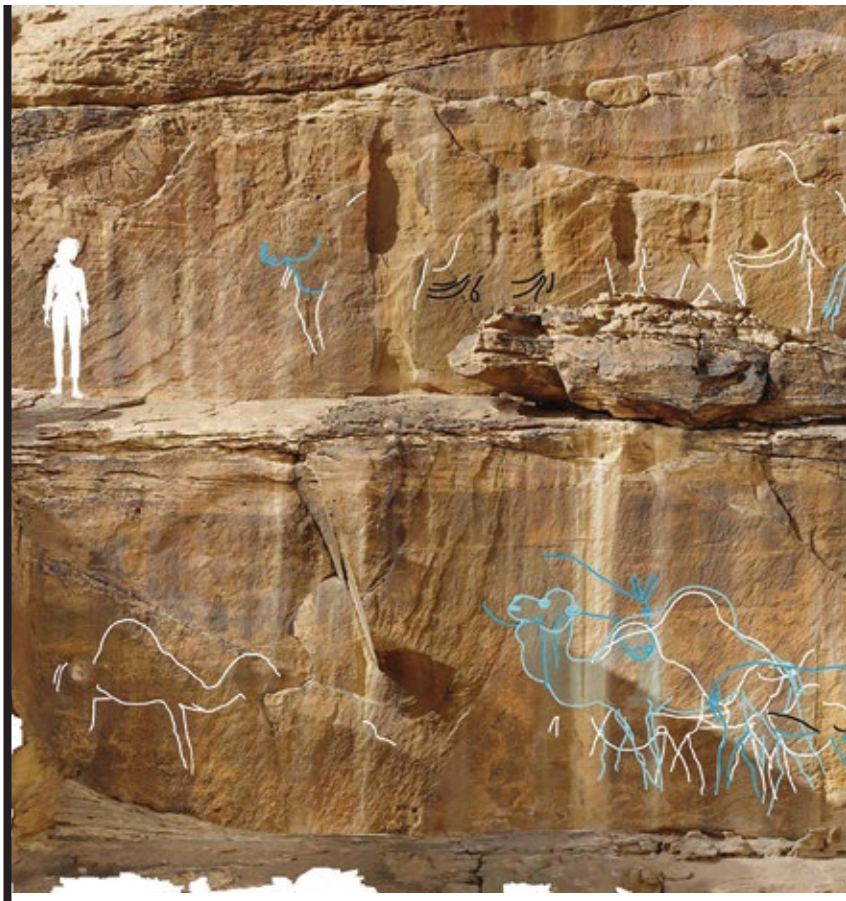
● Crystals inside dinosaur eggs have revealed how old their ancient fossilized nests really are.

Finding these eggs' true shelf life makes it possible to connect large-scale changes in climate to tiny shifts in eggshell structure, researchers report in *Frontiers in Earth Science*. That, in turn, offers a new way to assess the dinosaurs' nesting environments.

The Qinglongshan assemblage in central China contains over 3,000 dinosaur eggs of unknown parentage and—until now—uncertain age. But a clutch of 28 eggs at the site contains a secret clue.

The geodelike eggs bear large calcium carbonate crystals that have trace amounts of uranium. Based on the rate at which uranium radioactively decays into lead, the researchers estimate the eggs were deposited about 86 million years ago during the Late Cretaceous Epoch. By then, the planet had cooled considerably from the hothouse temperatures of the mid-Cretaceous.

That temperature drop could explain why the shells are very porous, the team says. The number of pores can indicate humidity, temperature or even how deeply buried a nest might have been. ✖



ARCHAEOLOGY

Life-size camel engravings hint at Arabia's verdant past

By Tom Metcalfe

● **The camels at Jebel Misma** have been frozen in a march for thousands of years.

Engraved on a cliffside at the archaeological site in Saudi Arabia's Nefud, part of the larger Arabian Desert, the life-size herd moseys near some 150 other petroglyphs. The rock art dates to between 12,800 and 11,400 years ago, when the area was thought to have been too arid to support human life, scientists report in *Nature Communications*.

The engravings, some measuring up to 3 meters long and

FROM LEFT: BI ZHAO; M. GUAGNIN *ET AL/NATURE COMMUNICATIONS* 2025

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over 2 meters tall, can be seen for miles. "They are really spectacular," says paleoanthropologist Michael Petraglia, director of the Australian Research Center for Human Evolution at Griffith University in Brisbane.

Petraglia suspects the rock art was intended to mark territory or indicate nearby sources of water. His team recently published evidence that the Arabian Desert was periodically lush and verdant over the last 8 million years until about 6,000 years ago. In the new study, sediment analyses of dry basins near Jebel Misma and another art-bearing outcrop revealed that seasonal lakes existed around the time of the petroglyphs' creation.

The earliest engravings may have been made by the first nomadic people to enter the Nefud after the Last Glacial Maximum, which made the region arid but ended about 20,000 years ago, the team suggests. As the climate became wetter and rain accumulated in temporary lakes, animals such as camels, gazelles and ibex arrived — followed by hunters who relied on the creatures for food.

Petroglyphs of those animals and human figures are etched into natural dark varnish on the rocks, exposing the sandstone beneath. Small, stylized figures of women were carved first, followed by larger human figures. Next came life-size animals, each one depicted with distinctive individual features. Animal depictions became more stylized over time, the team says, representing the evolution of the tradition.

Stone tools and other objects unearthed at the sites reveal the artists had close links to other prehistoric peoples in the Eastern Mediterranean. But the size and style of the petroglyphs set them apart and show the origins of a new tradition. The nomads were "creating this monumental rock art, which we never saw before," Petraglia says. "This is a brand-new phenomenon."

The research shows how prehistoric humans adapted to changes in climate, says paleoclimatologist Paul Wilson of the University of Southampton in England. "The Arabian desert is graced by countless prehistoric engravings and paintings that provide ... incontrovertible evidence of occupation by our ancient ancestors," he says.

Archaeologist Anna Belfer-Cohen of the Hebrew University of Jerusalem says the study opens a new window into a past time. "It tells the story of a region that was for years terra incognita, so much so that people did not even consider exploring it," she says. "These findings are eye-openers." ✖

↖ **Nomadic hunters may have engraved these camels into a cliffside in Saudi Arabia's Nefud about 12,000 years ago. The figure of a woman is superimposed next to the carvings (outlined in blue, white and black) to show their scale.**

THE HEALTH CHECKUP

BUILDING A BETTER SKIN BARRIER

BY ANNA GIBBS

Is your face a glazed doughnut or a dewy dumpling? I don't mean which of these foods are stuck on your face. Instead, these are all recent skin care trends, which, despite some key differences, share a similarity beyond their gastronomically delightful nomenclature: the popular belief that skin should glow. It should be radiant, lustrous, luminous — and even, as the aptly named glass skin trend implies, almost translucent.

In the effort to go for glass, however, it's important to remember what skin really is: a barrier. "It's not there just to hold everything in place," says cosmetic chemist Valerie George, who is the CEO of Simply Beauty Group in Dallas. "It's actually the first line of defense from pathogens entering our body." Skin keeps out not only germs and allergens, but also other external substances. That includes water — so we can swim without turning into sponges — and skin care ingredients that would irritate if too much were absorbed.

Not too long ago, George says, it was popular to rigorously exfoliate with abrasive scrubs and acids to slough off the dead cells in the skin's top layers. "It kind of wrecked people's skin," she says. "So now we're really focused on putting the barrier back." Now, influenced by the popularity of Korean regimens, Western trends have shifted to focus on restoring the barrier, which leads to clear, smooth, healthy-looking skin.

The first step? Hydration. Skin "can't provide that barrier function as well if it's all dried out," says cosmetic dermatologist Hadley King of Weill Cornell Medicine in New York City. (Picture your dry, cracked hands in the winter. Those cracks allow bacteria and irritants to get in.) Skin is always losing water, which is why moisturizing is helpful. Many moisturizers contain humectants such as glycerin and hyaluronic acid, which bind well with water and attract moisture from both the atmosphere and the skin's deeper layers. But that water can easily evaporate. That's where common occlusive ingredients, such as waxes and oils, come into play. They sit on top of the skin and physically block water loss. Hydration is key to glowy skin trends that promote a "wet" look, with a moistness that can be achieved by slathering on ingredients called emollients, which reflect light.

Healthy skin also benefits from active ingredients that target skin cells' metabolic processes — things like retinoids, vitamin A–based compounds that tackle wrinkles, or niacinamide, a type of vitamin B with antioxidant benefits. Unlike humectants and occlusives, which interact with dead cells in the stratum corneum, the skin's top layers, active ingredients need to do their work in living cells. Reaching those cells can be a challenge. The stratum corneum includes layers with lipids that help keep water out. If a molecule's chemistry is water soluble — meaning it won't mix with lipids — "it's going to have a hard time penetrating," George says.

Other factors that determine how easily a molecule can penetrate the skin include size and polarity, or the distribution of charge across the molecule. Smaller molecules that have the same charge as the stratum corneum's lipids tend to slip in more readily. In products with ingredients that don't penetrate easily, such as retinoids, cosmetic chemists can add solvents to aid penetration.

Because different skin care ingredients work in different layers of the skin, application order matters. Dermatologists typically recommend starting with thinner products (think serums) and moving to the thickest (say, sunscreen), because otherwise heavy products could block the ingredients in lighter ones.

If you're striving for a translucent glow, focus on strengthening your barrier, and add some humectants if you want that moist, glassy look. As King says, "healthy skin looks good." ✖

A. GIBBS

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NEUROSCIENCE

The brain preserves maps of missing hands for years

By Laura Sanders

● **The brain holds space** for a missing limb, even years after the limb is gone.

For three women who underwent planned hand amputations, brain scans revealed remarkably durable maps of hand areas, lasting for five years in one case. The results, published in *Nature Neuroscience*, counter the long-held idea that the adult brain remakes itself in prominent ways after a change to the body, such as an amputation.

Previous research, much of it in rodents and nonhuman primates, suggested that the brain's real estate shifts after a limb is gone. It was thought that the brain area that used to receive input from a missing hand would be taken over by neighboring areas, particularly those corresponding to the face and lips.

But that idea doesn't fit with a common phenomenon: People often retain vivid sensations of their missing limb, including what's known as phantom pain, says Hunter Schone, a neuroscientist at the University of Pittsburgh. "These two ideas of 'The brain is completely changing,' and the amputee experience, saying, 'I can still feel the limb,' are very much in conflict with each other."

Schone and colleagues set out to see how the brain adjusts — or doesn't — after amputation. The study depended on three women facing planned hand amputations, each of whom agreed to functional MRI brain scans before and after their surgeries. "They offered their time at one of the most difficult periods of their lives," Schone says.

During the scans, the women moved their fingers one at a time, curled their toes and pursed their lips. These small movements triggered changes in blood flow in the brain that marked activity in the primary somatosensory cortex, a neural strip that runs up each side of the brain, from just above the ear to the top of the head. This area handles signals from the body, including touch, pain and spatial position.

That neural real estate remained unchanged after amputation, additional brain scans showed. When

PETE RYAN

the women attempted to move their missing fingers one at a time, the same brain activity patterns showed up as before, even though the fingers weren't there. And pursing their lips didn't lead to any new activity in the hand area, suggesting that the lips' neural connections didn't expand into this territory.

The hand maps were sturdy. When one woman was scanned five years after surgery, her hand map showed no overt differences. Those results fit with scans of 26 other amputees that the team analyzed.

"There is really strong, consistent evidence in pretty much every amputee I scan that there is persistent representation of their missing hand," says Tamar Makin, a cognitive neuroscientist at the University of Cambridge.

By comparing the three women's brains before and after surgery, the study design "is a powerful way to say, at the macroscopic, global scale, we can't really detect the strong reorganization," says Dan Feldman, a neuroscientist at the University of California, Berkeley who was not involved in the research.

"That doesn't mean [reorganization] is not there at the local scale and may be doing important things," Feldman cautions. But on bigger scales, such as those detected by fMRI, "maybe the maps are not changing."

The finding may have implications for the design of prosthetics and treatments for phantom limb pain, which is common and sometimes debilitating for people who have lost limbs. Some approaches aim to stop or shift purported brain rewiring, but they are based on flawed reasoning, Schone says. "Our study says we need to stop chasing or trying to fix broken brain maps that aren't actually broken." ✖

ARTIFICIAL INTELLIGENCE

AI GENERATES BLUEPRINTS FOR BACTERIA-KILLING VIRUSES

BY ERIN GARCIA DE JESÚS

Artificial intelligence can dash off more than routine emails. It has now written tiny working genomes.

Two AI models designed the blueprints for over a dozen viruses capable of attacking *Escherichia coli* in lab dishes, researchers report in a paper posted to bioRxiv.org. A mixture of these AI-generated bacteriophages stopped virus-resistant *E. coli* strains from growing, suggesting that the technique could help scientists design therapies capable of taking on tough-to-treat microbial infections. The work has not yet been peer-reviewed.

AI models have already been used to devise genes and proteins. This is the first time that AI has successfully generated an entire genome, says Brian Hie, a computational biologist at Stanford University and the Arc Institute in Palo Alto, Calif. And while it's debatable whether viruses are alive or not, the work is a step toward AI designing living organisms.

Hie's team turned to the AI models Evo 1 and Evo 2 to create genomes for bacteria-killing viruses. The models were trained on billions of pairs of the genetic alphabet's basic units — A, C, G and T — from phage genomes, the way ChatGPT was trained on novels and internet posts. The team used a well-studied bacteriophage called ΦX174 as a guide to help the AI design a similar genome. "If the AI was making novel mutations to the phage, we would be able to see how novel they are," Hie says.

The AIs generated about 300 potential phage genomes. From those blueprints, scientists created 16 viruses that could infect *E. coli*. Some of the phages killed *E. coli* more quickly than ΦX174 did. And cocktails of AI-generated phages rapidly evolved to overcome infection-resistant *E. coli* strains.

The findings suggest that AI could help develop viruses to treat antibiotic-resistant infections. In such cases, "the need to find a phage that targets the bacterial strain would be very urgent," says microbiologist Kimberly Davis of Johns Hopkins Bloomberg School of Public Health. "AI could be a powerful way of rapidly generating a phage match to treat patients."

The use of AI-generated phages would need to be tightly controlled, Davis notes. For instance, extensive testing could ensure that such phages don't harm other kinds of microbes. ✖

From One Patient to Many: **How Baby KJ is Ushering in a New Era in CRISPR Medicine**

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When the world's first personalized CRISPR gene editing therapy was administered to "Baby KJ" Muldoon in May 2025, it marked the pinnacle of an unprecedented six-month collaboration between academic scientists and the biopharmaceutical industry. Children's Hospital of Philadelphia and the University of Pennsylvania worked closely with Danaher companies, Aldevron and Integrated DNA Technologies (IDT), as well as Acuitas Therapeutics, to fast-track the creation of the CRISPR-based therapy, which was developed after KJ was diagnosed with Urea Cycle Disorder (UCD), a life-threatening genetic disease.

UCD, a disease marked by dangerous levels of ammonia that build up in the bloodstream, is caused by a single pathogenic point mutation in the CPS1 gene. That makes it a prime candidate for a type of CRISPR gene editing called base editing, which can correct such mutations. The technically complex therapy required the rapid development of a new guide RNA (gRNA) sequence, a novel mRNA-encoded base editor, custom off-target analysis services and a clinically validated lipid nanoparticle (LNP) formulation from Acuitas Therapeutics.

Aldevron and IDT, along with Acuitas Therapeutics, worked hand-in-hand to produce the treatment in a third of the time that would normally be required to develop a CRISPR-based therapy. The joint manufacturing achievement reflects a first-of-its kind for the industry — an historic medical breakthrough that will pave the path for the rapid development of CRISPR-based therapies for other genetic diseases.

Streamlining CRISPR Workflows

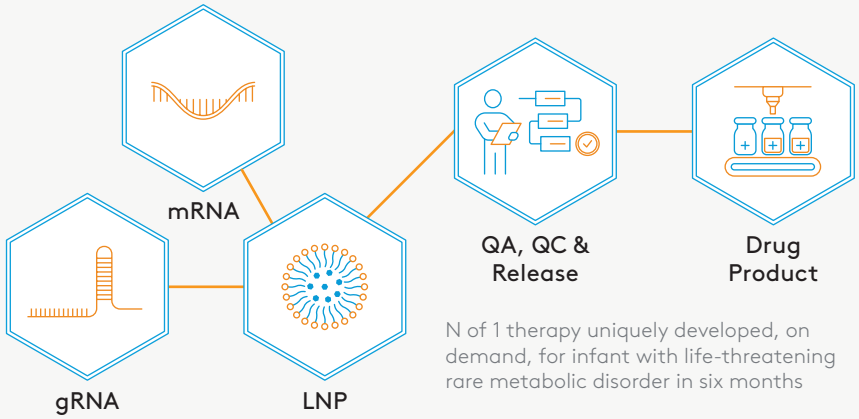
UCD is caused by a deficiency in one of six enzymes responsible for converting nitrogen from protein metabolism into urea, which is normally excreted in urine. Because of this deficiency, nitrogen accumulates as ammonia in the bloodstream, leading to neurotoxicity that can result in coma, irreversible brain damage or death. Current treatments, which include protein-restricted diets and intravenous nitrogen-scavenging drugs, can only manage symptoms.

CRISPR-based editing offers a potential solution for the targeted correction of enzyme deficiencies such as UCD. The rapid development of KJ's CRISPR therapy was made possible by using the Danaher Business System (DBS), the platform helps facilitate multi-party collaboration and complex manufacturing. This approach represents a paradigm shift from traditional 18-24 month development cycles to personalized treatments delivered in months, making previously impossible therapies accessible.

Each of the three elements of KJ's therapy — the mRNA base editor, gRNA and LNP — required precise manufacturing processes. Aldevron has a clinical-grade mRNA production platform, allowing it to expedite the development of the base editor. Meanwhile, IDT led the manufacturing of the cGMP gRNA. IDT's existing assays for on and off-target analysis studies, UNCOVERseq and rhAmpSeq™, helped the collaborators to move fast once KJ's disease-causing mutation was identified. UNCOVERseq was used to determine 300-plus potential sites of cleavage/mutations, while rhAmpSeq™ confirmed there were no concerning off-target edits.

Clinically validated LNP technology and manufacturing processes from Acuitas Therapeutics were used to produce this therapy. Acuitas' LNP manufacturing processes had already been established at Aldevron in May 2024 in a partnership with Acuitas to enable Aldevron to manufacture Acuitas' proprietary LNP to support global partners. This baseline implementation, together with direct engagement of Acuitas

There were three key elements to the therapy – gRNA, mRNA base-editor, LNP – all requiring precise manufacturing.



N of 1 therapy uniquely developed, on demand, for infant with life-threatening rare metabolic disorder in six months

The world's first, personalized, mRNA-based, CRISPR therapy was manufactured at Aldevron's cGMP facility in Fargo, ND.

and Aldevron SME's in the manufacturing suite, allowed the production of KJ's treatment without the need for additional drug product development, further accelerating the timeline.

The support of IDT's and Aldevron's Quality Assurance and Regulatory Affairs teams enabled the rapid transition from design to clinical readiness. In the first three months, these teams developed the most precise gene-editing approach. Months four through six were spent manufacturing the RNA-LNP components and ultimately the drug product in collaboration with Acuitas for toxicology studies, performing safety studies in mice and nonhuman primates, and then manufacturing the CRISPR-based therapy that was ultimately approved for KJ.

Expediting the development of this therapy required all of the collaborators to look at every possible way to save time, said Sandy Ottensmann, vice president and general manager of gene writing and editing at IDT. "We parallel processed a lot of things," she said during a Genetic Engineering & Biotechnology News webinar in July. That meant starting some steps of the process before all of the data came in from previous steps, for example. This sometimes required taking on more risk than they might have on a traditional, more extended development timeline. But it was worth it, Ottensmann said, "because having those extra days, those extra weeks, counts so much." In this case, those extra days helped IDT and Aldevron manufacture the mRNA and gRNA drug substances at speed under phase-appropriate cGMP, working with their quality and regulatory teams to ensure they were aligned with FDA guidance for compassionate use.

KJ received the first dose of the CRISPR therapy at six months of age, with a second dose administered several weeks later. Within seven weeks of the first dose, he was able to tolerate an increase in dietary protein, and his dose of a nitrogen-scavenging drug was halved. No serious adverse events were reported.

Shaping the Future of Genomic Medicine

Can the success of Baby KJ's treatment be replicated to create more rapid personalized CRISPR-based therapies? Aldevron and IDT are committed to working together with genomics innovators to make that vision a reality. The CRISPR platforms both companies have been developing can offer a single-vendor solution for a range of gene editing therapeutics.

IDT offers a complete workflow for every stage of gRNA development, from discovery through cGMP manufacturing. Aldevron delivers cGMP mRNA, including LNP encapsulation, analytical testing and sterile fill and finish, eliminating logistical risks and enabling faster timelines with seamless mRNA manufacturing.

One key to the success of Baby KJ's treatment was Aldevron and IDT's unified quality framework and regulatory approach. This facilitated regulatory speed without compromising rigor. Together, all the companies, including Acuitas, aligned on cGMP expectations, streamlined documentation while protecting intellectual property, and maintained direct communication with the FDA to enable real-time issue resolution. As a result, the teams delivered a 300-page technical package to the FDA in four days, and the agency approved the Emergency Investigational New Drug Application in seven days, vs. the standard 30-day approval process.

This strategic alignment demonstrated the power of Aldevron's and IDT's ability to scale quality systems and accelerate regulatory submissions for future CRISPR therapies.

"This project demonstrates the transformative potential of mRNA gene-editing therapies and marks a significant milestone in the industry," said Jennifer Meade, president of Aldevron. "Our vision is to be the engine of innovation for genomic medicine pioneers, and this project is a clear proof of concept that we are ready to put our innovations to work for our clients and the patients they serve."

To learn more, visit World's First mRNA-based Personalized CRISPR Therapy. Early outcomes are observational. Long-term safety and efficacy are being evaluated.

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Features

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SCIENCE & SOCIETY

MEASLES COMES ROARING BACK

● In Texas, a woman and child read about immunizations as they wait for a measles vaccine. Highly contagious, measles reared its head in the Lone Star State and 40 others this year, sickening over 1,600 people and killing three as of press time. It's the largest measles spike the country has experienced in three decades; outbreaks are ongoing. Actions by the Trump administration have hindered the federal emergency response and sowed confusion about vaccine safety, making it harder for parents to manage their children's vaccines (see Page 38). — *Cassie Martin*

SCIENCE, BLINDSIDED

Science has always made America great.
What happens when its biggest supporter attacks?

By Nancy Shute

Illustration by Martin O'Neill

● **When the United States faced** the looming threat of World War II in the 1930s, it bet big on science — and won. The nation invested billions of dollars in research at universities and in industry. That influx of funds led to multiple advances in weaponry, including the atom bomb. Less morally fraught innovations included radar, computer technologies and large-scale production of penicillin.

Near the war's end, President Franklin D. Roosevelt asked science advisor Vannevar Bush to chart a path forward. Bush said that investing federal dollars in training and supporting scientists and engineers would deliver a bigger payoff over time than focusing on a new weapon or product. The scientists' skills could be called on during the next national emergency. In the meantime the basic research they conducted would benefit the health, security and prosperity of the nation.

That bet paid off spectacularly; the United States quickly became a world leader in scientific, medical and technological innovation. That dominance continues. For instance, U.S. researchers currently hold more Nobel prizes than do those from any other nation.

But the expectation of continued success for American science was shaken this year when President Donald Trump's administration cut billions of dollars in funding for federal science institutions and research universities, fired thousands of scientists and gave incentives for more to retire early.

The federal budget for 2026 has yet to be approved, but the administration's draft budget proposes cutting funding by 40 percent for the National Institutes of Health, 38 percent for the Centers for Disease Control and Prevention and 21 percent for the National Oceanic and Atmospheric Administration.

This massive retrenchment runs counter to history: Science has been core to the American experiment since its beginning. In his 1796 State of the Union address, President George Washington advocated for science as key to "national prosperity and reputation."

Early innovations often came from solo inventors and reflected the pragmatic needs of a growing nation: the mechanical grain reaper, the sewing machine, the typewriter.

The federal government made its first big investments in science and technology in 1862, during the Civil War. With agriculture still accounting for the bulk of the national economy, Congress founded the U.S. Department of Agriculture and the land-grant program that funds state colleges of agriculture and technology. The National Academy of Sciences was created in 1863 and the U.S. Weather Bureau — now the National Weather Service — was formed in 1890.

In this special report, we examine how the administration's attacks on science in 2025 are already impacting public health, innovation and economic prosperity in ways that will be challenging to overcome even if funding is eventually restored. We talk to leaders in key fields to understand how impediments to the scientific enterprise in the United States are being felt worldwide.

And we find hope in the ways states, scientists, organizations and even private individuals are seeking paths forward despite the chaos and uncertainty. Their question is not whether American science will continue, but how they will make it happen. ✖

Eroding access to childhood vaccines jeopardizes health for all

By Aimee Cunningham

Childhood vaccines are one of the biggest public health wins, protecting people against nearly 20 preventable infectious diseases.

JOE RAEDLE/GETTY IMAGES

● **In September, the federal committee** that makes vaccine recommendations voted to change the childhood immunization schedule. That in itself isn't unusual; past committees have done so over the years. But this time, careful deliberations and evidence-based decisions, hallmarks of past meetings, were absent.

The committee removed the option for a combination vaccine as the first dose to protect against measles, mumps, rubella and varicella, better known as chicken pox. Now, 12- to 15-month-olds would get the chicken pox shot separately. The reason for the vote: a rare chance a child might have a febrile seizure, a usually harmless side effect that was already known.

The change may seem insignificant, since the majority of parents already chose to separate the chicken pox shot for their kids' first dose. But, along with comments by President Donald Trump and his top public health leaders raising doubts about other vaccines, it signals bigger changes to come, ones that could threaten the very foundation of the national childhood vaccination schedule.

Begun in the mid-1960s, this schedule has been a tremendous public health success. Today it protects people against close to 20 diseases, including polio, tetanus, hepatitis B and measles. It also helps prevent cancers of the cervix and liver.

But Trump named Robert F. Kennedy Jr., an antivaccine advocate, to head the U.S. Department of Health and Human Services. Kennedy then fired vaccine and public health experts on the Advisory Committee on Immunization Practices, or ACIP, the group that establishes vaccine recommendations. His replacements included people with similar antivaccine views and little expertise in vaccines.

The September meeting was a stark reminder that the new ACIP would not be following in the footsteps of its predecessors. Past ACIP committees have historically been known for their scientific rigor. For instance, when measles outbreaks occurred in 1989, the group recommended

adding a second dose of the measles, mumps and rubella, or MMR, shot. Research later revealed a small but increased risk of febrile seizures with the combination with varicella, or MMRV, shot as a first dose.

A febrile seizure is a convulsion caused by a high fever due to viral illness or following certain vaccinations, or because of a genetic predisposition. Between 200 and 500 kids per 10,000 will have a febrile seizure for any reason, most often from the ages of 6 to 60 months. About 4 of every 10,000 kids who, for a first dose, get the MMR and chicken pox shots separately have a febrile seizure; about 8 in 10,000 do with the MMRV jab. While scary, they rarely cause harm. Still, ACIP in 2009 recommended that children get two separate shots for that dose, unless parents prefer the MMRV and have been told of the risk.

The new ACIP's September meeting "was a clear departure from standard operating procedures," said Helen Chu, an infectious diseases doctor at the University of Washington School of Medicine in Seattle and a former voting member on ACIP, at a news briefing days later. Along with removing MMRV as an option for the first dose, the members discussed delaying the birth dose of the hepatitis B vaccine — despite a dearth of new evidence that would call for a review.

Then, Trump and HHS officials spent the next days sowing more doubt, questioning the safety of the MMR vaccine itself, in use for more than 50 years. They suggested it should be separated into three shots, even though the single vaccines are no longer available in the United States.

Combination vaccines are a staple of the childhood vaccination schedule, and for good reason. Children who get the combo shots are more likely to get all the doses for a vaccine and get them on time. They need fewer pokes and fewer trips to the doctor's office to acquire full protection against diseases.

The premise that vaccines shouldn't be combined "is a misunderstanding of how the immune system works," says Flor Muñoz, a pediatric infectious diseases specialist and vaccine trials investigator at Baylor College of Medicine in Houston. A large body of evidence has refuted claims that getting multiple vaccines during early childhood weakens the immune system.

False information about vaccines has existed for about as long as vaccines have. In recent years, it's been amplified by social media. At the state level, antivaccine legislation has been ramping up, with Florida even announcing plans in 2025 to abolish school vaccine mandates.

Now, questions about the safety and effectiveness of vaccines are coming from the federal government, too. The difference is, it has the power to make national policy, setting in motion changes that increase our vulnerability to preventable infectious diseases.

There is much to lose. A study from the U.S. Centers for Disease Control and Prevention estimates that among people born during 1994 through 2023, immunizations given during childhood will have stopped around 508 million cases of illness and will have prevented more than 1 million children's deaths. If the Trump administration continues to chip away at the childhood vaccine schedule, the United States could, over time, return to the days when infectious diseases regularly hospitalized children and unnecessarily cut short young lives.

"It means that we will have a high chance of recurring outbreaks of some of the diseases that we've been able to control," says pediatric infectious diseases physician and epidemiologist Andrew Pavia of the University of Utah in Salt Lake City. "Most people have never seen a child go deaf from measles," Pavia says. "They've not seen a child develop terrible complications of regular flu and end up in the ICU."

That is in part because of the decades of work

LIFETIME HEALTH AND ECONOMIC OUTCOMES IN CHILDREN — UNITED STATES, 1994–2023

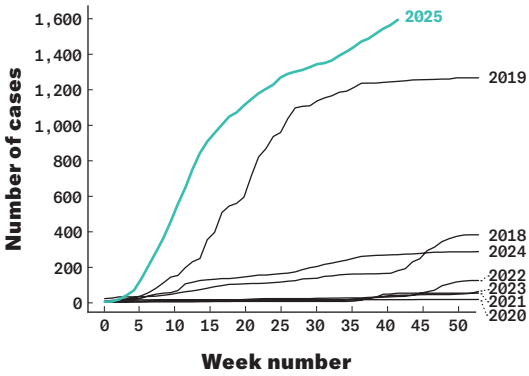
507,683,000
Total illnesses prevented

31,955,000
Total hospitalizations prevented

1,129,000
Total deaths prevented

Source: CDC

CUMULATIVE REPORTED U.S. MEASLES CASES, 2018–2025



Measles surge The 2025 measles outbreak is the largest in the United States in more than three decades. This chart shows cumulative measles cases reported per week in each year since 2018. The steep rise in 2025 mirrors resurgence in 2019, when U.S. cases last surged past a thousand. As of late October, more than 1,600 measles cases have been confirmed across 41 states. Source: Johns Hopkins Univ.

by the many experts in public health, pediatrics, immunology and other scientific fields who have served on ACIP, culminating in a unified, national childhood vaccination schedule. Shots cover one or multiple pathogens and are given in different numbers of doses and at different times, starting at birth and continuing through the teenage years.

ACIP recommendations establish which vaccines must be covered by insurance and by the federal Vaccines for Children, or VFC, program. Created to address disparities in vaccine coverage, VFC provides vaccines at no cost to children and teens eligible for Medicaid, those who are uninsured or underinsured and American Indian and Alaska Native youth. The program covers about half of U.S. kids. Health insurance companies have announced they will continue to cover vaccines recommended prior to September 2025 until the end of 2026. But VFC must follow current ACIP recommendations. That means that with their September vote on MMRV, the new ACIP has taken a vaccine choice away from tens of millions of children. If the September meeting is a preview of more vaccine shifts to come, the country is headed toward a divide in vaccine access, putting the health of VFC kids at risk.

And eventually, it will affect everyone. Disparities can lead to pockets of unvaccinated and under-vaccinated children. Those pockets spur outbreaks. Take highly contagious measles. The first outbreak in 2025 began in Gaines County, Texas, where the MMR vaccination rate among kindergartners was only 82 percent, far below the 95 percent coverage needed to stop measles from spreading in the community.

Public health alarm bells are also going off regarding the committee's discussion about the hepatitis B vaccine birth dose. If it is delayed or no longer given to all babies, past experience indicates dire consequences. Infancy is the most harmful time to become infected with the disease: Around 90 percent of infected infants will develop chronic hepatitis B. Chronic disease damages the liver and increases the risk of liver cancer. A quarter of people who become ill with hepatitis B in childhood will die prematurely.

Since universal hepatitis B vaccination for infants was recommended in 1991, the total number of reported hepatitis B cases has fallen from around 18,000 a year to about 2,200 in 2023. And cases among children and teens have almost completely vanished. A universal approach for newborns "has been a tremendous success that's benefited many, many children," Pavia says. Without it, "almost certainly, more children will end up getting infected with hepatitis B."

To counter federal leaders' attacks on vaccines, medical societies and some states are stepping in. The American Academy of Pediatrics, the Infectious Diseases Society of America and others have been providing trustworthy vaccine information and countering falsehoods. Parents can look to AAP's childhood vaccination schedule for the most recent, evidence-based version. Some states have formed public health coalitions to provide vaccine recommendations, although a patchwork approach can't do what a unified vaccine schedule can. "Diseases don't respect state borders," Chu said.

So far, there is still widespread support for childhood vaccines among parents, with around 9 in 10 saying it is important for kids to get MMR and polio shots, according to a KFF-*Washington Post* poll released in October. About 8 in 10 want public schools to require these vaccines. Pavia hopes this confidence in vaccines "will counteract this hijacking of health care."

Because of the success of childhood vaccinations, we can focus on other health issues children face, Muñoz says. "The growth and ability of children to thrive in all aspects of their lives has been supported in great part through prevention of infectious diseases." ✖

THIS PAGE: C. CROCKETT; OPPOSITE PAGE: ALLI KANE

Life-saving research on extreme heat comes under fire

By Nikk Ogasa

● **Located just a few hours' drive** from the Canadian border, Missoula, Mont. is not known for sweltering temperatures. And yet heat waves are becoming more common in the mountainous region due to climate change, and researchers are concerned that a catastrophic heat event could soon shock the 120,000 or so people who call Missoula County home. Recent history reveals the cost of being unprepared for extreme heat; in 2021, the Pacific Northwest was caught off guard by the strongest heat wave the region had seen in a thousand years, resulting in more than 1,400 deaths.

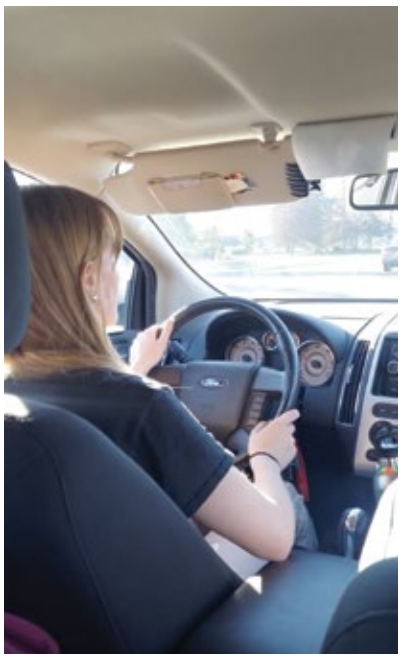
"We've come to understand that heat is a major threat to our region," says Alli Kane, the Climate Action Program Coordinator for Missoula County. "And it's something that we're not prepared for."

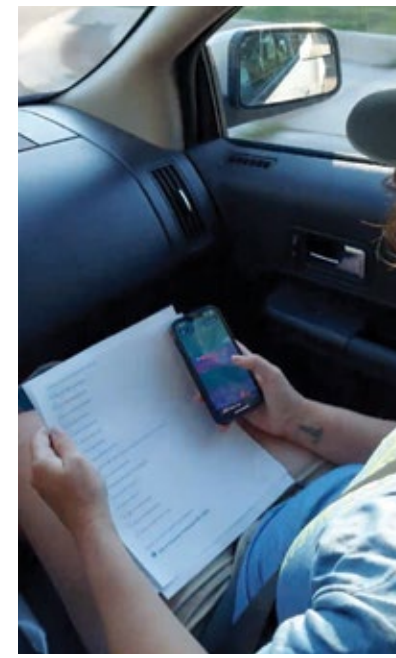
In January, Missoula successfully applied to work with the Center for Collaborative Heat Monitoring, a federally funded partnership of science museums and heat experts tasked with mapping heat in communities across the country. The virtually-based center had planned to provide expertise and $10,000 in funding to Kane and her colleagues to identify the hottest places across Missoula County.

But in May, federal funding for the Center for Collaborative Heat Monitoring was terminated.

The boots-on-the-ground effort would have provided a more detailed picture than satellite data of where Missoula's heat was most intense, helping the county focus its efforts where they were most needed. "This is life-saving data," Kane says. "We know heat is the number one weather-related killer across the United States." In the last decade, heat has on average killed more people each year than floods, tornadoes and hurricanes combined.

The center is one of many casualties in the Trump administration's cuts to research into extreme heat nationwide. Many of those cuts were part of the administration's attack on climate science and environmental justice. But the impacts to heat research have been especially rough, because many unanswered questions





In August, volunteers (left, right) drove around Missoula County measuring heat and humidity using sensors (center) mounted on their vehicles.

remain about how heat affects different populations, how to manage heat and how to keep people safe.

"Every heat-related death is potentially preventable," says Kristie Ebi, an epidemiologist at the University of Washington in Seattle who studies the human health impacts of climate warming. But with all the unanswered questions, "they're not being prevented."

The cuts come at a time when extreme heat waves are becoming more common and intense as the climate warms from humankind's burning of fossil fuels. The 10 most recent years have been the 10 warmest ever recorded. Last year was the hottest so far. The Centers for Disease Control and Prevention estimate more than 700 people die from heat annually in the United States. But heat-related deaths are drastically underreported; the true toll may reach up to 15,000 fatalities each year, says environmental epidemiologist Tarik Benmarhnia of the University of California San Diego.

The Center for Collaborative Heat Monitoring was created in 2024 by the National Integrated Heat Health Information System, or NIHHIS. It's a partnership of federal agencies established during the Obama administration to generate and share science-based information and tools to keep people safe from heat. Since 2015, NIHHIS has supported heat mapping campaigns in urban and rural areas, helped produce resources like the Heat.gov website and the HeatRisk online tool, and funded a swath of efforts to make communities more resilient against extreme heat.

But this year, NIHHIS has been devastated by funding cuts to programs and by people being fired or choosing to leave, says Juli Trtanj. She left her role as executive director of NIHHIS in April, partly because so many of her colleagues departed. "The ability for forward planning, the long-term stuff, any of that, is just gone," she says. Due to the government shutdown in October, NIHHIS officials did not respond to requests for comment.

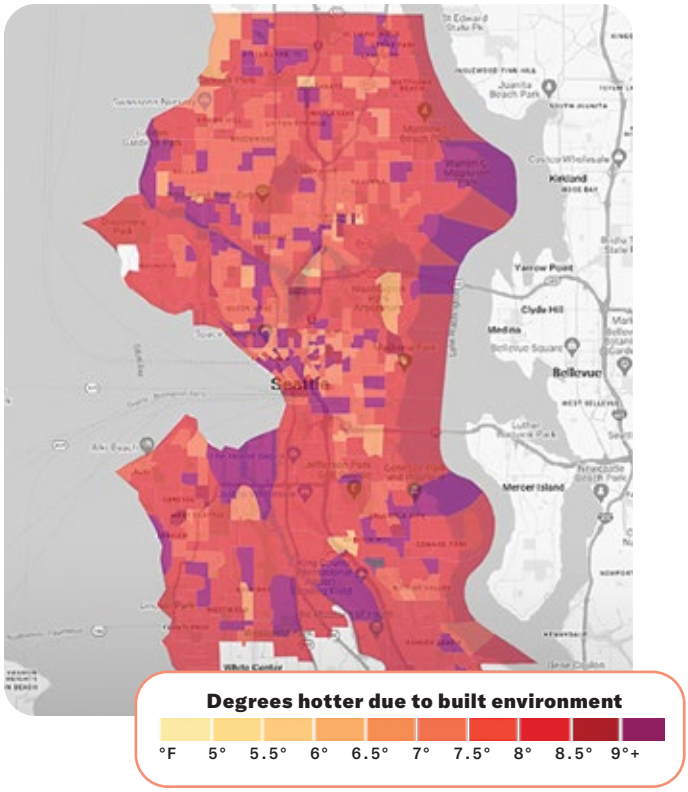
The Center for Collaborative Heat Monitoring was supposed to map roughly 30 communities over the next three years. The first cohort of 11 communities had already been selected. That included Missoula County, which had been in the middle of planning when the news landed. The terminated funds would have gone to organize and support the volunteers who would be mapping heat throughout the county. Instead, "there was a lot of unknown, a lot of confusion," Kane says.

In 2024, NIHHIS also created the Center for Heat Resilient Communities in Los Angeles. That center was meant to use science to tailor blueprints for managing heat in communities across the country, while giving researchers an opportunity to test heat planning strategies in a mix of settings. But like the Center for Collaborative Heat Monitoring, its funding was terminated.

Layoffs also have slammed the CDC's National Institute for Occupational Safety and Health, or NIOSH, the only federal research entity that studies how heat harms workers. Around 90 percent of its workers were laid off in spring. While a fraction has since been reinstated, NIOSH heat experts are among those who have not returned. The first federal standard protecting workers from heat, which was based on NIOSH guidance, was proposed in 2024. But laid-off NIOSH heat experts were unable to defend the standard in public hearings this summer, fueling concerns about its fate.

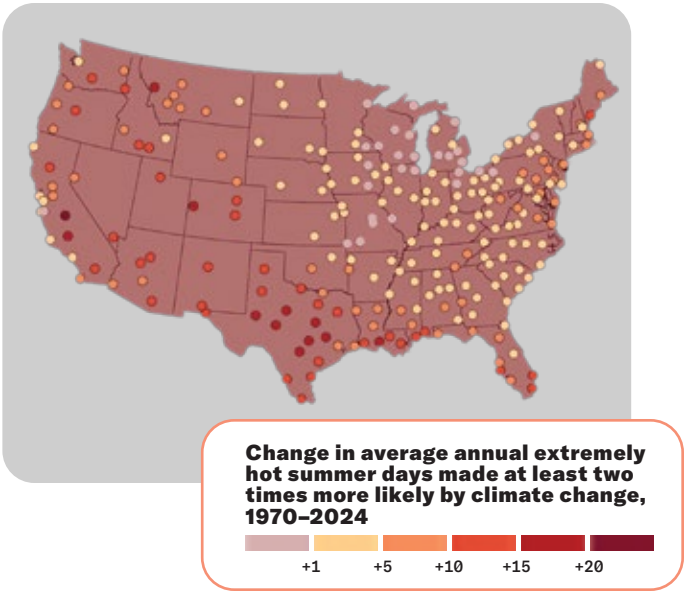
Additional cuts to funding from the National Science Foundation, the National Institutes of Health and other federal sources have further

SEATTLE'S URBAN HEAT HOT SPOTS



The heat map below shows how temperatures in parts of Seattle can get more than 9° F higher than what the area would feel like without heat-trapping urban materials.

EXTREMELY HOT SUMMER DAYS ON THE RISE



This map shows how more than 200 U.S. cities have seen a rising number of extremely hot summer days over the last 55 years.

weakened the heat research ecosystem.

Benmarhnia, of UC San Diego, studies how extreme heat and other climate risks affect public health. From January to June, he was forced to scrap research plans, including a project on heat's impacts on unhoused people, and to shrink his team of more than 30 researchers to fewer than 10. "That was horrible," he says. Researchers are now forced to avoid using keywords like "climate" and "environmental justice" in grant applications, Benmarhnia says. But it's nearly impossible to divorce heat from those concepts.

For instance, a 2020 study of nearly 500 U.S. urban areas found that poorer and nonwhite urban residents tended to experience more intense summer daytime heat. The United States had an opportunity to build heat management programs that place equity at the fore from the ground up, says Kelly Turner, an urban environment researcher at the University of California, Los Angeles, and director of the Center for Heat Resilient Communities. But "that opportunity has been squashed."

Benmarhnia worries the cuts will not only impact the direction of heat research, but also could lead to fewer scientists studying heat in general. His concerns resonate with Mayra Cruz, a University of Miami heat and health researcher who expects to finish her Ph.D. soon. While Cruz doesn't see a scarcity of jobs working on flooding and other environmental hazards, "I don't see any heat positions," she says. "That definitely signals to me that there's a difference there in how we're thinking about heat in this administration versus other issues."

And if heat researchers move overseas to pursue funding, that could lead to more U.S. lives lost over time, Trtanj says. Roughly 75 percent of the 1,608 scientists who responded to a *Nature* poll said they were considering leaving the country following disruptions to science by the Trump administration. "The knowledge that we should be learning about what works for the U.S. economy and U.S. citizens, that's being applied to other countries," she says.

Even with the losses in funding and personnel, folks have found ways to keep some heat research alive.

In Missoula County, a fleet of more than 30 volunteers drove a dozen routes through both rural and urban areas on August 12, gathering data on heat and humidity with antenna-shaped sensors mounted on their vehicles.

The work was made possible because Kane and her colleagues managed to piece together a small amount of funds to replace some of the lost federal dollars. They used it to pay for technical guidance, equipment and data analysis by the Center for Collaborative Heat Monitoring and CAPA Strategies, a Portland, Oregon–based consultancy. That supported the heat-mapping efforts in Missoula and most of the other communities. But gaps remain.

"We had, with Missoula, also intended to do some longer-term monitoring and modeling [and] other community engagement," says Max Cawley, the center's director who is based in Raleigh, N.C. "Those became incredibly challenging to try to figure out how to fit into a very busy and now unfunded set of summer projects."

Smaller entities such as states, local governments and community-based organizations are trying to fill the gap, but many communities lack the resources and expertise to address extreme heat on their own.

"Climate impacts are already hurting vulnerable communities the most," says Susan Teitelman, a climate resilience specialist at Climate Smart Missoula, a local nonprofit that helped organize Missoula's heat mapping effort. "When federal funding is taken away, those groups or communities are going to be harmed first and hardest," she says.

For now, it falls upon senior scientists to keep the candle burning, Benmarhnia says. "That's really how I see my responsibility right now," he says. "To keep doing it." ✖

Funding chaos may unravel decades of biomedical research

By Tina Hesman Saey

A scientist examines a culture of bacteria that cause tuberculosis at a lab in Peru operated by Socios En Salud. Megan Murray's grants help pay for equipment and Peruvian and U.S. scientists' salaries.

WILLIAM RODRIGUEZ/SOCIOS EN SALUD

● **Megan Murray has been in limbo.** The Harvard University epidemiologist and infectious diseases doctor has grants from the U.S. National Institutes of Health to fund ongoing research on tuberculosis. Over decades, her work has produced insights on how TB spreads, how genetic and microbial characteristics interact in the disease and better ways to diagnose TB in people who don't have symptoms. NIH told Murray in September that she would be getting a large new grant to study long-term lung damage from TB.

Yet between April and October, the agency didn't give Harvard any money. Many of her colleagues and collaborators have had their grants cut or suspended. "Weirdly, my grant" Murray says, "was not terminated." In principle, the money was restored in October, but the government shutdown meant she couldn't spend it. Without money from NIH in hand, Murray was in a strange netherworld in which she both did and didn't have research funding. Her scenario highlights the damage being done to biomedical research as labs get caught in battles between the Trump administration and academic institutions.

Harvard is just one of the universities that had its federal research funding threatened in 2025 as the Trump administration waged a campaign to reshape higher education according to the president's agenda. In a post October 12 on his social media platform Truth Social, Trump wrote that "much of Higher Education has lost its way, and is now corrupting our Youth and Society with WOKE, SOCIALIST, and ANTI-AMERICAN Ideology."

Murray was drawn into the fray when the administration froze $2.2 billion in NIH grants to Harvard researchers. The administration claimed that the university failed to protect students and faculty from antisemitism on campus. Harvard sued, and a federal judge ruled that the administration's actions violated First Amendment rights to free speech, saying the government could not enforce these funding freezes or terminations. The government said it will appeal the ruling and is trying to ban Harvard from getting federal funds in the future.

Some universities have bowed to administration demands to keep federal funds flowing. In July, Columbia University agreed to pay $221 million to the federal government to settle antidiscrimination charges similar to those levied against Harvard and restore grant funding. Brown University and the University of Pennsylvania also struck deals with the administration, while several other universities have been locked in negotiations for months.

In October, the administration sent a compact to nine institutions — later extended to all colleges and universities — asking them to agree to provisions such as ending diversity, equity and inclusion programs, dismantling departments the administration deems hostile to conservative ideas, defining women according to certain biological characteristics, and limiting the number of foreign students. In exchange, the universities

would get priority access to grant money. A refusal may lead to loss of federal benefits.

MIT was first to publicly reject the proposal on October 10; six other institutions followed MIT's lead by the administration's October 20 deadline. "Fundamentally, the premise of the document is inconsistent with our core belief that scientific funding should be based on scientific merit alone," MIT president Sally Kornbluth wrote in a letter to U.S. Education Secretary Linda McMahon. Other schools may make different decisions. On October 27, the New College of Florida in Sarasota announced it would "happily be the first college in America to formally embrace and sign President Trump's vision for higher education."

The compact "seems to be trying to federalize our system of higher education and threaten academic freedom," says Sarah Spreitzer, vice president and chief of staff for government relations for the American Council on Education. If it were implemented, grants would be given not based on merit decided through peer review, as they are now, but by "agreeing to change your governance structure, capping your international enrollment, freezing tuition prices.... How is that tied to your scientific capability?"

These unprecedented actions leave the door open for future administrations from either party to put their political stamp on higher education and science, Spreitzer says.

Murray is the lead researcher on grants supporting large consortia of scientists who examine the genetics and metabolism of people and of tuberculosis bacteria, trace social and nutritional factors that help the disease spread, and conduct studies with animals. Much of the money in Murray's NIH grant supports research conducted in Peru, where tuberculosis affected 173 of every 100,000 people in 2023. TB is much more common there than in the United States, where only about 3 of every 100,000 people contracted the disease in 2023. That makes infection patterns and risk factors easier to study in Peru.

The Peruvian project has "been a very important, influential and high-value study for a number of years now," says Richard Chaisson, an infectious diseases doctor at the Johns Hopkins University School of Medicine. "Everything that we learn there, we use here." For instance, a large TB outbreak in Kansas that started in 2024 has infected 178 people, including 68 active cases as of October 17. "All the tools they're using to diagnose and treat those people were studied overseas," Chaisson says.

Part of Murray's work done in Peru involved recruiting about 18,000 people for a study and collecting blood, saliva and bacteria samples from them. A later study involved samples from

The Trump administration cut biomedical research grants to Harvard, saying the university didn't do enough to stem antisemitism on campus.

APCORTIZASJR/ISTOCK UNRELEASED/GETTY IMAGES PLUS

578

grants to Harvard marked as terminated or frozen

~$2.2 billion

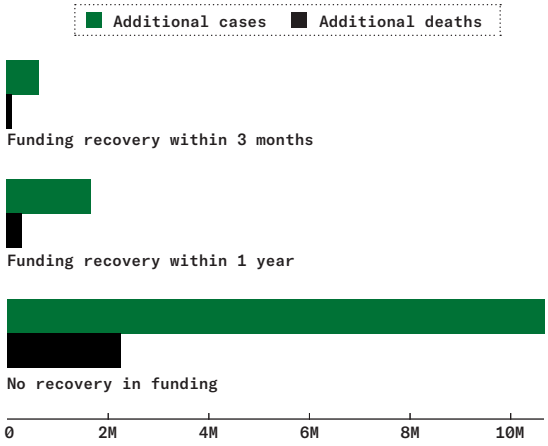
total awarded in those grants

~$1.3 billion

total remaining to be spent on those grants

*data available as of October 2025

GLOBAL TOLL OF USAID TUBERCULOSIS FUNDING CUTS



Projected impacts from 2025 to 2030 of the loss of USAID TB funding across 26 countries with high TB case loads. Source: S. Mandel *et al*/*PLOS Global Public Health* 2025

roughly 2,000 people.

A lab built inside a converted shipping container houses those irreplaceable samples in multiple freezers in Lima. The lab is owned and operated by Socios En Salud, the Peruvian arm of Partners in Health, an international nonprofit health care provider affiliated with Harvard. The lab was already dealing with the loss of funding from the U.S. Agency for International Development that the Trump administration cut earlier this year. Just over $400,000 is earmarked in Murray's supplemental NIH grant for the work in Peru. If she can't spend it due to the shutdown, Murray and colleagues won't have resources to recontact 1,000 of those people who were previously cured of the bacterium that causes tuberculosis.

The plan was to conduct tests such as CT scans of the chest and several other expensive procedures to determine which of those people still have lung damage. Then the researchers would compare genetic data from the people and their bacteria, biomarkers in blood and saliva and other factors to see if any patterns can predict who is and isn't likely to get debilitating lung damage.

"The faster we get back to them, the more likely it is that we'll be able to find them," Murray says of the participants. If they can't be found, the samples they gave earlier would be useless for this study. "We have freezers full of incredibly valuable samples, and they cost money to run," she says. Without Murray's NIH grant money, the researchers and health care workers who conduct the screening may be laid off.

Such losses would be significant. No one has really studied TB's long-term effects, says Maryline Bonnet, a medical epidemiologist at the French National Research Institute for Sustainable Development in Montpellier. "This is extremely important, because we realize now that maybe 50 percent of patients who are cured of the bacteria are living with existing lung disease, which affects significantly their quality of life."

Murray spent much of 2025 scrambling to find a backup so that if she couldn't recoup funds from the federal government, she wouldn't put Harvard deeper in debt. She turned to private donors and nongovernmental organizations for help. She tried to get funding from philanthropy "to make sure the freezers aren't unplugged, lights aren't turned off and so that we don't lose our staff who are incredibly well-trained." But most charitable organizations can't match NIH's investment. And it is increasingly difficult to get funding for work done in other countries.

Labs such as Murray's may survive in greatly pared-down form, but that could come at a cost to the United States' economy and health, says Stephen Carpenter, an infectious diseases physician and immunology researcher at Case Western Reserve University in Cleveland. Each dollar NIH spends on research generated $2.56 in economic activity in 2024, according to advocacy group United for Medical Research. If President Trump's requested cuts to the NIH budget are approved by Congress, 40 percent of that economic activity could be gone. Such deep cuts would slow the pace of developing new treatments for a wide variety of diseases, including tuberculosis.

What's more, talented scientists may be lured to China, Europe or elsewhere, Carpenter says. "That would be a huge loss for us in innovation, for our intellectual property [and] therapeutics."

Even though the Trump administration's ire has been directed at Harvard, Murray says the situation felt a little personal. She hopes she would be seen as a good person who cares about her patients. "But [the administration] would say, 'No. You're an elitist university professor who does all these things we don't like,'" she says.

"We've been trying to be good global citizens," she added. "It's weird to be told that that we're evil because we're doing those things." ✖

THIS PAGE: C. CROCKETT; OPPOSITE PAGE: THE PLANETARY SOCIETY

America risks losing its role as a space science pioneer

By McKenzie Prillaman | Additional reporting by Emily Conover

Casey Dreier, chief of space policy at The Planetary Society, spoke to a crowd at a space advocacy event at the U.S. Capitol on October 6.

● **On the steps of the U.S. Capitol** on a balmy October morning, a crowd of people sporting "Save NASA Science" buttons buzzes with anticipation. Among them stands Eli Orland, who likens America's space science to the gleaming white building behind him.

"It sits on a very solid foundation, and it would completely topple over if it didn't have that foundation," says Orland, an Earth scientist at the University of Maryland, Baltimore County. The United States has explored more of the solar system than any other country, having sent probes to every planet. NASA's research and exploration lays the groundwork for the private space sector, driving innovation and stimulating the economy, Orland notes.

But that foundation is at risk of crumbling. Orland and about 250 others participated in an event on October 6, led by space advocacy nonprofit group The Planetary Society. It's urging Congress to continue funding NASA at the same level in fiscal year 2026 as it has over the past few years. In May, the Trump administration proposed cutting the agency's entire budget by almost 25 percent compared with the previous year's enacted amount, $24.8 billion. Adjusted for inflation, that would reduce current spending to the lowest amount since fiscal year 1961 — the year that nascent NASA sent the first American to space after a Soviet cosmonaut became the first human to get there.

The president's budget request for 2026 has put employment, future research grants and more than 40 missions at risk. That means some spacecraft doing valuable science could be lost forever. Since its launch in 2006, the New Horizons probe snapped redefining pictures of Pluto and is on track to become one of the few craft to report back on the strange space between stars. If turned off, New Horizons can't be rebooted.

Uncertainty hits space science especially hard, since yearslong preparations are usually required to study the frontier beyond Earth. More than a decade of planning and roughly $800 million went into the OSIRIS-REx probe before it launched in 2016 to gather bits of the asteroid Bennu and then

deliver them to Earth seven years later.

But Congress hasn't agreed on a budget for the new fiscal year at the time of this writing, contributing to a lengthy government shutdown that started October 1. And funding uncertainties throughout 2025 have already led some space scientists to retire early, leave the country or grow discouraged early in their careers, experts say.

"The uncertainty itself may be just as damaging as a lot of these other fiscal losses," says Janet Vertesi, a sociologist of science and technology at Princeton University. The United States could lose the next generation of leaders in space, she says. At stake: the country's dominant role in space exploration.

Trump's FY 2026 budget request, which would cut NASA's science funding almost in half compared with the previous fiscal year's $7.3 billion, was a recommendation, not a law. Each Congressional chamber put forth its own proposed budget that would provide funding at levels closer to 2025. Despite that, a report by Senate Democrats claims that the White House Office of Management and Budget directed NASA to start implementing the president's proposed 2026 cuts as early as June. NASA did not respond to a request for comment.

About 80 percent of NASA's annual funding goes to contracts and grants with external organizations. But the agency gave fewer grants in FY 2025 than it had the previous year, despite having the same budget, says Casey Dreier, the chief of space policy at the Planetary Society. Between Trump's inauguration and October 7, NASA canceled nearly 200 awards totaling more than $300 million to universities, companies and other organizations. Many were cut without an explicit reason, Dreier says.

NASA's funding uncertainties have led universities to restrict graduate student admissions, says astrobiologist Britney Schmidt of Cornell University. The school's astronomy department is one of several accepting fewer trainees this academic year. "My inbox is full of fantastic, brilliant, hard-working people who just want to go to graduate school," she says. "I have to tell them I'm not allowed to take students, even if I [currently] have the money."

It's not just NASA that's hurting. The National Science Foundation, which funds space and astronomy research among other subjects, was slated for a 57 percent cut in the president's budget request. At press time, the House and Senate were still wrangling over whether to cut the NSF budget and by how much.

One major NSF project, LIGO, has revolutionized scientists' understanding of black holes by studying the gravitational waves produced when they collide with one another. The detection of gravitational waves opened a new way to observe the cosmos, and was recognized with a Nobel Prize in 2017. But the budget request called for shutting down one of LIGO's two observatories. Although LIGO researchers say they've found ways to keep both observatories online should the budget request become reality, it would mean curtailing upgrades to the facility.

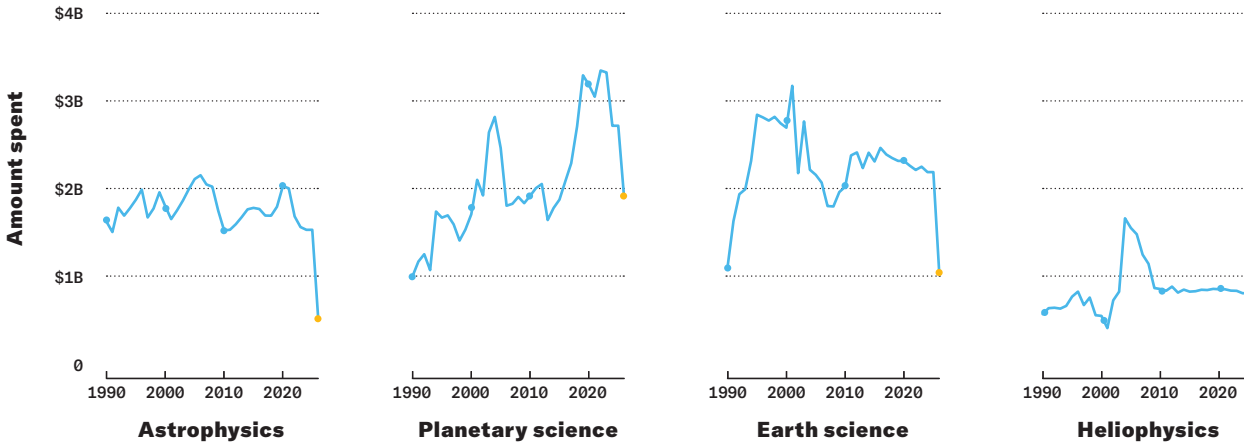
"Hopefully people come back to their senses and they realize that the U.S. is leading the way in a whole new field of physics and astronomy," says physicist Emanuele Berti of Johns Hopkins University. "It makes no sense to shoot yourself in the foot. But if you do, then we'll have to learn how to walk with one foot."

Unstable funding keeps researchers from

SpaceX has flown astronauts on its Falcon 9 rocket (below) and is developing a spacecraft to bring people to the moon. The company's efforts rest on a foundation of NASA science, researchers say.

JOEL KOWSKY/NASA VIA GETTY IMAGES

BUDGET TRENDS FOR NASA SCIENCE DIVISIONS, 1990–2026



The Trump administration's budget request for fiscal year 2026 (yellow dots) proposes major cuts to NASA's four major science divisions (blue dots denote previous years' spent amounts). All amounts are adjusted for inflation.

THE PLANETARY SOCIETY, ADAPTED BY C. CROCKETT

building labs, hiring employees, acquiring equipment and analyzing data, especially when attempting to do something novel, Dreier says. Subjecting all federal grants to political review as well as raising fees on H1-B temporary worker visas worsens the uncertainty.

Banning diversity, equity and inclusion, or DEI, programs may harm the workforce too. Planetary scientist Julie Rathbun's NASA-funded workshop to help researchers lead diverse teams, slated to take place in February, was canceled after Trump signed an executive order on his first day in office banning DEI-related work. An official grant termination notice arrived in March.

"There is social scientific proof that more diverse teams do better work," says Rathbun, of Cornell. "By destroying that, we're taking steps backwards in planetary science.... We are removing the different ways of thinking."

One of the administration's main goals is to get astronauts to the moon and eventually Mars, with a proposed human lunar-landing mission in 2027 — the first in more than 50 years.

"We want a long-term presence of life on the moon, led by America," acting NASA administrator Sean Duffy said in a September 10 news briefing. "What we learn on this mission to the moon is going to help us to actually put American boots on Mars." The president's budget request calls for more than $1 billion to be invested in technology to take humans to the Red Planet.

But those investments will be less likely to pay off in an agency that has forfeited expertise gathered over decades, says space policy analyst Victoria Samson of the Secure World Foundation, a space advocacy group in Washington, D.C.

"That is a recipe for forgetting," Vertesi agrees. She suspects that the nation has a short timeframe to reverse course. "If a year from now we're still in the same situation, I think we'll be facing a generational deficit in science and technical leadership in this country," she says. "That leadership will move elsewhere. So it's not just that we lose it in America — another country will gain at our expense." China, for example, plans to launch a Mars sample-return mission in 2028 that's expected back on Earth three years later. NASA and the European Space Agency's similar mission won't return to our home planet until at least 2035.

Despite the turmoil, some people are finding glimmers of hope. Rathbun says she's noticed more chatter about solving systemic problems in science, such as changing how graduate students are funded and giving them multiple academic mentors. "I see more ... thinking outside the box for a future that is more hopeful, that will result in more people doing science and doing it better."

Others are encouraged by the people telling politicians why space research matters. Twice as many people showed up to the October 6 advocacy day compared with the past highest turnout for The Planetary Society's event at the U.S. Capitol, says Jack Kiraly, director of government relations at the society, who is based in Alexandria, Va. Supporters came from nearly 40 states.

"This is the epicenter of democracy," Kiraly says, while standing by the Capitol Building. "People from all over the country have come here, and it's given me a lot of hope for what is possible when people come together." ✖

Scientists to Watch

New scientific findings come out every day. Often, people only learn about the researchers behind some of these discoveries years or decades later when they win a Nobel Prize. We think you should know about them much sooner.

This year, *Science News* is highlighting five early- and mid-career scientists as part of our Scientists to Watch series. Some are working to solve big societal challenges while others aim to expand our knowledge of the world. In these pages, you'll meet scientists who are unraveling the mysteries of black holes, investigating the geology of icy moons, tying childhood experiences to mental health, studying diseases that disproportionately affect women of color and assessing the impact of climate change on the Arctic.

For the first time, you can also watch interviews with the scientists at sciencenews.org/S2W. We hope you'll be inspired by their passion for using science to answer big questions. As always, please send nominations for next year's Scientists to Watch to S2W@sciencenews.org.

—Karen Kwon, Research and Special Projects Editor

ERIKA MOORE

Biomedical engineer
University of Maryland

Painful experience has taught Erika Moore that benign doesn't always mean harmless. Moore, a biomedical engineer at the University of Maryland in College Park, lives with noncancerous tumors in the uterus called uterine fibroids. "That's what drew me in to wanting to understand these diseases and try to make not only my life better, but the lives of my loved ones better too," she says.

Uterine fibroids can cause anemia, pain, reproductive issues and heavy or irregular menstrual bleeding. An estimated 70 percent of white women and 80 percent of Black women in the United States will develop uterine fibroids by age 50. Moore is dedicated to finding the molecular underpinnings of fibroids and other diseases, such as lupus, that disproportionately affect women of color.

No one fully understands how and why fibroids grow. So, Moore and her team are using Jell-O-like materials called hydrogels to investigate the mechanism. Hydrogels mimic the 3-D properties of the uterine environment better than two-dimensional materials do. Moore and her team plan to incorporate cells important for fibroid formation, such as muscle and immune cells.

With this lab-based system, Moore says she hopes to "better understand, well, why did my fibroids form? Why did they form for other people?" Armed with that knowledge she may be able to devise new treatments for the condition. *—Tina Hesman Saey*

Pluto pulled Adeene Denton into its orbit during her undergraduate internship at the Lunar and Planetary Institute in Houston. It was summer 2015, when the New Horizons spacecraft zoomed past the dwarf planet.

"The Pluto flyby happened, and I was in the right place at the right time — perfectly positioned to fall in love with it," says Denton, a planetary scientist at the Southwest Research Institute in Boulder, Colo. "And I did."

The dwarf planet became the center of her world. She ran computer simulations to study how objects may have hit Pluto, shaping its history. Some of her research suggests that Pluto acquired its largest moon, Charon, through a "kiss-and-capture" collision, and that the dwarf planet's heart-shaped feature may hide the rocky remnant from an ancient impact.

Denton is currently taking a break from Pluto. Last year, she was an astronomer in residence at Grand Canyon National Park, where she, a lifelong dancer, choreographed a dance connecting the canyon's history with space exploration. Now, Denton is studying Saturn's moons, looking at why Enceladus, with its icy geysers, is more geologically active than its neighbors. "There are so many cool solar system bodies out there that we know so little about," she says. *—McKenzie Prillaman*

ADEENE DENTON

Planetary scientist
Southwest Research Institute

A mysterious ring of light is thought to surround every black hole, and Alex Lupsasca wants to glimpse one for the first time. The tendril-thin halo, called a photon ring, has the power to reveal secrets from the black hole's edge.

Black holes are regions of the universe where spacetime is warped so dramatically that nothing can escape. Physicists predict that particles of light, or photons, can graze the edge of the black hole without falling in. These photons orbit the black hole one or more times before breaking away. This light makes up the photon ring.

Spotting the photon ring could help test physicists' theories about these mysterious objects, and whether any alternative explanations could account for them. "Seeing this photon ring and confirming that it's really produced by orbiting photons would be ironclad, definitive proof that the object that we're looking at really is a black hole," Lupsasca says.

Lupsasca, a theoretical physicist at Vanderbilt University in Nashville, is the project scientist for the Black Hole Explorer. His work has illuminated the potential properties of the photon ring the researchers aim to detect. The project's goal is to put a space-based radio telescope in Earth orbit in 2031. By joining forces with other radio telescopes on the ground, it would effectively create a telescope

FROM LEFT: KELLIE FINCH; A. DENTON

ALEX LUPSASCA

Theoretical physicist
Vanderbilt University | OpenAI

three times the size of Earth. That would allow scientists to take the sharpest images in the history of astronomy, Lupsasca says, and hopefully reveal the photon ring.

This summer, the capabilities of AI startled Lupsasca. When he prodded the large language model GPT-5 Pro, it reproduced the conclusion of one of his papers, deducing in minutes what he'd spent weeks pondering. In October, he also joined OpenAI for Science, where he'll continue researching black holes.

For Lupsasca, the search for the photon ring is paramount. "What higher calling could you find than to try to understand the mysteries of the universe?" —*Emily Conover*

Neuroscientist M. Catalina "Cat" Camacho spends a lot of time playing with kids. They're not her children, but participants in her research, which looks at how young brains learn to process emotions and how that development relates to mental health.

"Every kid is so different, and I love getting little insights into their worlds," says Camacho, of Washington University School of Medicine in St. Louis. "You really do come to appreciate just how much kids grow in such a short amount of time."

That realization years ago drew her into neuroscience. After Camacho, a first-generation college student, earned a bachelor's degree, she worked in a laboratory imaging infants' brains and was shocked at how quickly they changed. Now, she's continuing that line of research by studying kids while playing games and watching movies with them, even going to their homes to understand their lives.

Camacho is especially interested in the overlap between cognitive development and mental health. "Anxiety and depression are just supercommon," says Camacho, who now recognizes that her mom struggled with depression during Camacho's childhood. That drives her research today, which she hopes can inform "how it is that we intervene and when and for who, so that we can best bolster mental health in general." —*McKenzie Prillaman*

The Arctic char, a red-pink bellied relative of trout and salmon, is a staple food source for millions of people living in the Arctic. But that dynamic is being embrangled by climate change, as the Arctic is warming two to four times faster

M. CATALINA "CAT" CAMACHO

Neuroscientist
Washington University
School of Medicine in St. Louis

MARIANNE FALARDEAU

Polar marine ecologist
Université TÉLUQ

than the rest of the world.

Marianne Falardeau, a polar marine ecologist at Université TÉLUQ in Quebec City, Canada, studies how climate change is reshaping boreal and polar marine ecosystems and the benefits those ecosystems provide to people, aiming to help northern communities adapt to the shifting environment. In 2022, she coauthored a study showing how to make small-scale fisheries in the Arctic more resilient in the face of climate change.

Much of Falardeau's research involves working closely with Indigenous coastal communities. For another 2022 study, she and colleagues combined biophysical data from Arctic char with observations made by Inuit fishers to assess how environmental changes had shifted the timing of fish migrations over a 30-year period. The collaborative approach helped to broadly capture the influence that seasonal ice changes had on the diet and nutrient quality of fish.

"In the Arctic, there [are] Indigenous people who have been living there for millennia—they have deep knowledge about the land, the ocean, the animals, how they're changing," she says. "My research wouldn't be possible without these connections." —*Nikk Ogasa* ✖

FROM LEFT: VANDERBILT UNIV.; M.C. CAMACHO; UNIVERSITÉ TÉLUQ

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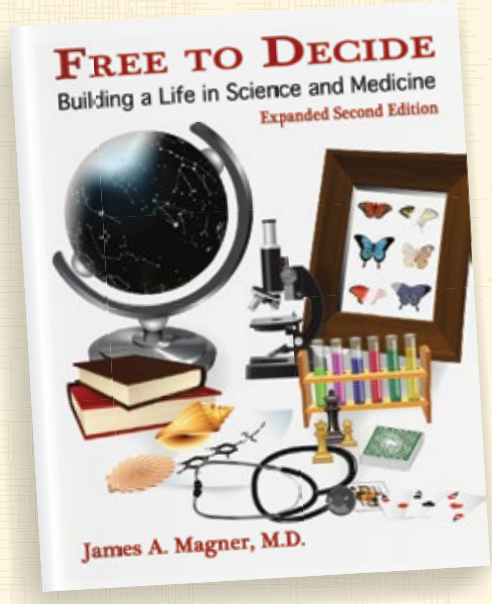
ANIMALS

THE WOMAN WHO GAVE CHIMPS A CLOSER LOOK

● Jane Goodall's pioneering work got its start with help from David Greybeard. David wasn't a fellow scientist but a distinguished older chimpanzee that the primatologist met (and named) in Tanzania in 1960. He allowed her to surveil him, and his acceptance of her led to other chimpanzees following suit. Goodall's observations of these primates established that chimps make and use tools — traits that had been deemed unique to humans until that point. See Page 62 for a tribute to Goodall, who died in October. — *Cassie Martin*



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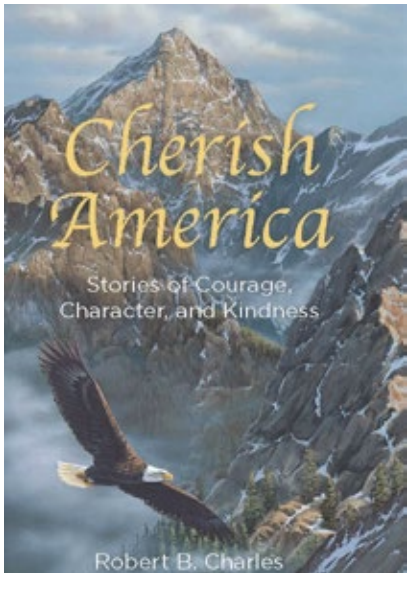

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SCIENCE NEWS' TOP READS OF 2025

Our staff's favorite books of the year pondered science's role in some of society's most pressing issues, from AI to childhood trauma to river restoration. Did we miss your favorite? Let us know at feedback@sciencenews.org.

REHAB | *Shoshana Walter*
Simon & Schuster | $29.99
In a journalist's exposé of U.S. drug treatment centers, stories of people who participated in rehab programs unveil how barriers to access and sometimes unethical practices can impede recovery from addiction.

SHADOWS INTO LIGHT | *Theresa S. Betancourt*
Harvard Univ. | $35
A long-term study followed the lives of children forced to fight in Sierra Leone's civil war from 1991 to 2002. The research revealed trauma's effects on their psychosocial development and the factors that have helped some former child soldiers recover.

BLACK RELIGION IN THE MADHOUSE | *Judith Weisenfeld*
NYU Press | $35
After slavery's abolition and the U.S. Civil War, white psychiatrists pathologized Black religious practices as mental illness. A historian of religion unpacks how these racist views shaped the burgeoning field of psychiatry.

THE SALMON CANNON AND THE LEVITATING FROG | *Carly Anne York*
Basic Books | $30
An animal physiologist makes a case for the value of basic science: Curiosity-driven research, which seeks to understand how the world works, may not always have foreseeable applications but could lead to unexpected benefits.

EVERYTHING IS TUBERCULOSIS | *John Green*
Crash Course Books | $28
Tuberculosis is one of the world's deadliest infectious diseases despite available treatments and cures. In an examination of the medical and social history of the disease, a famous author builds a case for how modern social injustice sustains it.

THE WATER REMEMBERS | *Amy Bowers Cordalis*
Little, Brown & Co. | $30
A Yurok tribal member and attorney recounts her family's role in the fight to remove dams from the Klamath River in the U.S. Northwest. The Indigenous-led effort to restore the river's ecosystems culminated in the world's largest dam removal project thus far.

A YEAR WITH THE SEALS | *Alix Morris*
Algonquin Books | $30
Seal populations in North America have rebounded from the brink of extinction over the last century. A science journalist investigates how the growing number of seals has sparked tension in coastal communities.

THE MARTIANS | *David Baron*
Liveright | $29.99
Reports of "canals" on Mars in the late 1800s and early 1900s ignited a craze about the possibility of intelligent life there. A journalist retraces how the canal theory infiltrated public consciousness and shaped astronomy.

MORE EVERYTHING FOREVER | *Adam Becker*
Basic Books | $32
Tech billionaires envision a future in which humankind, served by superintelligent AI, lives in an ever-growing society in outer space. This sci-fi future, while seductive, is implausible and ethically fraught, a scientist journalist argues.

TALES OF MILITANT CHEMISTRY | *Alice Lovejoy*
Univ. of California Press | $27.95
A media and cultural historian unfurls how film giant Kodak used its chemical engineering expertise to support the United States' weapons manufacturing — including the creation of the first atomic bombs — during the two world wars. ✖

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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.

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Each year, hundreds of dedicated STEM educators travel to Washington, D.C., to connect, collaborate and strengthen their ability to guide the next generation of student researchers. The High School and Middle School Research Teachers conferences, both programs of Society for Science, offer an all-expenses-paid weekend of peer-led professional development designed to share best practices, inspire new ideas and expand access to authentic research experiences for students nationwide.

"I am grateful for the opportunity to learn from distinguished educators, researchers and fellow advocates of science education," says Mildred Pates, a science teacher at Eleanor Roosevelt High School in Greenbelt, Md. "The insights and connections gained from this conference will undoubtedly enhance my work in promoting authentic research experiences and sustainability-driven learning in my classroom."

Held concurrently in October, the conferences united teachers for plenary sessions, networking opportunities and breakout discussions. The conferences aim to build classroom capacity and cultivate a thriving community of teacher-leaders across the United States.

Session topics included "Teaching Students to Think Like Inventors," "Forming Partnerships with Research Institutions" and "Using AI Tools in the Research Process." The educators also explored ways to engage their communities through citizen science, visualize data effectively and guide students toward STEM competitions such as the Regeneron International Science and Engineering Fair and Thermo Fisher Scientific Junior Innovators Challenge, which are owned and produced by the Society.

For many participants, the experience sparked new connections and renewed purpose. "It was so positive and informative. Most of all, I was able to expand my field of collaborators," says Wayne Oelfke, of Fort White Middle School in Fort White, Fla. "I also see my students internalizing a vision of being researchers. Life is good!"

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RUDOLPH'S NOSE, GLOW? WHEN REINDEER FLY

BY MARIA TEMMING

This time of year, "Rudolph the Red-Nosed Reindeer" is a nearly inescapable earworm. Rudolph, the old song goes, is bullied for having a nose so bright it glows (*like a lightbulb!*). But one Christmas Eve, his much-mocked nose makes Rudolph a hero. Using it as a beacon, Rudolph guides Santa's flying sleigh through the foggy night to deliver gifts around the world. Rudolph's superbright snout might seem as fantastical as his ability to fly. But a light-up body part needs no holiday magic. Many animals glow through bioluminescence, and a built-in red headlight would make a great adaptive trait for a sleigh-pulling reindeer. Though thanks to physics, Rudolph's nose might not even look red to someone on the ground.

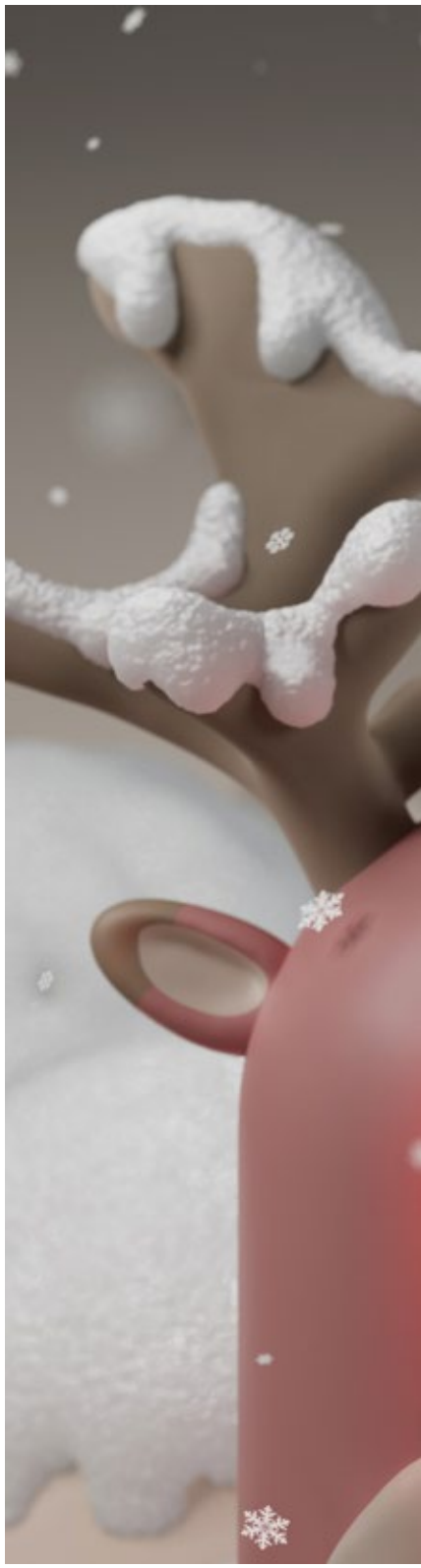
Most bioluminescent animals use the same chemical reaction to glow. It takes only two main ingredients: a compound called a luciferin and an enzyme called a luciferase. "When oxygen is present in the cell, [the pair] react together and give off light," says Danielle DeLeo, a marine biologist at Florida International University in Miami.

Bioluminescent reactions light up the lanterns of anglerfish a bluish-green, illuminate fireflies' flashy backsides yellow and allow some insects and deep-sea fish to radiate red.

The odds of this trait evolving in reindeer is "very, very low," DeLeo says. Most glowing animals are found in the ocean — and among the land animals that do give off their own bioluminescent light, none are mammals. Still, it's not impossible for bioluminescence to emerge in a new species. "It's evolved at least 100 times across the tree of life," DeLeo notes.

If a sleigh-pulling reindeer were going to glow, red would be the best color for it, says Nathaniel Dominy, an evolutionary biologist at Dartmouth College.

With the longest wavelengths of any color we can see, red light is least likely to get scattered by airborne water droplets. As a result, "red light is going to allow them to navigate under foggy conditions



MR.KAPLIN

more effectively than any other light," Dominy says.

To someone on the ground who spied Rudolph soaring through the sky, his nose may not look red at all. That's because when a light source is moving toward you, its light waves get squished and look bluer. It's only when the source is moving away that light waves get stretched out and appear redder.

"We don't see that typically around us, because things have to travel really fast for the redshift or the blueshift" to occur, says Laura Driessen, a radio astronomer at the University of Sydney. Santa's sleigh could be an exception. That's because it would have to hit extreme speeds to visit houses around the world in a single night, she says.

Say Santa travels at 10 percent the speed of light. As Rudolph approaches a house, his nose would be blueshifted to look orange. As he flies away, his nose would redshift to nearly the deepest crimson red that human eyes can see — so dark it would look almost black.

Rudolph's nose wouldn't be the only thing blueshifted and redshifted, either. For example, blueshifted brown hues, like reindeer fur and a wooden sleigh, would take on a greenish tinge. "We'd see a green sleigh and reindeer coming towards us," Driessen says. As they flew away, Santa and his reindeer would almost disappear as they moved beyond visible light into infrared.

Such fast movement and a brightly glowing nose would cost Rudolph a lot of energy, Dominy says.

"I would want to make sure that he could get as much energy as possible — sugary foods." So anyone planning to leave out treats for Santa this Christmas Eve should be sure to leave out plenty of cookies for his reindeer, too. ✖

ANTHROPOLOGY

WHAT JANE GOODALL TAUGHT ME ABOUT BONES, LOSS AND NOT WASTING ANYTHING

BY BRUCE BOWER

Jane Goodall died in October at age 91. When I heard the news, my mind raced back 35 years to a conversation I had with the pioneering observer and student of chimpanzee behavior. As the '90s began, Goodall had been studying chimps in Tanzania's Gombe National Park for nearly 30 years. Her work had illuminated the previously unknown complexity of these apes' social lives. But I was surprised to learn that the genteel-looking British ethologist had assembled a one-of-a-kind collection of chimp skeletons.

Goodall and her team retrieved the bodies of chimps within days of their deaths, placed the carcasses in a tin drum where insects pared down the remains, and then cleaned the bones. Each skeleton came from a Gombe individual with known sex, age, body weight and life experiences. That information let researchers investigate how individual development influenced the skeletal features of the apes.

Scientists who study ancient hominid fossils have no such luxury. They study the skeletons of strangers. Goodall's project raised the possibility of analyzing our evolutionary ancestors from a new perspective, informed by insights into how the characteristics of bones reflect the good, the bad and the ugly of an individual's journey from birth to death.

Anxious to write about Goodall's unusual skeletal pursuits, I called the Jane Goodall Institute. In 1990, email was not an option at *Science News*. Zoom was as realistic as a flying car. An institute official gave me a phone number to call in Africa. At the appointed time, I dialed the number. I heard a click. Jane Goodall said hello.

I took a deep breath and introduced myself. With a blessedly slowing heartbeat, I launched into a series of journalistic questions. Goodall spoke softly and avoided trumpeting the importance of her preservation efforts.

When I asked about the implications of Gombe chimp skeletons for understanding ancient hominids, such as Lucy's 3.2-million-year-old partial skeleton, Goodall responded with blunt humility: "We just don't know." My queries about the reasons for the dramatic variations and quirks in the skeletal structure of Gombe chimps, revealed for the first time in her skeletal collection, elicited the same response. Perhaps speculation will turn into solid answers as research gets rolling, the famous chimp whisperer said.

Goodall became most animated when describing why she wanted not only to observe living chimps but also to preserve the bony frameworks of dead ones. I included the following quote in a 1990 *Science News* story: "I began collecting chimpanzee skeletons from the beginning of my research. When you're working in the field, you shouldn't waste anything."

To my young ears, that approach seemed oddly pragmatic and detached. After all, Goodall made her bones, so to speak, forming close personal relationships with living Gombe chimps. But I could not have been more wrong.

Goodall's connection to individual Gombe chimps probably deepened as their skeletons accumulated. Consider Flo, a dominant matriarch who was one of the first chimps to approach Goodall's camp.

FROM TOP: HUGO VAN LAWICK/THE JANE GOODALL INSTITUTE; SUMY SADURNI/AFP/GETTY IMAGES

← Flo, an adult female chimpanzee, shed light on chimp social bonds in life and skeletal biology in death. ↙ The late primatologist Jane Goodall spent her career championing the conservation of great apes and their habitats.

Goodall's project raised the possibility of analyzing our evolutionary ancestors from a new perspective.

Flo was an aggressive mover and shaker in the Gombe social scene, raising her five young with patience and affection. Flo's death in 1972 hit Goodall hard.

True to her reputation as a Gombe influencer, Flo provided one of the most intriguing skeletal stories in Goodall's collection.

Flo's skeleton was larger than most at Gombe, male or female. Yet she weighed less than a smaller but stockier male dubbed Charlie, thus demonstrating the difficulty of estimating body weights from bone sizes. And Flo experienced a pattern of bone loss unlike that of human women with osteoporosis, a condition associated with hormone loss after menopause. Flo's skeletal status coincided with Goodall's field observations that this chimp matriarch had given birth within a few years of her death at nearly age 50. Only recently have researchers found evidence for menopause in female chimps that live past 50, an especially old age in the wild.

Flo's anatomical afterlife, and those of her compatriots, taught academics about the intricacies of skeletal formation, which must have given Goodall great satisfaction. Even as advanced age moved Goodall away from fieldwork and into environmental activism and book writing, her refusal to waste anything as a young befriender of Gombe chimps continued to pay scientific dividends.

I like to think that if an afterlife exists beyond the scientific kind, Goodall and Flo are gazing at each other with renewed affection. ✖

A LOOPY HOLIDAY GIFT EXCHANGE

BY ZACH WISSNER-GROSS

You are participating in a holiday gift exchange with a few classmates. You each write down your own name on a slip of paper and fold it up. Then all the students place their names into a single hat. Next, students pull a random name from the hat, one at a time. If at any point someone pulls their own name from the hat, the whole class starts over, with everyone returning the names to the hat. Once the whole process is complete, each student purchases a gift for the classmate whose name they pulled. Gifts are handed out at a big holiday party at the end of the year.

At this party, you observe that there are "loops" of gift-giving within the class. For example, student A might have gotten a gift for B, who got a gift for C, who got a gift for D, who got a gift for A. In this case, A, B, C and D would form a loop of length four. Another way to have a loop of length four is if student A got a gift for C, who got a gift for B, who got a gift for D, who got a gift for A. And of course, there are other ways.

1. If there are a total of three students in the class, how likely is it that they form a single loop that includes the entire class (that is, a loop of length three)?
2. If there are a total of four students in the class, how likely is it that they form a single loop that includes the entire class?
3. If there are a total of five students in the class, how likely is it that they form a single loop that includes the entire class?
4. If there are N students in the class, where N is some large number, how likely is it that they form a single loop that includes the entire class, in terms of N? ✖

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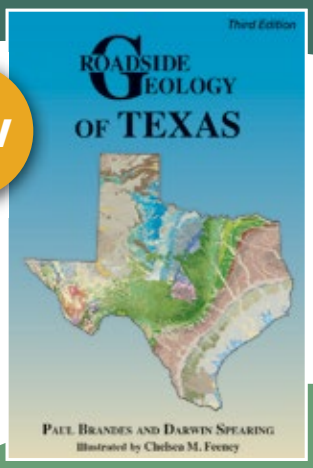

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