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The Truth about Polyamory

Life in the Age of AI

The promise and peril of artificial intelligence everywhere

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Inside the new AI world order: A special report

From the exam room to the classroom, artificial intelligence is no longer just a tool—it's infrastructure. An introduction to our special report on life in the age of AI.

By Eric Sullivan edited by Seth Fletcher

Tavis Coburn

In San Diego, a high school English teacher can clear her grading queue in a matter of days by outsourcing her initial assessments to ChatGPT. In New Hampshire, middle schoolers use generative tools to strip the clothes off their classmates in digital photographs, leaving the community grasping for a policy response. In Sweden, a payments company touts its AI customer-service system for carrying the work of 700 people—only for its CEO to later admit they'd overdone it on automation and would start bringing people back.

Artificial intelligence—computer systems trained on vast datasets to predict the next likely pixel or word—is everywhere. In the three years since ChatGPT was released, AI has shifted from a browser-based novelty to a kind of background infrastructure. It is the ears in the exam room, the silent partner in the C-suite, the uncredited co-author of the classroom rubric. The College Board reports that 84 percent of high school students now use AI for schoolwork. For bosses and boardrooms, its promise of cheap labor is irresistible; spending on AI hit $1.8 trillion last year, according to research firm Gartner. There are environmental costs, too: a single AI-focused data center can consume as much electricity as 100,000 homes, and even bigger centers are under construction. The cloud, it turns out, is heavy.

The advent of AI is often framed as a battle of human versus machine, but that view misses the point. The reality today is human plus machine, operating under budget constraints in flawed institutions, fed by imperfect data. While companies race to generate more and more sophisticated models and aspire to AI that can rival human intelligence, it's the mundane uses of the technology that are making the biggest impact. A clinician might offload the drudgery of documentation to an ambient scribe, allowing her to look her patient in the eye rather than at a bedside monitor. A call center can answer in 35 languages at 3 A.M. without an army of night-shift polyglots.

The risk, though, is that the harms will scale faster than the benefits. Deepfakes turn the technology into a personal weapon: a manipulated video can ruin a reputation long before anyone can prove where it came from. A hallucinated fact can be a minor nuisance in a school assignment or a dangerous claim in a clinical note.

And even when no one means harm, the partnership changes how people make judgments. Outputs arrive with the unearned confidence of a carefully considered thought. An AI “copilot” redistributes labor—and liability. What gets sold as assistance often turns into supervision. It offers the gift of speed while multiplying the number of moments when a human must decide whether to trust the system’s suggestion.

The articles in this special report track this transformation across key fronts: in hospitals struggling to modernize care without eroding it, in communities discovering how fast a synthetic video clip can outrun correction, and in the working lives of people using these tools—sometimes to speed up the day, sometimes to outsource responsibility. When a technology’s upsides are easy to claim and its downsides easy to deny, who pays for its mistakes?

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https://www.scientificamerican.com/article/how-ai-copilots-became-everyday-infrastructure

AI enters the exam room

When alerts misfire or can't explain themselves, nurses still carry the risk

By Hilke Schellmann edited by Eric Sullivan

Tavis Coburn

Adam Hart has been a nurse at St. Rose Dominican Hospital in Henderson, Nev., for 14 years. A few years ago, while assigned to help out in the emergency department, he was listening to the ambulance report on a patient who'd just arrived—an elderly woman with dangerously low blood pressure—when a sepsis flag flashed in the hospital's electronic system.

Sepsis, a life-threatening response to infection, is a major cause of death in U.S. hospitals, and early treatment is critical. The flag prompted the charge nurse to instruct Hart to room the patient immediately, take her vitals and begin intravenous (IV) fluids. It was protocol; in an emergency room, that often means speed.

But when Hart examined the woman, he saw that she had a dialysis catheter below her collarbone. Her kidneys weren't keeping up. A routine flood of IV fluids, he warned, could overwhelm her system and end up in her lungs. The charge nurse told him to do it anyway because of the sepsis alert generated by the hospital's artificial-intelligence system. Hart refused.

A physician overheard the escalating conversation and stepped in. Instead of fluids, the doctor ordered dopamine to raise the patient's blood pressure without adding volume—averting what Hart believed could have led to a life-threatening complication.

What stayed with Hart was the choreography that the AI-generated alert produced. A screen prompted urgency, which a protocol turned into an order; a bedside objection grounded in clinical reasoning landed, at least in the moment, as defiance. No one was acting in bad faith. Still, the tool pushed them to comply when the evidence right in front of them—the patient and her compromised kidneys—demanded the exact opposite. (A hospital spokesperson said that they could not comment on a specific case but that the hospital views AI as "one of the many tools that supports, not supersedes, the expertise and judgment of our care teams.")

That dynamic is becoming familiar in U.S. health care. Over the past several years hospitals have woven algorithmic models into routine practice. Clinical care often relies on matching a patient's symptoms against rigid protocols—an environment ideal for automation. For an exhausted workforce, the appeal of handing off routine tasks such as documentation to AI is undeniable.

The technologies already implemented span a spectrum from predictive models that calculate simple risk scores to agentic AI that promises autonomous decision-making—enabling systems to titrate a patient's oxygen flow or reprioritize an ER triage queue with little human input. A pilot project launched in Utah a few months ago uses chatbot technology with agentic capabilities to renew prescriptions, a move proponents say gives providers more time, although physician associations have opposed the removal of human oversight. Across the country, health systems are using similar tools to flag risks, ambiently listen to visits with patients, generate clinical notes, monitor patients via wearable devices, match participants to clinical trials, and even manage the logistics of operating rooms and intensive care unit transfers.

> Nurses saw how an imperfect product could become policy—and then become their problem.

The industry is chasing a vision of truly continuous care: a decision-making infrastructure that keeps tabs on patients between appointments by combining what's in the medical record—laboratory test results, imaging, notes, meds—with population data and with the data people generate on their own by using, for instance, wearables and food logs. It watches for meaningful changes, sends guidance or prompts, and flags cases that need human input. Proponents argue this kind of data-intensive, always-on monitoring is beyond the cognitive scope of any human provider.

Others say clinicians must stay in the loop, using AI not as autopilot but as a tool to help them make sense of vast troves of data. Last year Stanford Medicine rolled out ChatEHR, a tool that allows clinicians to "chat" with a patient's medical records. One physician shared that the tool found critical information buried in the records of a cancer patient, which helped a team including six pathologists to give a definitive diagnosis. "If that doesn't prove the value of EHR, I don't know what does," they reported.

At the same time, on many hospital floors these digital promises often fracture, according to Anaeze Offodile, chief strategy officer at Memorial Sloan Kettering Cancer Center in New York City. He notes that faulty algorithms, poor implementation and low return on investment have caused some projects to stall. On the ground, nurses, who are tasked with caring for patients, are increasingly wary of unvalidated tools. This friction has moved from the ward into the streets. In the past two years nurses in California and New York City have staged demonstrations to draw attention to unregulated algorithmic tools entering the health-care system, arguing that while hospitals invest in AI the bedside remains dangerously short-staffed.

Sepsis prediction has become a cautionary case. Hospitals across the U.S. widely adopted information health technology company Epic's sepsis-prediction algorithm. Later evaluations found it substantially less accurate than marketed. Epic says that studies in clinical settings have found its sepsis model improved outcomes and that it has since released a second version it claims performs better. Still, nurses saw how an imperfect product could become policy—and then become their problem.

Burnout, staffing shortages and rising workplace violence are already thinning the nursing workforce, according to a 2024 nursing survey. Those pressures spilled onto the steps of New York City Hall last November, when members of the New York State Nurses Association rallied and then testified before the City Council's hospitals committee. They argued that some of the city's biggest private systems are pouring money into executives and AI projects while hospital units remain understaffed and nurses face escalating safety risks. As this story was going to press in mid-January, 15,000 nurses at hospital systems in New York City were on strike, demanding safer staffing levels and workplace protections.

New AI-enabled monitoring models often arrive in hospitals with the same kind of hype that has accompanied AI in other industries. In 2023 UC Davis Health rolled out BioButton in its oncology bone marrow transplant unit, calling it "transformational." The device, a small, hexagonal silicone sensor worn on a patient’s chest, continuously tracked vital signs such as heart rate, temperature and breathing patterns.

On the floor it frequently generated alerts that were difficult for nurses to interpret. For Melissa Beebe, a registered nurse who has worked at UC Davis Health for 17 years, the pings offered little actionable data. “This is where it became really problematic,” she says. “It was vague.” The notifications flagged changes in vital signs without specifics.

Beebe says she often followed alarms that led nowhere. “I have my own internal alerts—‘something’s wrong with this patient, I want to keep an eye on them’—and then the BioButton would have its own thing going on. It was overdoing it but not really giving great information.”

As a union representative for the California Nurses Association at UC Davis Health, Beebe requested a formal discussion with hospital leadership before the devices were rolled out, as allowed by the union’s contract. “It’s just really hyped: ‘Oh, my gosh, this is going to be so transformative, and aren’t you so lucky to be able to do it?’” she says. She felt that when she and other nurses raised questions, they were seen as resistant to technology. “I’m a WHY nurse. To understand something, I have to know why. Why am I doing it?”

Among the nurses’ concerns were how the device would work on different body types and how quickly they were expected to respond to alerts. Beebe says leadership had few clear answers. Instead nurses were told the device could help with early detection of hemorrhagic strokes, which patients were particularly at risk for on her floor. “But the problem is that heart rate, temperature and respiratory rate, for a stroke, would be some pretty late signs of an issue,” she says. “You’d be kind of dying at that point.” Earlier signs of a hemorrhagic stroke may be difficulty rousing the patient, slurred speech or balance problems. “None of those things are BioButton parameters.”

In the end, UC Davis Health stopped using the BioButtons after piloting the technology for about a year, Beebe says. “What they were finding was that in the patients who were really sick and would benefit from that kind of alert, the nurses were catching it much faster,” she explains. (UC Davis Health said in a statement that it piloted BioButton alongside existing monitors and ultimately chose not to adopt it because its alerts did not offer a clear advantage over current monitoring.)

Beebe argues that clinical judgment, shaped by years of training and experience and informed by subtle sensory cues and signals from technical equipment, cannot be automated. “I can’t tell you how many times I have that feeling, *I don’t feel right about this patient*. It could be just the way their skin looks or feels to me.” Elven Mitchell, an intensive care nurse of 13 years now at Kaiser Permanente Hospital in Modesto, Calif., echoes that view. “Sometimes you can see a patient and, just looking at them, [know they’re] not doing well. It doesn’t show in the labs, and it doesn’t show on the monitor,” he says. “We have five senses, and computers only get input.”

> Clinical care often relies on matching a patient’s symptoms against rigid protocols—an environment ideal for automation.

Algorithms can augment clinical judgment, experts say, but they cannot replace it. “The models will never have access to all of the data that the provider has,” says Ziad Obermeyer, Blue Cross of California Distinguished Associate Professor of Health Policy and Management at the University of California, Berkeley, School of Public Health. The models are mostly analyzing electronic medical records, but not everything is in the digital file. “And that turns out to be a bunch of really important stuff like, How are they answering questions? How are they walking? All these subtle things that physicians and nurses see and understand about patients."

Mitchell, who also serves on his hospital's rapid-response team, says his colleagues have trouble trusting the alerts. He estimates that roughly half of the alerts generated by a centralized monitoring team are false positives, yet hospital policy requires bedside staff to evaluate each one, pulling nurses away from patients already flagged as high risk. (Kaiser Permanente said in a statement that its AI monitoring tools are meant to support clinicians, with decisions remaining with care teams, and that the systems are rigorously tested and continuously monitored.)

"Maybe in 50 years it will be more beneficial, but as it stands, it is a trying-to-make-it-work system," Mitchell says. He wishes there were more regulation in the space because health-care decisions can, in extreme cases, be about life or death.

Across interviews for this article, nurses consistently emphasized that they are not opposed to technology in the hospital. Many said they welcome tools that are carefully validated and demonstrably improve care. What has made them wary, they argue, is the rapid rollout of heavily marketed AI models whose performance in real-world settings falls short of promises. Rolling out unvalidated tools can have lasting consequences. "You are creating mistrust in a generation of clinicians and providers," warns one expert, who requested anonymity out of concern about professional repercussions.

Concerns extend beyond private vendors. Hospitals themselves are sometimes bypassing safeguards that once governed the introduction of new medical technologies, says Nancy Hagans, nurse and president of the New York State Nurses Association.

The risks are not merely theoretical. Obermeyer, the professor at Berkeley's School of Public Health, found that some algorithms used in patient care turned out to be racist. “They’re being used to screen about 100 million to 150 million people every year for these kinds of decisions, so it’s very widespread,” he says. “It does bring up the question of why we don’t have a system for catching those things before they are deployed and start affecting all these important decisions,” he adds, comparing the introduction of AI tools in health care to medical drug development. Unlike with drugs, there is no single gatekeeper for AI; hospitals are often left to validate tools on their own.

At the bedside, opacity has consequences: If the alert is hard to explain, the aftermath still belongs to the clinician. If a device performs differently across patients—missing some, overflagging others—the clinician inherits that, too.

Hype surrounding AI has further complicated matters. Over the past couple of years AI-based listening tools that record doctor-patient interactions and generate a clinical note to document the visit spread quickly through health care. Many institutions bought them hoping they’d save clinicians time. Many providers appreciate being freed from taking notes while talking to patients, but emerging evidence suggests the efficiency gains may be modest. Studies have reported time savings ranging from negligible to up to 22 minutes per day. “Everybody rushed in saying these things are magical; they’re gonna save us hours. Those savings did not materialize,” says Nigam Shah, a professor of medicine at Stanford University and chief data scientist for Stanford Health Care. “What’s the return on investment of saving six minutes per day?”

Similar experiences have made some elite institutions wary of relying only on outside companies for algorithmic tools. A few years back Stanford Health Care, Mount Sinai Health System in New York City, and others brought AI development in-house so they could develop their own tools, test tools from vendors, tune them and defend them to clinicians. “It’s a strategic redefinition of health-care AI as an institutional capability rather than a commodity technology we purchase,” Shah says. At Mount Sinai, that shift has meant focusing less on algorithms themselves and more on adoption and trust—trying to create trust with health-care workers and fitting new tools into the workflow.

AI tools also need to say why they’re recommending something and identify the specific signals that triggered the alert, not just present a score. Hospitals need to pay attention to human-machine interactions, says Suchi Saria, John C. Malone Associate Professor of Computer Science at Johns Hopkins University and director of the school’s Machine Learning and Healthcare Lab. AI models, she argues, should function more like well-trained team members. “It’s not gonna work if this new team member is disruptive. People aren’t gonna use it,” Saria says. “If this new member is unintelligible, people aren’t gonna use it.”

Yet many institutions do not consult or co-create with their nurses and other frontline staff when considering or building new AI tools that will be used in patient care. “Happens all the time,” says Stanford’s Shah. He recalls initially staffing his data-science team with doctors, not nurses, until his institution’s chief nursing officer pushed back. He now believes nurses’ perspectives are indispensable. “Ask nurses first, doctors second, and if the doctor and nurse disagree, believe the nurse, because they know what’s really happening,” he says.

To include more staff members in the process of developing AI tools, some institutions have implemented a bottom-up approach in addition to a top-down approach. “Many of the best ideas come from people closest to the work, so we created a process where anyone in the company can submit an idea,” says Robbie Freeman, a former bedside nurse and now chief digital transformation officer at Mount Sinai. A wound-care nurse had the great idea to build an AI tool to predict which patients are likely to develop bedsores.

The program has a high adoption rate, Freeman says, partly because that nurse is enthusiastically training her peers.

Freeman says the goal is not to replace clinical judgment but to build tools clinicians will use—tools that can explain themselves. In the version nurses want, the alert is an invitation to look closer, not an untrustworthy digital manager.

The next frontier arrived at Mount Sinai's cardiac-catheterization lab last year with a new agentic AI system called Sofiya. Instead of nurses calling patients ahead of a stenting procedure to provide instructions and answer questions, Sofiya now gives them a ring. The AI agent, designed with a "soft-spoken, calming" voice and depicted as a female model in scrubs on life-size promotional cutouts, saved Mount Sinai more than 200 nursing hours in five months, according to Annapoorna Kini, director of the cath lab. But some nurses aren't onboard with Sofiya. Last November, at a New York City Council meeting, Denash Forbes, a nurse at Mount Sinai for 37 years, testified that Sofiya's work must still be checked by nurses to ensure accuracy.

Even Freeman admits there is a "ways to go" until this agentic AI will provide an integrated and seamless experience. Or maybe it will join the ranks of failed AI pilots. As the industry chases the efficiency of autonomous agents, we need an algorithm-testing infrastructure. For now the safety of the patient remains anchored in the very thing AI cannot replicate: the intuition of the human clinician. Like in the case of Adam Hart, who rejected a digital verdict in order to protect a patient's lungs, the ultimate value of the nurse in the age of AI may be not their ability to follow the prompt but their willingness to override it.

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https://www.scientificamerican.com/article/ai-is-entering-health-care-and-nurses-are-being-asked-to-trust-it

A deepfake can ruin you before breakfast

Digital forensics pioneer Hany Farid explains what it will take to rebuild trust in the deepfake era

By Eric Sullivan edited by Seth Fletcher

Tavis Coburn

Deepfakes first spread as a tool of a specific and devastating kind of abuse: nonconsensual sexual imagery. Early iterations often were technically crude, with obvious doctoring or voices that didn't quite sound real. What's changed is the engine behind them. Generative artificial intelligence has made convincing imitation faster and cheaper to create and vastly easier to scale—turning what once took time, skill and specialized tools into something that can be produced on demand. Today's deepfakes have seeped into the background of modern life: a scammer's shortcut, a social media weapon, a video-call body double borrowing someone else's authority. Deception has become a consumer feature, capable of mimicking a child's voice on a 2 A.M. phone call before a parent is even fully awake. In this environment, speed is the point: by the time a fake is disproved, the damage is already done.

Hany Farid, a digital forensics researcher at the University of California, Berkeley, has spent years studying the traces these systems leave behind, the tells that give them away and why recognizing them is never the entire solution. He's skeptical of the AI mystique (he prefers the term "token tumbler") and even less convinced of the idea that we can simply filter our way back to truth. His argument is plainer and harder: if we want a world where evidence still counts, we must rebuild the rules of liability and go after the choke points that make digital deception cheap and profitable. Scientific American spoke with Farid about where deepfakes are headed and what works to blunt them.

An edited transcript of the interview follows.

When you say "trust infrastructure" in the age of generative AI, what are its core layers right now?

What we have been living with for the past 20 years in terms of disinformation on social media is now being driven by generative AI: more sophisticated bots, fake images, fake video, fake everything. Here you have to think about the intersection of the ability to generate images and audio and video of anybody saying and doing anything and the distribution channels of social media coming together. And by "trust," I'm referring to the question of how you trust anything that you see online.

There's another aspect of trust, which is in the courtroom, for example. How do you trust evidence in a civil case, a criminal case, a national security case? What do you do now? I mean, I deal with this almost every day. Some lawyers are like, "Well, we got this recording, and we have this image, and we have this closed-circuit TV video. All right, now what?"

And then there’s the fact that chatbots are going to go from sitting off to the side to being fully integrated. So what happens when we start building the next generation of everything—from self-driving cars to the code we write—that is now infused with AI, and how do we trust those systems anymore when we’re going to turn them over to critical infrastructure at some point?

What do you think most people misunderstand about today’s generative AI?

I think the biggest misconception is that it’s AI. My favorite term for it is “token tumbler.” What they’ve done is grab huge amounts of text, collapse words into numeric tokens and then do a sophisticated auto-complete: “Okay, I’ve seen these tokens. What’s the next token?” It is artificial, but it’s certainly not intelligence.

Here’s the other thing people have to understand: most of the “intelligence” is not in the computer—it’s actually humans. Scraping data and building a token tumbler doesn’t get you to ChatGPT. The way you get to ChatGPT is by then bringing tons of humans in who human-annotate questions and answers and say, “This is a good answer; that is a bad answer.” That is what’s called the fine-tuning and the reinforcement learning.

What are the biggest harms you’re seeing right now?

So, the nonconsensual intimate imagery, or NCII, is awful. Child sexual abuse, sextortion, kids talking to chatbots and the chatbots convincing them to take their own lives—which has happened, and that’s what the lawsuits are. Fraud is now being supercharged by generative AI in terms of voice scams at the individual level—Grandma getting a call, the CEO getting a call. I would say the disinformation campaigns, the poisoning of the information ecosystem.

And because I'm a university professor, I'll say you shouldn't underestimate the impact on education. I mean, there is not a single student who is not using this AI. And you can't say, "Do whatever you want." We have to fundamentally rethink how we teach students, not only to prepare them for a future where these tools will almost certainly be sitting side by side with them but also to figure out what they need to learn.

For nonconsensual intimate imagery, what's the best removal playbook right now—and what's the weakest link?

There's blame up and down the stack, from the person with their hands on the keyboard, to the product that was made, to the companies that are hosting it, and then of course to the social media companies that allow all this stuff to spread. Across the board, everybody gets blamed in varying amounts.

Is hash matching, based on the identification of digital "fingerprints" in media files, meaningfully effective, or is it whack-a-mole at this point?

I was part of the Microsoft team that built the image-identification program PhotoDNA back in the day for doing hash matching for child sexual abuse. And I've always been supersupportive of the technology. In the child sexual abuse space where it's real children being exploited, it actually works fairly well because we know that the same images, the same videos circulate over and over.

The NCII stuff today is AI-generated, which means you can produce it en masse. The problem with hash matching is, "All right, you're going to catch this image, but I can make 100 more in the next 30 seconds." So the hash matching gets you only to a certain level, and because people can now make these things so fast, I don't think you're going to be able to keep up.

What should lawmakers stop doing in deepfake bills, and what should they do more of?

For full disclosure, I worked on the early incarnations of the TAKE IT DOWN Act with law professors Mary Anne Franks and Danielle Citron. I would say it was a pretty good law when it started, and it is a terrible law on the way out.

If you're the creator of a Nudify app, it doesn't actually hold you accountable. It's got a 48-hour takedown window, which is ridiculous because it's the Internet, which means everything happens in the first 90 seconds—and it's the mother of all whack-a-moles. And the other issue is that there are no penalties for creating false reports, which is why I think the law will be weaponized.

So what they should stop doing is passing bills like that—completely ineffective. You can't go after the content. You have to go after infrastructure: the couple dozen companies out there that are hosting it; the Apple and Google stores; the Visa, MasterCard and PayPal systems that are enabling people to monetize it. You have to go upstream. When you've got 1,000 cockroaches, you've got to go find the nest and burn it to the ground. And by the way, right now the burden is still on the victims to find the content and send the notices.

> "What happens when we start building everything with AI? How do we trust those systems anymore?" —Hany Farid *U.C. Berkeley*

What has changed as generative AI has improved, and how is your company GetReal responding?

When we started in 2022, we were focused on file-based analysis: somebody sends you a file—image, audio or video—and you determine as much as you can about its authenticity. But then we started seeing real-time attacks where people were getting on Zoom calls and Teams calls and impersonating other people. So we started branching out to say, “We can’t just focus on the file. We have to start focusing on these streams.”

And what has happened is what always happens with technology: it gets better, faster, cheaper and more ubiquitous.

We take a digital-forensics-first approach. We ask: What are the artifacts you see not just in this one Sora video but across video generators, voice generators and image generators? We find a forensic trace we believe we will be able to measure even after the file has been recompressed and resized and manipulated, and then we build techniques to find that artifact. When I go into a court of law and testify, I don’t tell the judge and the jury, “Well, I think this thing is fake because the computer told me so.” I say, “I think this thing is fake because we look for these specific artifacts—and look, we found that artifact.”

Two years from now what would have to be true for you to say we’ve built workable trust infrastructure?

There are two types of mistakes you can make. You can say something real is fake—we call that a false positive—and you can say something fake is real, which we call a false negative. And the hardest thing is keeping those false positives really low. If every time you get on a call the technology’s like, “Oh, Eric’s fake, Hany’s fake,” you’re just going to ignore it. It’s like car alarms on the street.

So false positives have to be low. Obviously, you need to keep up with the tech, and you need to catch the bad guy. It has to be fast, especially on a stream. You can’t wait 10 minutes. And I think it has to be explainable. You can’t go into a court of law or talk to folks over at the Central Intelligence Agency or the National Security Agency and say, “Well, this is fake because we said so.” Explainability really matters.

Now, the good news is that, I think almost paradoxically, we will get streams before we get files. In a stream, the bad guy has to produce the fake in real time. I can wait five seconds—that's hundreds of frames. With a file, my adversary can sit in the quiet of their home and work all day long creating a really good fake and then launch it into the world. At GetReal we have a product that sits on Teams and Zoom and WebEx calls, and it analyzes audio and video streams with very high fidelity.

If you could change one thing about platforms or apps to protect people the fastest, what would it be?

First I'd create liability. The laws aren't going to do it. You create a product that does harm, and you knew or should have known it did, and I'm going to sue you back to the dark ages the way we do in the physical world. We haven't said that to the digital world.

Aren't these platforms protected under Section 230, the law that shields Internet platforms from liability for content posted by their users?

Section 230 most likely doesn't protect you from generative AI, because generative AI is not third-party content. It's your content. You created it. You made an app that's called Nudify. Your chatbot is the one that told the kid to kill himself and not tell his parents about that conversation. That's your product.

And, by the way, I would love to have 230 reform to hold the Facebooks and Twitters and TikToks responsible.

Another good protective step is what Australia did, which is ban social media for children younger than 16. Social media for kids was an experiment. It didn't work. It's a disaster. The evidence is overwhelming.

What do you tell families about voice-cloning scams?

I love safety words. My wife and I have one. It's an analog solution to a digital problem. It's low tech.

The other advice we give to everybody is to stay aware. Know that this is happening. Know that you're going to get a call at two in the morning from your son, who's saying something terrifying—so hang up, call him back. This situation is like everything in cybersecurity: don't click on links. Public awareness doesn't solve the problem, but it minimizes the impact, and it makes it less efficient for the bad guy.

Do you and your wife use a safe word in every call, every digital exchange?

Only if something dramatic happens. This isn't hypothetical: I got attacked with a voice clone. An attorney I was working with on a very sensitive case got a call from my number, talking about it in my voice. At some point he got suspicious and called me back and said, "Was that you?" I said, "What are you talking about?" So he and I made a code word for the rest of that case. For me and my wife, it's "I've been in an accident," "I've been kidnapped"—that kind of thing.

Between those who fear AI as an existential threat and those who think the current wave is all hype, where do you land?

If you talk to people in the technology space, it seems like there are two basic anti-AI camps. There's the camp with computer scientist Geoffrey Hinton, an AI pioneer, that's like, "Oh, God, we're all going to die. What have I done?" And then there's cognitive scientist Gary Marcus and his camp that's like, "This is all bullshit, and I've been telling you it's bullshit for 10 years."

I think they're both wrong. I don't necessarily think we're all going to die, but it's clear something is shifting the world. The next few years are going to be very interesting. We have to think seriously about the future we want and put the systems in place now. Otherwise we will have a repeat of the past 20 years.

Eric Sullivan is senior desk editor for technology and engineering at *Scientific American*.

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Exotic black hole stars could explain the mystery of Little Red Dots

Astronomers are racing to understand mysterious ancient objects that pepper James Webb Space Telescope images

By Rebecca Boyle edited by Clara Moskowitz

NASA, ESA, CSA, STScI, Dale Kocevski/Colby College

When astronomers glimpsed the first images from the James Webb Space Telescope (JWST) in July 2022, they saw the kind of universe most of them have come to expect. There were dazzling blue bursts of light, glowing trails of stardust, curtains of gas backlit by the birth of stars.

But things got weird very quickly. Almost every new image showed mysterious, tiny red points. The spots were extremely compact, very bright and distinctly red. There were so many of them. Everywhere JWST looked, the telescope found at least one specimen of what are now commonly called Little Red Dots (LRDs).

Astronomers quickly dated the dots to about 600 million years after the big bang, which means their light traveled almost the entire lifetime of the universe before arriving in JWST's honeycomblike hexagonal mirrors. The dots were everywhere, until they were nowhere; about 1.5 billion years after the big bang, they mostly disappear.

The age, size and sheer number of the Little Red Dots all point to something new, something that JWST is uniquely capable of seeing. "They are in every single image the telescope takes," says Massachusetts Institute of Technology astrophysicist Rohan Naidu. "We have to find out about them if we want to tell a complete story about the early universe."

At first, astrophysicists coalesced around a few theories to explain LRDs, each of which has implications for the evolution of the universe. Little Red Dots might be compact galaxies with brightly belching black holes at their centers. They could represent a never-before-seen stage of the black hole life cycle. They could be dusty starburst galaxies, exploding with new stellar populations like so many popcorn kernels encountering hot oil.

If Little Red Dots are indeed supermassive black holes, their prevalence could help us understand the nature of these weird perversions of gravity. The dots might reveal how black holes evolve and grow so fast and even how galaxy clusters develop. They could help theorists study direct-collapse black holes, a relatively new concept in which a black hole forms not from a dead star's carcass but in a sudden collapse of gas, much the way a star ignites.

But more recently, many astronomers are favoring the kind of conclusion that drives entire careers in science. The Little Red Dots may be a totally new class of cosmic object. The latest theories suggest they could be something called quasi-stars or black hole stars, a concept originally predicted 20 years ago. Although some experts remain skeptical, the idea is quickly gaining traction.

And if they do represent some entirely new feature of the universe, they stand to change our entire conception of the cosmos, just as the 1950s and 1960s discovery of quasars—hungry black holes in the centers of galaxies—revolutionized our understanding of galaxy evolution.

Several astronomers say they are having a hard time keeping up with the literature on LRDs because groups from dozens of countries are sharing new research papers almost every day. “I don’t think there is any consensus yet,” says M.I.T. astrophysicist Anna-Christina Eilers. “And even if there are theories we like, there are a million open questions.” Dale Kocevski, an astrophysicist at Colby College who has been scrutinizing LRDs since they started showing up, was somewhat more sanguine. “I’m sure in a year or two we will probably figure out what’s going on,” he says. For now the Little Red Dots hide in disguises no one recognizes—yet.

The redness of the Little Red Dots is an important signal about their identity, and they seem to be red for at least two reasons. For one, the dots are very old, and old things appear red because their light has stretched along with the expanding universe during the time it took to travel all the way to us. This stretching of light into longer wavelengths is known as redshift.

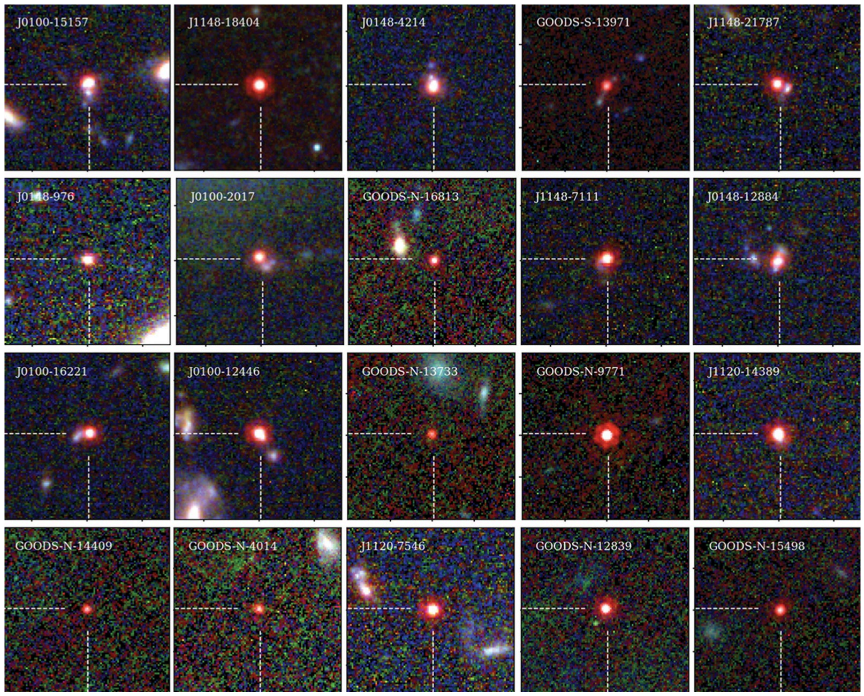
But astronomers have realized that Little Red Dots are also inherently red: not only has their light been stretched, but they also must be full of dust that blocks other wavelengths of light. One of the first scientific papers on the dots, published in March 2024, noted that they were abundant and “seem to be heavily enshrouded in dust, presenting as red point sources amidst blue star-forming clumps.” The authors, led by Jorryt Matthee of the Institute of

Science and Technology Austria, gave the objects their friendly, familiar-sounding name.

Little Red Dots are everywhere in JWST images because the telescope is designed to see red light, especially the mid-infrared wavelengths these objects emit. The Hubble Space Telescope can't see that light, and previous infrared observatories such as the Spitzer Space Telescope didn't have JWST's power. Two instruments on JWST, the Near-Infrared Camera (NIRCam) and the Mid-Infrared Instrument (MIRI), are the Little Red Dot workhorses, unveiling hundreds of the ruddy specks.

One key aspect of Little Red Dots requires a bit of chemistry to understand. The specks are characterized by a strong "Balmer break," a dip in the light they emit below a certain wavelength. This wavelength represents the amount of energy it takes to kick an electron out of a specific orbital in a hydrogen atom. When an object gives out less light below this wavelength than above it, astronomers can surmise that the energetic light is being absorbed by hydrogen electrons, which suggests there must be a source of these high-energy photons. Observing a Balmer break in a galaxy usually means it's full of young, hot stars. And the LRDs have a telltale Balmer break in their spectra.

Initially astronomers thought this meant the LRDs were galaxies producing tons of hot stars—up to tens of billions of suns. These galaxies would also be very efficient at producing dust, which would explain why they look so red instead of brilliant, baby-star blue. But there was a problem with this theory. It's normal for a galaxy the age of, say, the Milky Way to have produced billions of stars, but that's all but impossible for a galaxy that has been around for only an eyeblink of cosmic time, as the Little Red Dots have. What's more, the dots are too small to contain billions of stars. Based on their light signatures, packing that many stars into an object the size of an LRD would be equivalent to squeezing several hundred thousand more suns between here and the next-nearest star system, Proxima Centauri. This would be hard to square with current cosmological theories for the early universe, not to mention theories for how stars form and interact.



Since it turned on, the James Webb Space Telescope has revealed dozens of mysterious red blobs in space. The so-called Little Red Dots start to appear around 600 million years after the big bang and seem to disappear by around 1.5 billion years after the big bang.
Images isolated from "Little Red Dots: An Abundant Population of Faint Active Galactic Nuclei at z ~ 5 Revealed by the EIGER and FRESCO JWST Surveys," by Jorryt Matthee et al., in the *Astrophysical Journal*, Vol. 963; March 10, 2024 (CC BY 4.0)

As astronomers observed more Little Red Dots throughout 2024, they discovered that the pinpricks were spinning rapidly—evidence they could instead be small galaxies anchored by roiling, incandescent black holes, known as active galactic nuclei. But this theory also has issues because the LRDs show no evidence of x-ray emission, which is common for black holes, or of the kind of light that we know surrounds other dust-reddened active galactic nuclei. And mass is again a problem: the black holes would need to be huge compared with the tiny galaxies that housed them, some of which would be about 100 times smaller than the modern Milky Way.

By the end of 2025 new observations had shown that not all LRDs were as dense as originally thought. In a couple of cases, they were not actually as far away as astronomers thought, either. In fact, one key study argued that the Balmer break, that line indicating young, hot stars, could be made by other things, too.

Many questions remained. Are the Little Red Dots indeed dusty starbursts? Are they shrouded active galactic nuclei? Are they something new instead? Or, as at least a few astronomers have suggested, are they some combination of all of the above? Any of these answers could have cosmic implications. “It’s this big mystery that is in every single image we take, so let’s figure it out,” Naidu says.

As astronomers gathered more examples of Little Red Dots, many became convinced that black holes must be involved somehow. “Even if they are extremely compact star-forming galaxies, stellar collisions in them would naturally lead to formation of massive black holes,” says Muhammad Latif, an astrophysicist at United Arab Emirates University.

In widely cited research, Kohei Inayoshi, an astrophysicist at the Kavli Institute for Astronomy and Astrophysics at Peking University, calculated that a cloud of gas in front of a black hole would produce a signature similar to that of the LRD light. “That kind of killed the idea that these are massive galaxies,” Kocevski says.

In February 2023 Anna de Graaff of the Center for Astrophysics | Harvard & Smithsonian teamed up with colleagues to propose a new LRD-hunting program called RUBIES, for “Red Unknowns: Bright Infrared Extragalactic Survey.” They used nearly 60 hours of JWST time to observe 4,500 distant galaxies and found about 40 Little Red Dots. They found a doozy nicknamed the Cliff, which the team coined after the sharp Balmer break in the spectrum of light it emitted 11.9 billion years ago.

De Graaff’s group produced a graph of this LRD’s light showing nearly zero ultraviolet light and a sudden spike for longer, less energetic wavelengths of light. This sharp transition in light emission is not something a typical galaxy can pull off, de Graaff says. And no black holes in the nearby universe can do it, either. Rather the strange cliff in light emission suggests that the Little Red Dot must be superenergetic, like a black hole, but it also must be swaddled in a cocoon of warm, dense gas—just like the atmosphere of a star.

These developments got Mitch Begelman’s attention. An astrophysicist at the University of Colorado Boulder, Begelman had predicted just such a structure in a theoretical paper in 2006. What he called “quasi-stars” could form within hot clouds of gas, which would quickly collapse to ignite a gargantuan star that undergoes nuclear fusion for a short time. Within a few million years, after its supply of hydrogen burns out, the core contracts, implodes and forms a black hole.

“To our surprise, when we tried to follow this theory, we found the implosion would not release enough energy to blow the envelope away,” Begelman recalls. “You would end up with a black hole and with 99 percent of the stellar envelope left. The black hole would be in the center, so it is releasing energy, but not through nuclear fusion”—in other words, it’s shining because the black hole is gobbling gas, instead of a stellar furnace powering the glow. His concept predicts that quasi-stars would be humongous, corresponding to about a million times the mass of the sun. And so far the LRDs seem to fit the bill. “They don’t look like they are made of stars,” Begelman says. But they are not ordinary black holes, either.

Last July, Naidu, de Graaff and their colleagues argued that LRDs are objects very much like Begelman’s quasi-stars: not quite star and not quite black hole but a bit like both. Naidu and de Graaff have been calling such objects “black hole stars,” which would be gigantic, bright balls of gas lit up by the energy of a black hole at their heart rather than by nuclear fusion.

“I think this is definitely, by far, the most exciting thing to come out of JWST,” Naidu says. “I am fully working on this and setting everything else aside. It’s very rare in astronomy that you come across an entirely new class of object, and I am pretty convinced that is the case here.”

His and de Graaff’s model explains several peculiarities of Little Red Dots, including their apparent lack of x-ray emission, otherwise a black hole calling card. “If you start thinking about them now as essentially this enormous star that has a black hole at its center, things start falling into place,” he says. “You understand a whole gamut of really peculiar features.”

De Graaff says the Cliff is probably a black hole star, and a couple of other LRDs are also very likely to be in the same class. But debate persists about whether all the mysterious objects fit into that category, she says. “If you ask a random astronomer on the street, I don’t think they would say every LRD is a black hole star,” she says. “But if you ask my team, yes.”

One question is whether black hole stars represent an early phase of black holes in the universe—before they lose their red-dimmed outer envelopes of gas. If Little Red Dots do represent some strange stage of the black hole lifespan, they could help solve a mystery about how the large ones formed.

Black holes were predicted by Albert Einstein’s theory of gravity, and astrophysicists have imagined that they are born after giant stars implode and cave inward. The cosmos is chockablock with black holes that seem to have originated this way. But supermassive black holes, the ones that churn at the heart of nearly every galaxy and weigh hundreds of millions or billions of suns, are harder to understand. They had to grow large enough quickly enough to shape the galaxies that surround them, but most models for black hole growth can’t make behemoth objects that fast.

Some theorists have argued for a new model called direct-collapse black holes, in which an enormous black hole “seed” grows from a dense cloud of gas. Instead of a star igniting in the cloud, an ultradense, gravitationally gargantuan black hole is born instead.

Begelman thinks black hole stars might represent a version of this theory. “Theoretically, we can understand the conditions that would lead to the gas collecting and then collapsing immediately into a black hole,” he says. “But my personal suspicion is that it is very difficult to avoid the intervening stage of having something like a supermassive star.”

> Little Red Dots could represent a variety of objects at different ages, revealing different phases of existence.

And whether or not the direct-collapse idea is right, LRDs could be the precursors of the supermassive black holes that form the hearts of modern galaxies. Inayoshi, who theorized that the dots could be black holes with gas envelopes surrounding them, suggests they are just a phase of black hole growth, possibly the first time newborn black holes begin gobbling up mass. Little Red Dots would therefore be black hole baby pictures.

In a separate paper submitted last December, Inayoshi and his colleagues argue that the black hole envelope model, or black hole stars, can explain the Little Red Dots’ strange light features and their apparent densities. If this paradigm is right, then the LRDs are a short-lived, efficient growth phase in the early lives of supermassive black holes.

This could explain the huge amount of dots in the early universe, as well as where they are now, Begelman says. “They become supermassive black holes, and there is one per modern galaxy, so you need a lot of them," he says.

As the theorists have been sharing these ideas, observers have come back with evidence that strengthens the case—and challenges the prevailing wisdom. A team co-led by Pierluigi Rinaldi of the Space Telescope Science Institute, for instance, reported another oddball last November, a galaxy called Virgil that seems to have a reddish, supermassive black hole at its heart.

When viewed in visible light and even bright-blue ultraviolet, Virgil is a normal-seeming galaxy, seen about 800 million years after the big bang. But when JWST's MIRI instrument takes a look, the galaxy's light suggests the presence of a giant black hole that is seemingly too big for Virgil to hold.

The discovery suggests a new path for black hole and galaxy growth. Before JWST, astronomers had assumed that galaxies formed first and ultimately came to host supermassive black holes—whether seeded by direct collapse or otherwise—in their hearts. But now it looks like black holes might grow first.

This finding could have implications for the quest to understand the first light of the universe. Astronomers still struggle to explain the so-called cosmic dawn, a turning point sometime between 50 million and 100 million years after the big bang when the first stars ignited. Somehow their sparkling ultraviolet light recharged the neutral gas that pervaded the universe, preventing free hydrogen nuclei from combining with electrons to make neutral atoms. This process is called the epoch of reionization. But astronomers are not sure how it happened. Did the ionizing light come from young stars? Or did it come from gluttonous black holes stealing the warm wind and superheating gas?

The story of Virgil, and maybe other LRDs, suggests astronomers have been missing something big. Dust-obscured black holes seem to have played a bigger role in reionization than anyone thought—we just could not see them until now, because they shine in red light that only JWST is powerful enough to finally observe. Many more such giants might be out there, unseen until JWST takes more long, deep looks, Rinaldi says. “That is blowing my mind,” he says. “Maybe we are missing a very important piece of the puzzle because of the fact that we don’t have enough deep-field data.”

Meanwhile the search continues for more Little Red Dots. Last July astronomers claimed a discovery of three Little Red Dots about a billion light-years from Earth. These closer dots, which are inherently much younger, suggest LRDs can crop up later in the universe, too.

Then, last December, astronomers used the Very Large Array to detect one in radio wavelengths, also fairly local. And Kocevski says astronomers are sifting through existing datasets, such as observations from the Sloan Digital Sky Survey, to uncover even more nearby specks.

In one unusual case, announced last December, another galaxy between a Little Red Dot and us helped astronomers see the object through various snapshots of time. This LRD’s light was magnified four separate times by a galaxy positioned in front of it from our perspective. The effect, called gravitational lensing, is another consequence of Einstein’s theory of gravity. The Little Red Dot in question seemed to vary over 130 years, according to the researchers, led by Zijian Zhang of Peking University. More deep observations are necessary to figure out how LRDs evolve over time, says Rinaldi, who was not involved in that work. “The more data you get across different epochs, the more you can time travel,” he says.

Finding Little Red Dots at different distances and times will help astronomers understand how they evolve and whether they do represent black hole infancy, a black hole star structure, or some other phenomena.

Perhaps Little Red Dots formed within very slowly spinning halos of dark matter, as one example. Invisible dark matter sculpts the universe, surrounding galaxies and clusters of galaxies like a halo. Dark matter halos spin, which astronomers can observe by studying gas flows. In a paper submitted last April, Fabio Pacucci of the Center for Astrophysics | Harvard & Smithsonian and his colleagues argue that LRDs could have formed in dark matter halos that spin very slowly, which would naturally create very compact galaxies. In a recent example, a Little Red Dot is surrounded by eight nearby galaxies and embedded in a dark matter blob. Eventually such an LRD could evolve into a quasar, the most luminous galaxy type, which is usually found inside a dark matter halo.

Another theory holds that LRDs could represent a variety of objects at different ages, revealing different phases of existence. Rinaldi, Karina Caputi of the University of Groningen in the Netherlands and their colleagues say that different LRDs have different characteristics and may be different things entirely. In a paper published last October, the team argues that some LRDs hold the telltale evidence of active black holes, showing gas streaming at thousands of kilometers per second. But other LRDs seem to host star factories instead. That sharp break in their light absorption ability, so typical of LRDs, could defy a simple answer, they say. “I am not totally convinced they are the same kind of object,” Caputi says.

Although most astronomers are convinced the Little Red Dots are black holes of some kind—infant, gas-shrouded, direct collapse, or stellar—many questions remain. Dozens of research groups submitted proposals last year for the next cycle of JWST observations. The team of astronomers that divvies up every minute of the telescope’s time has been working through those applications and will announce project selections soon.

A top priority is figuring out how massive the Little Red Dots are, which will help scientists determine what types of objects they could be, and whether they might be many different things at once. Current methods for measuring black holes fail for the dots, so new strategies and theories are necessary. M.I.T.’s Naidu aims to produce a life-cycle chart for black hole stars, much like the fundamental Hertzsprung-Russell diagram that plots the life stages of stars according to their brightness and surface temperature. “The fate and the destiny of all stars is encoded in a few parameters: how hot they are, how bright they are and what their surface parameters are. These are the kind of things we have to measure for the LRDs,” Naidu says. Someday, he hopes, these oddball red spots will be understood just as well.

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https://www.scientificamerican.com/article/what-are-jwsts-little-red-dots-astronomers-may-finally-have-an-answer

The truth about polyamory

An anthropologist’s detailed research shows polyamorists focus on intimacy and honesty, not sleeping around

By Rebecca J. Lester edited by Josh Fischman

Klaus Kremmerz

The first time her husband went on a date with another woman, Kelly felt sick to her stomach. Consumed by jealousy, she threw up twice and cried for three hours straight until he came home. The second time he had a date night, with a different woman, Kelly sat on the couch wrapped in a blanket, hate-watching *90 Day Fiancé* until she heard his car in the driveway. By the fifth time, she just went to bed early. The eighth time, Kelly met her husband for drinks after his date. Then, she says, they went home and had the best sex of their lives.

Kelly, a trial attorney, is no shrinking violet. She goes on her own dates with other men, and her husband, Tim, is thrilled. (Names have been changed in this story to protect the privacy of the people I interviewed.) “There’s nothing like that feeling when Kelly comes home from a date, and she's soaring and giddy because it went so well," he says. "And I'm like, 'That's amazing, babe! I'm so happy for you!' And I truly am."

Kelly and Tim practice polyamory: they form deep, meaningful, romantic relationships with more than one person at a time, with the full knowledge and consent of everyone involved. This departure from traditional dating and marriage is gaining popularity in the U.S., according to research and surveys. In popular media, though, it is usually ridiculed and dismissed.

Critics deride polyamorists as decadent liberal hedonists looking for ethical cover for their desire to sleep with lots of people. An *Atlantic* article says polyamory is emblematic of the "banal pleasure-seeking of wealthy, elite culture in the 2020s," allowing people to justify indiscriminate sex and avoid the hard work of commitment. "No one can truly feel safe inside a marriage whose vows have an asterisk," claim the authors of a piece distributed by the Institute for Family Studies. "Anyway, these people are crazy," writes Rod Dreher, a former writer at *The American Conservative*.

These views of polyamory are dead wrong.

I am an anthropologist and licensed therapist, and I have spent the past seven years researching polyamory the way anthropologists do: by spending a lot of time with a lot of people who engage in it. I've interviewed more than 100 practicing polyamorists in depth, and we talked about their experiences, motivations and aspirations, as well as regrets and lessons learned. I've heard about how polyamorists view themselves and the world, and I've observed what they do. And what I've found is, in many respects, supported by other scientific research—but not by popular perceptions.

First, polyamorists are not a privileged elite. They are more likely than monogamous people to earn less than $40,000 a year, according to one study, although they do tend to be more highly educated. They are regular folks. They have jobs and children. They run carpools and pay rent and go to the grocery store and watch the news. There is nothing inherently class-specific about the practice. (Nor is it limited to particular race or ethnic backgrounds, although the population skews white.)

Politically, polyamory is a rare place where the left and right meet: you might encounter a libertarian or a Donald Trump supporter or a Bernie Sanders bro. The philosophy and practice of polyamory resonate with people across political divides and are not simply liberal indulgences—in fact, they tie into a libertarian and conservative ethos with deep roots in U.S. society, where people rebel against the powers that be telling them what to do.

Where popular portrayals of polyamory most miss the mark, though, is in the idea that the practice is primarily about having sex with multiple partners. Polyamory is mostly about intimacy, not sex, say the people involved in it, and it has ethics at its core. My observations support this claim, and so does other social science research. In a detailed 2021 study of 540 people published in the *Archives of Sexual Behavior*, psychologist Jessica Wood of the Sex Information and Education Council of Canada and her team found that relationships based primarily on sex are viewed negatively by many polyamorous people. People in these relationships prioritize mutual emotional support and opportunities for self-discovery. Respect, consent, trust, communication, flexibility and honesty are fundamental to these unconventional dynamics, according to a large review by researchers at Virginia Tech published in 2023.

> "We are not sex-crazed freaks in some crazy lifestyle. We spend more time communicating than anything else."

And these principles can have beneficial consequences. Psychologist Justin Lehmiller, a senior research fellow at the Kinsey Institute, reported in the *Journal of Sexual Medicine* that polyamorists engage in safer sexual practices than the people who say they are monogamous—a quarter of whom reported having sexual relationships unknown to their partner—and this caution may reduce rates of sexually transmitted infections.

In short, polyamory is radically different from what many people may envision. Its current flourishing is not just a curiosity or random event: it indexes something important about this cultural moment and how people experience and value intimacy and relationships.

I am not an apologist for polyamory. I have been in such relationships in the past and had positive experiences, but I ultimately decided polyamory wasn't for me. It activated some insecurities that I have spent years of my life working to heal, and I never felt that polyamory resonated deeply with my sense of who I am. For me, participating in polyamory successfully would take continual, deep work around old and familiar emotional wounds, and I simply wasn't all in.

Clearly, however, other people are all in, and profound misunderstandings of polyamory have been circulating since its rise in popularity. Getting beyond such misconceptions offers a valuable opportunity to comprehend the power and importance of human needs for intimacy in a variety of forms.

Reality TV shows like *The Bachelor*, *Love Is Blind* and *Say Yes to the Dress* are popular for a reason—they tap into a dominant cultural narrative about "true love" and monogamy. The story is familiar: Someday we will find our one true love, the person who will "complete" us. They will be our best friend, lover, intellectual partner and emotional-support system all rolled into one. If we aren't fulfilled, then there is something wrong.

Polyamory holds that what's wrong is the very premise of monogamy in the first place. One person cannot possibly meet all our needs. "It's like this," Kris, a 37-year-old real estate agent, says. “We have groups of friends, right? Maybe one you go out dancing with on the weekends, another one is the person you call when you’ve had a horrible day; maybe someone else is a sports fan, so you go to ball games together. Totally normal, right? We don’t expect one friend to be our *only* friend, because we have different kinds of relationships with different people. It’s unrealistic to expect one person to do it all.”

Love, polyamory practitioners say, is similar. Like friendship, it is not a limited resource—it is additive. More love begets more love. “When you have multiple kids, you don’t love one of them less just because another one is born,” John, a 36-year-old business analyst, explains. “There’s enough love for all of them. You love them each for who they are uniquely.” A 2024 study by gender and sexuality scholar Jessica J. Hille of the Kinsey Institute and her colleagues highlights the flexible definitions of intimacy in polyamorous communities where intimacy is not always predicated on sex. Such relationships are common enough to have their own term, “platonic polyamory,” which describes connections with multiple people that may be deeply significant and intimate but not sexual.

And despite the perception that polyamory is justification for bed-hopping, polyamorous relationships are generally not fleeting. They might involve commitments that last months, years or a lifetime. A 2017 study of about 2,000 monogamous and nonmonogamous people found no difference in relationship length between the two groups, with an average length of slightly more than 10 years. They were also comparable on measures of relationship satisfaction, commitment and passionate love. This finding suggests polyamorous relationships can be just as fulfilling, meaningful and enduring as monogamous ones.

None of this means polyamorous relationships are easy. Jenna and Michael are in their late 40s and have been married for 23 years. In the summer of 2023 we sat down at a coffee shop in Nevada to talk about their journey to and through polyamory. For the first 10 years of their marriage Jenna and Michael were happily monogamous. Then things changed. Michael, a reservist in the armed forces, was deployed overseas and experienced a harrowing near-death incident. “After that,” Michael recounts, “I really thought a lot about my life and what I wanted. I realized that, among other things, I didn’t want to be monogamous anymore. I loved my wife more than anything and didn’t want out of the marriage. But coming that close to death made me realize how much more life there is for me to experience.”

Michael returned from his deployment and raised the issue of opening the marriage with Jenna. “She was not in favor at all,” Michael says. “She had a lot of fears and concerns, which is totally understandable. I did, too. So we read everything we could get our hands on about polyamory and talked to people we know who are in the lifestyle. We took it slowly. About a year after that initial discussion, we were both ready to open things up.”

“And how did it go?” I ask.

“Michael had a really hard time at first,” Jenna says, “even though it was his idea. Nothing can really prepare you for what it will feel like to see your partner go out without you. But to his credit, he didn’t just pull the plug. We worked through the issues together.”

“It was important for me to acknowledge my jealousy,” Michael says, “and for us to talk about it. But not like in monogamy—the point wasn’t to get Jenna to change her behavior. She wasn’t doing anything we hadn’t agreed to. Jealousy was *my* feeling to deal with and work through. I don’t own her. Jenna is her own person. It’s a big risk because it means trusting that your partner is still going to want to be with you even though they are free to have other relationships. But ultimately I’d rather she be with me because she chooses to, not because she’s locked into the relationship legally or morally.” Jenna adds that “it makes the relationship about who we are as people to each other and how we value each other, not just about rules about possession and exclusivity."

Not all polyamorous relationships have a couple at their core. I talked with Kim, Mark and Marina at a polyamory conference in Denver in 2018. All were in their mid-30s and worked in various aspects of the food-service industry. Kim identifies as white, Mark as biracial (white/Black) and Marina as Latino. Kim and Mark had been together and polyamorous for four years before they met Marina. "When people see us together," Marina begins, "I can tell they're wondering, 'What is the deal here?' I think they assume that Mark is some alpha male with two chicks on his arm, but that's not our situation at all. I'm a lesbian. I have no interest in sex with men—Kim and I are the ones who are involved sexually. And Kim with Mark. But Mark and I get along really well, and the three of us consider ourselves a unit. Mark dates other women as well, and it's possible that in the future we would welcome one of his partners into our polycule."


Klaus Kremmerz

Mark chimes in: “Kim and I have never been monogamous, so it wasn’t a matter of opening up. I knew Kim was bisexual when we got together and that she would have needs I can’t personally meet. I am totally fine with that.”

“Would you feel the same if Kim wanted to date a man?” I ask.

“Oh, I’ve dated men since we’ve been together,” Kim clarifies. “If Mark had had a problem with that, we wouldn’t be here. There are some men out there who do that, though—they’ll accept their girlfriends or wives having other partners but only if they’re women. It’s called having a ‘one penis policy.’ That’s considered unethical in the poly world because it’s one person making rules and controlling the intimate life of someone else, and it reinforces a bunch of patriarchal nonsense."

Mark really wants to point out that the trio are normal people: "We're not sex-crazed freaks or living some kind of crazy lifestyle. We spend a lot more time and energy communicating than anything else and making sure we are going about things ethically and with care for everyone involved."

These observations from Kim, Mark and Marina match up well with those in sociologist Elisabeth Sheff's 2013 book, *The Polyamorists Next Door*, based on more than 10 years of research. Sheff outlines the emotional demands of maintaining multiple intimate relationships, including constant negotiation, time-distribution challenges and emotional regulation. She finds that the mental and logistical work needed to keep polyamorous relationships functioning is significant, requiring practitioners to sustain a level of self-awareness and attunement above and beyond what is generally needed in monogamous relationships.

"In monogamy, people have a tendency to go on autopilot," says Jesse, a 28-year-old bus driver. "You can't do that in polyamory. You have to be extremely intentional all the time in every single relationship. Otherwise things could go bad fast." Again, the research bears out these claims. A 2022 study by psychologist Thomas R. Brooks and his colleagues found that, compared with people in monogamous relationships, those in consensually nonmonogamous arrangements reported greater commitment, intimacy, love and passion in their relationships. They favored positive problem-solving with their partners, whereas monogamous participants often used withdrawal tactics.

As part of that intentionality—and the complexity of dealing with multiple people—polyamorous partners enter into relationship agreements about what is and is not permissible. People I interviewed described a range of agreements, such as using condoms with new partners until they have been tested for sexually transmitted infections, being respectful of a partner’s privacy and autonomy by not texting them while they’re out on a date, informing existing partners when they meet someone new, not talking about problems in one relationship with another partner, and so on.

The first and most important agreement, according to everyone I spoke with, is the promise to be honest about involvements with other people. Polyamorists say this openness distinguishes their behavior from cheating. Larissa, a 28-year-old college professor, had a lot to say on this subject. “People say polyamory is just a rationalization for cheating, but nothing could be further from the truth,” she says. “Cheating is about dishonesty, whereas polyamory is built on a foundation of truthfulness and transparency. A friend of mine had a partner she’d been seeing for about four years. They were totally open, free to date other people. Then she found out he’d been seeing a neighbor of theirs and hadn’t told her. That’s cheating. It’s absolutely possible to cheat in a poly dynamic. But why? He was free to date anyone he wanted to, as long as he was honest about it. He wasn’t. So that was the end of their relationship.”

The emphasis on autonomy, another key principle, renders unethical any attempt to control or restrict a partner’s behavior beyond issues of safety and respect. “No one should have control over someone else’s sexuality,” says André, a graduate student in his early 30s. “If you’re dictating who your partner can and can’t explore a connection with, that’s problematic.” Psychologists Denisa Derevjaniková and Gabriel Bianchi of the Slovak Academy of Sciences found, in research published in 2022, that this desire for autonomy was a primary motivator for many people to participate in polyamory in the first place; other psychological researchers have found that this sense of being able to control one’s own life contributes strongly to relationship satisfaction.

Power dynamics within poly arrangements are also of the utmost concern. For example, “unicorn hunting” (when a couple seeks a single woman to bring into their relationship as a third) is an ethical anathema in polyamory. “Unicorn hunting is considered unethical because it treats the single woman as, essentially, a sex toy for the couple,” Maria, an office worker in her mid-30s, explains. “And there’s a radical power differential between the couple and the third. They can just drop her anytime and still have each other. She’s in a really vulnerable situation there.”

Cowgirling (or cowboying) is yet another ethical violation, consisting of someone entering into a poly dynamic with the intent of “stealing away” one of the partners for a monogamous relationship. Aarti, a 29-year-old woman, had a close-up experience with cowgirling. She was going through a divorce at the time of our interview.

“My husband and I had been poly for several years with no problems, but then he started dating this new woman who had only been in monogamous relationships,” she says. “This was her first poly situation. She really had a hard time wrapping her head around it all. I felt a lot of empathy for her, so I bent over backward to try to make her feel comfortable. And things were okay but not great. Then, when the pandemic hit, we decided we would all move in together: him and her, and me and my girlfriend. The four of us. Boy, was that a mistake.”

There was a lot of jealousy and anxiety, Aarti says. “Finally, she told my husband she was moving out, and he could either come with her or not,” she says. “That’s when he told me he wanted a divorce, and he moved out with her.”

Aarti cites her husband’s girlfriend’s anxiety and jealousy as the core difficulty in their dynamic and as the ultimate catalyst of things falling apart. In her view, these feelings were associated with the girlfriend’s monogamous experiences and inability to make the shift to a polyamorous mindset. This idea is consistent with clinical psychologist Deborah Anapol's finding, presented in her 2010 book *Polyamory in the 21st Century,* that emotional upheaval is common in the transition from monogamy to polyamory and that not everyone wants to or can make this shift. Psychologist Amy C. Moors of Chapman University and her colleagues reported in a 2019 paper that those with more anxious attachment styles tend to have lower relationship satisfaction in polyamorous relationships than those with more secure experiences of attachment, affirming the notion that polyamory is not necessarily "good" for everyone.

Aarti is adamant that a mismatch of needs and priorities, not polyamory itself, was the cause of the breakup. "It had nothing to do with us being poly," she says. "Monogamous marriages end in divorce all the time, and no one says, 'Aha! It's because of monogamy!' In our case, there were other problems in the relationship that had nothing to do with polyamory. When his girlfriend just couldn't make the shift, I think he saw it as an easy way out, and he made a choice."

It seems clear from my conversations with Tim, Kelly, Michael, Jenna, André, Maria, and dozens of other people who identify as polyamorous, as well as from the research on polyamorous practices, that most people don't enter into this way of life lightly. People spend months, if not years, reading and learning about it before attempting it, and they continue to read books and consult with others in the lifestyle about how to best navigate different situations.

And despite some of its antiestablishment appearances, polyamory is, in many ways, a quintessential expression of American individualism. Each person is their own free agent, cultivating connections and relationships to meet their needs, which allows for maximum personalization and flexibility. "Polyamory is really about building relationships that suit *you*," says Carl, a 42-year-old lawyer.

In this way, the burgeoning polyamory movement is in step with other 21st-century social transformations such as the move from network television to online streaming, the preference for online shopping over going to the mall, or the rise of Uber and Lyft. It's all about personalization. When we make a Spotify playlist for the gym, for example, we control the mood, the vibe and the experience. It is tailored to our specific tastes and needs. People want control over what they invest time and money in, and they want personalized experiences that they find meaningful. They don't want corporations, the music industry, the government, or other social institutions—such as monogamy—to dictate what they should like and what options they can choose from. In this regard, the rising interest in polyamory over the past decade is not evidence of a fad so much as it is part of a larger cultural shift in how people relate to their own desires and to their willingness and ability to pursue those goals.

The human need for intimacy seems to be universal. But it is also complicated. What intimacy means to someone and why it matters depend on many things—not only personal disposition and physiological, emotional and intellectual needs but also what that individual learns from our culture about acceptable forms of connection.

A big lesson of polyamory is that our mainstream models of love and intimacy are not as rooted in nature as we might assume. There are alternative ways of living and loving that, for many people, can open up new opportunities for fulfillment, joy and social connection that exceed the boundaries of traditional relationships. Such approaches can be challenging, but what's important is that they also can be engaged in ethically and successfully for everyone involved.

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https://www.scientificamerican.com/article/polyamory-isnt-all-about-sex

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Mountain photographer stumbles on one of the largest ever collections of Triassic dinosaur prints

A newfound site in the Italian Alps holds one of the largest collections of Triassic dinosaur footprints ever seen

By Humberto Basilio edited by Sarah Lewin Frasier

About 2,000 fossil footprints appear on this part of the mountain site’s walls, researchers say. Elio Della Ferrera/PaleoStelvio Arch. (PNS, MSNM, SABAP CO-LC)

Last September photographer Elio Della Ferrera spotted thousands of dinosaur tracks traversing vertical rock faces in the Fraele Valley of Stelvio National Park, high in the Italian Alps. Some of the prints, spanning as many as 40 centimeters across, date back about 210 million years, making the newly identified site one of the richest deposits of Triassic dinosaur tracks in the world.

The footprints are so well preserved that “it took me a few seconds to realize the photos were real,” says paleontologist Cristiano Dal Sasso of the Natural History Museum of Milan, who is leading the investigation of the site. “Now we can go back in time and study the evolution of dinosaurs in this place.”

In a preliminary study, Dal Sasso and his team deduced that the prints were made by herds of large, herbivorous dinosaurs, probably prosauropods, ancestors of Jurassic sauropods such as Brontosaurus. The tracks formed when dinosaurs walked across muddy tidal flats along the shores of the prehistoric Tethys Ocean, long before the Alps rose.

Studying this newly named “Triassic Park” will be challenging because it is so difficult to access, Dal Sasso says—researchers will have to rely on drones and remote sensing to study and digitally preserve the footprints.

Some of the best-preserved fossilized footprints at the newfound site show impressions of the Triassic walkers’ long heels, toes and claws.
Elio Della Ferrera/PaleoStelvio Arch. (PNS, MSNM, SABAP CO-LC)

Humberto Basilio is a Mexican science journalist covering policy, health, misconduct, archaeology and the environment. He is also a former news intern at *Scientific American.* His work has been published in the *New York Times*, *National Geographic*, *Science*, *Nature*, and more.

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https://www.scientificamerican.com/article/photographer-finds-thousands-of-triassic-dinosaur-prints-on-sheer-mountain

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This mind-bending relativity illusion has never been seen—until now

Physicists have observed the bizarre Terrell-Penrose effect in real life

By Victoria Helm, Thomas Juffmann & Peter Schattschneider edited by Clara Moskowitz

Physicists artificially slowed down time to reveal the bizarre Terrell-Penrose effect, a consequence of special relativity. This image from the experiment shows a sphere seemingly moving at 99.9 percent of the speed of light. It is squeezed to a disk by the Lorentz effect, but to a stationary observer it appears unsqueezed and rotated.
Image isolated from “A Snapshot of Relativistic Motion: Visualizing the Terrell-Penrose Effect,” by Dominik Hornof et al., in *Communications Physics,* Vol. 161; May 1, 2025 (CC BY 4.0)

In his classic science-fiction story “The New Accelerator,” published in 1901, H. G. Wells describes a drug that speeds up a person’s metabolism by a factor of 1,000. For the two protagonists who valiantly test the potion, the world appears strangely slowed down, almost frozen in movement. The story got one of us (Schattschneider) thinking: If we could slow down time, could we see single photons fly through space? Could we observe relativistic phenomena? In particular, could we ever glimpse a strange prediction called the Terrell-Penrose effect?

The Terrell-Penrose effect would make objects moving at nearly the speed of light look oddly rotated. The notion seems to go against another prediction of Einstein’s special theory of relativity known as Lorentz contraction, which holds that as things go faster they will shrink. Although the Terrell-Penrose effect had been tested in thought experiments and simulated on computers, it had never been demonstrated in real life.

The prospect of real-world testing lay dormant until recently, when one of Schattschneider’s colleagues, quantum scientist Philipp Haslinger of the Vienna University of Technology, mentioned to him an experiment called the SEEC project, which aims to visualize the way light moves across surfaces. He shared a video in which a laser pulse seems to move at a speed of meters per second, only about one billionth of the speed of light. There it was again: the idea of slowing down time—Wells's New Accelerator, this time in the form of not a magic potion but ultrafast photography.

But the scenes in the project were stills; the object didn't move. What if we accelerated the subject being photographed to a speed close to that of the laser? Would we then see Lorentz contraction? Or would we instead see the even stranger Terrell-Penrose effect? Almost immediately we hatched a plan for an experiment. When two of us (Schattschneider and Juffmann) met up in Juffmann's laboratory, we found that we were both inspired by the Wells story.

Schattschneider teamed with the SEEC project (Haslinger, Juffmann and artist Enar de Dios Rodríguez) and with master's students Helm and Dominik Hornof to demonstrate the Terrell-Penrose effect in a lab for the first time.

If we could pull it off, we would see an element of relativistic physics that had never been observed. We'd also show that relativity is still offering surprises more than a century after the theory was first introduced.

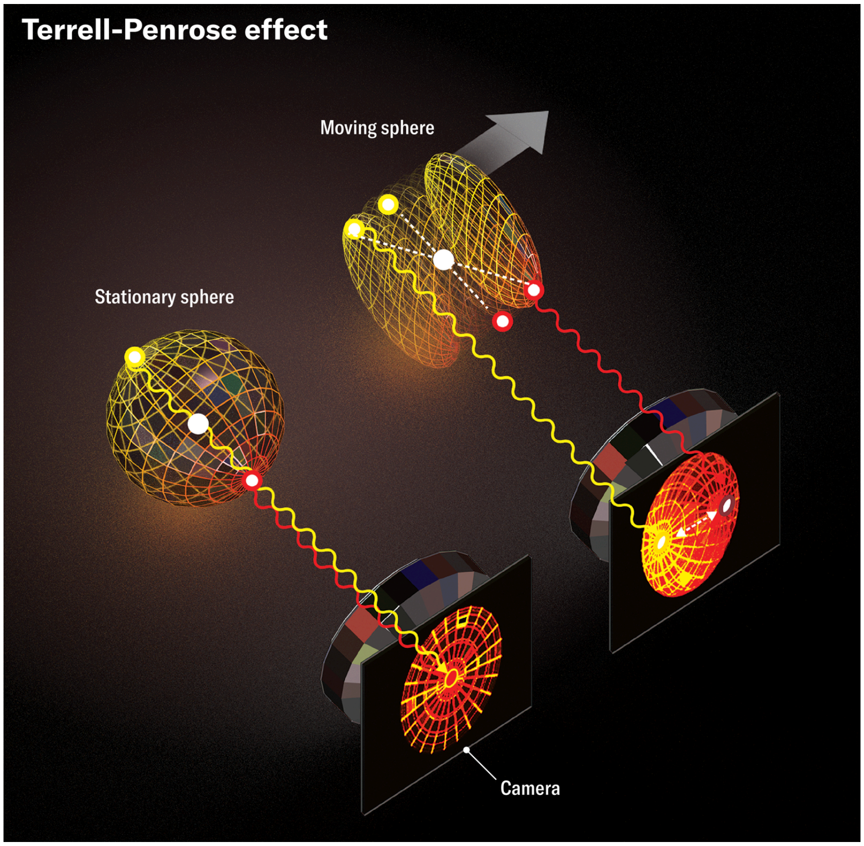
To understand what exactly the Terrell-Penrose effect is, we first need to consider the Lorentz contraction, one of the more puzzling predictions of special relativity. According to this principle, the length of an object moving at speed v shrinks along the direction of motion when measured by a stationary observer. The compression factor is $\sqrt{1 - v^2/c^2}$, where c is the speed of light.

Could a distant observer detect the compression? Austrian physicist Anton Lampa, inspired by Albert Einstein's concept of using calibrated rods to measure distance, discussed this question in 1924. He found that the different travel time of light from one or another end of the rod to the observer obscured the effect. For Lampa, the visual appearance of the Lorentz contraction was sort of an unwanted side effect to be eliminated. This was probably why his groundbreaking work did not receive the attention it deserved.

Dutch theoretical physicist Hendrik Lorentz, working in the 1920s and 1930s, believed the contraction (which would later be named after him) would be visible. This assumption was not widely questioned until three decades later, when English mathematician Roger Penrose and American physicist James Terrell, working independently, both arrived at a surprising conclusion: The Lorentz contraction is not visible. An object moving at nearly the speed of light wouldn't appear shortened. Instead it would look rotated. This intriguing result, published in 1959, came to be known as the Terrell-Penrose effect.

The optical illusion occurs because the light an observer sees from an object did not all get reflected off that object simultaneously. Light from the far side had to start its journey a bit earlier than light from the near side. For slowly moving objects, this difference has no effect. But imagine the object is moving incredibly fast.

In the small amount of time it takes light to travel just one meter, the object will have already moved noticeably. The light that reaches your eyes simultaneously from different points originated at different moments in the object's journey—creating the illusion of rotation and elongation. In the end, however, we don't see the elongation: interestingly enough, it is exactly compensated by the Lorentz contraction, yielding a purely rotated image of the object.



Violet Frances

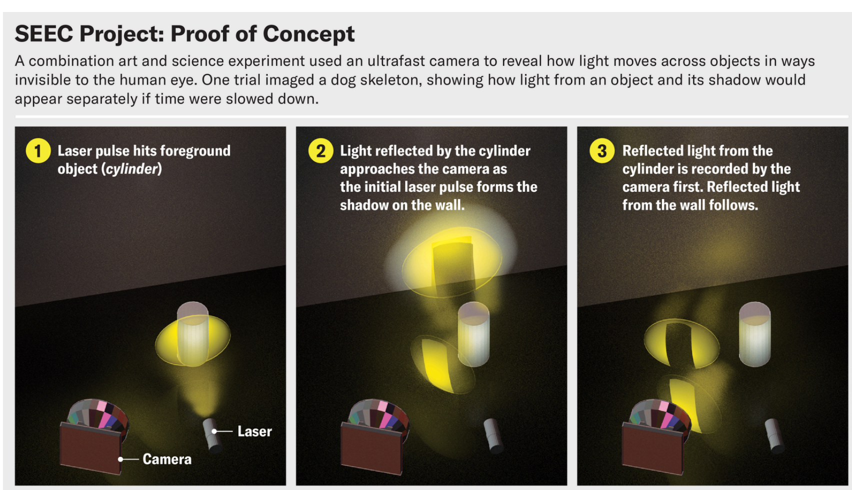
This striking effect had never been observed because the speeds required are astonishingly high, far beyond what we can achieve with macroscopic objects in a lab. As a result, the Terrell-Penrose effect had long remained a theoretical prediction. But with the technology of the SEEC project, we’ve escaped these limitations. By using ultrafast lasers, high-speed cameras and precision-timing systems, we mimicked relativistic speeds and made the Terrell-Penrose effect visible for the first time. Our results were published in *Communications Physics* in May 2025.

Our experimental setup relies on a few essential modern technologies. The first is a pulsed laser that emits bursts of light just one picosecond long—that’s 0.001 billionth of a second. Each pulse travels outward like a thin, spherical shell of light. This light scatters off the object we want to image, and the reflected light is collected by the lens of an ultrafast camera.

That camera is the second crucial piece of technology. One of the first attempts to capture motion at high speed was made by English photographer Eadweard Muybridge in 1878. Using a series of fast exposures, he proved that at some point in a gallop, all four of a horse’s hooves leave the ground. His cameras reached shutter speeds of about a millisecond—incredibly fast for the era. Today we’ve achieved exposure times orders of magnitude shorter—down to picoseconds or even femtoseconds. The camera we used has an exposure time of only 0.3 billionth of a second (that’s 300 picoseconds).

It relies on what’s called a gated image amplifier. In this device, an incoming photon hits a photocathode, where it is converted to an electron via the photoelectric effect. If the gating is on, the electron is accelerated toward a microchannel, where many consecutive collisions with the channel walls create a cloud of secondary electrons. These then hit a phosphor screen, which converts them back to photons that are detected by the CCD camera. The overall effect amplifies the light of each original incoming photon into multiple photons at the end point.

These tools are used by the art and science project SEEC Photography. The project visualizes how light moves across objects —a process so fast it is invisible to the human eye.



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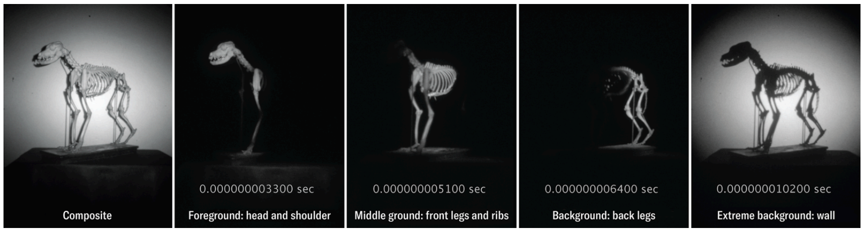


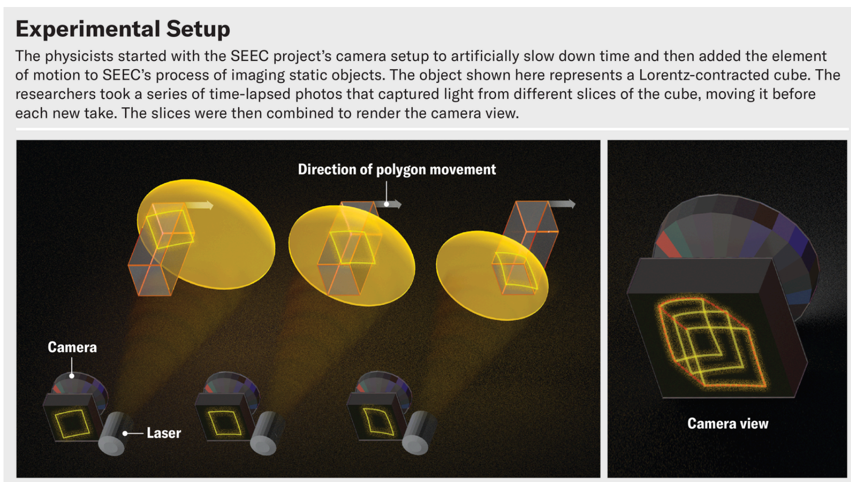
SEEC Photography

Human eyes work by creating images on our retinas when light scattered from objects reaches them. When an object is illuminated, regions of it that are farther from us will be imaged later than those that are closer. This time difference is tiny—for a spatial separation of one meter, it amounts to three billionths of a second (0.000000003 second). That delay is imperceptible to humans. But when we use a camera with an exposure time of less than one billionth of a second, we can see the effect.

To record this phenomenon, the SEEC project imaged several scenes, including one of a dog skeleton. The camera captured a series of frames, each one taken at a slightly different time with respect to an incoming laser pulse. In effect, each photograph captured a different "slice" of the skeleton—the area momentarily illuminated by the shell of light. This process enabled the project team to reconstruct light's movement across the surface as if time were slowed down. One bizarre implication is that the image of the object and its shadow will no longer coexist simultaneously.

To visualize the Terrell-Penrose effect, we just needed to apply this trick to a moving object. We carried out our test at Juffmann's lab at the University of Vienna. First we arranged the laser, the camera, and the stage where the object would move. We installed SEEC's intensified camera, which the team had bought on eBay several years ago. To our delight, the device worked flawlessly—although it took some work for the one of us overseeing the setup (Helm) to get used to the control software and an operating system older than she is. We then had to cope with limited lab space: to achieve the path we wanted, we had to steer the pulsed laser out of our lab, across a hallway and into a lecture hall on the other side of it. This setup restricted our time slots to the weekends.

Once we had established the pulsed laser illumination, we placed two objects, a sphere and a cube, on a movable cart at the front of the lecture hall. Hornof built the objects from materials bought at a hardware store. To mimic the Lorentz contraction that would be happening if they were truly moving at relativistic speeds, he intentionally compressed them along the axis of movement. (Without this step we would have seen elongation in addition to the rotation the Terrell-Penrose effect should produce.)



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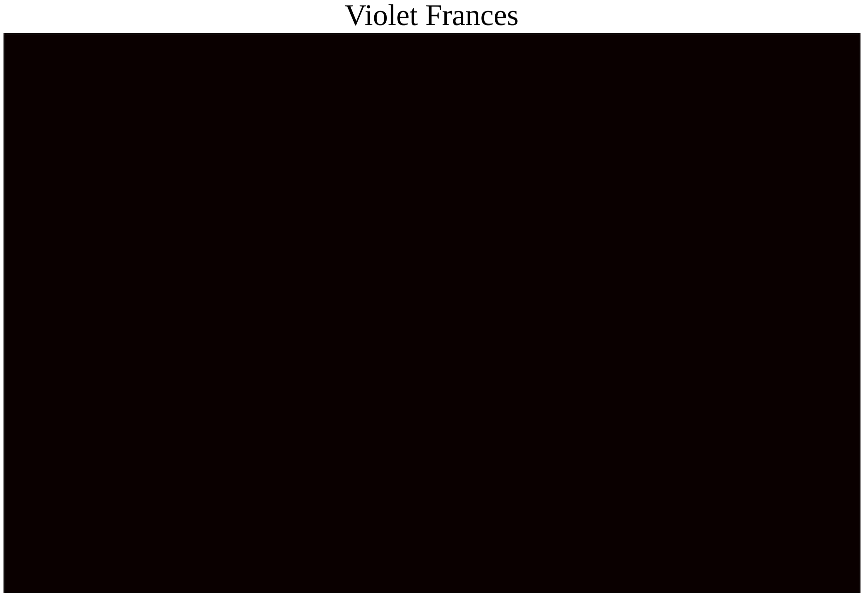

This image from the experiment shows Terrell-Penrose's rotating effect on a Lorentz-contracted cube that appeared, through clever camera tricks, to be moving at 80 percent of the speed of light. From "A Snapshot of Relativistic Motion: Visualizing the Terrell-Penrose Effect," by Dominik Hornof et al., in *Communications Physics*, Vol. 161; May 1, 2025 (CC BY 4.0)

We began by taking a sequence of 32 ultrafast photographs of both objects while they were stationary. For each photograph, we changed the timing between the laser pulse and the camera’s shutter so that each image captured light from a different “slice” of the object. This created a time-lapse series of light traveling across the object’s surface, exactly as the SEEC project did. We changed the timing by 400 picoseconds in between illuminating each next slice, corresponding to a distance of six centimeters between slices.

When imaging the contracted sphere, we moved it six centimeters between each recording. Effectively, the sphere appeared to travel at a speed of six centimeters per 200 picoseconds, which is 99.9 percent of the speed of light. We repeated this process 32 times and combined the recordings into one snapshot of the object. The result? The sphere, which we had flattened into a circle, appeared rotated and spherical in the snapshot, just as Terrell-Penrose predicts.

The outcome with the cube was similar. In this case, we moved the object five centimeters between each recording, mimicking a speed of 5 cm/200 ps—roughly 80 percent of the speed of light. Again, our resulting snapshot showed the cube rotated, in excellent agreement with the prediction from Terrell-Penrose. We found it interesting that the cube’s vertical edges also appeared curved as hyperbolae—a prediction made back in 1970 by Ramesh Bhandari.

Our result shows that we can study certain relativistic effects in a lab by artificially reducing the speed of light. The Terrell-Penrose effect is confirmed: “Lorentz-contracted” objects appear rotated, not contracted.

Our technique opens the door to testing other relativistic effects. Could we use similar tricks to see time dilation or the strange relativistic displacement of starlight called stellar aberration? Might we be able to enact Einstein’s thought experiment about lightning strikes seen from a moving train, which shattered the idea of absolute time and simultaneity?

Ultimately we transferred Wells's dream of slowing down time into real life. Our experiment revealed an aspect of physics never seen before, thanks to a serendipitous combination of art, science and science fiction.

Victoria Helm is a physicist working on quantum optics at the University of Vienna.

Thomas Juffmann is a physicist at the University of Vienna, where he runs a laboratory focused on light and electron microscopy.

Peter Schattschneider is a physicist and science-fiction writer at the Vienna University of Technology.

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https://www.scientificamerican.com/article/strange-special-relativity-effect-observed-for-the-first-time

The true worth of America’s public lands

An environmental scientist’s analysis reveals who will win and who will lose in the push to put federal land into private hands

By Kyle Manley edited by Kate Wong

Two thirds of Arizona's Tonto National Forest--some two million acres--would have been made eligible for sale under a now defunct provision in the Trump administration's One Big Beautiful Bill. Witold Skrypczak/Alamy

Every year more than 12 million people visit the White River National Forest in central Colorado to ski, hike, bike, fish, camp and otherwise enjoy this iconic 2.3-million-acre landscape. As part of the public lands system, the forest is collectively owned by the American people and managed by the federal government on our behalf. Recently Senate Republicans tried to make half of it eligible for sale.

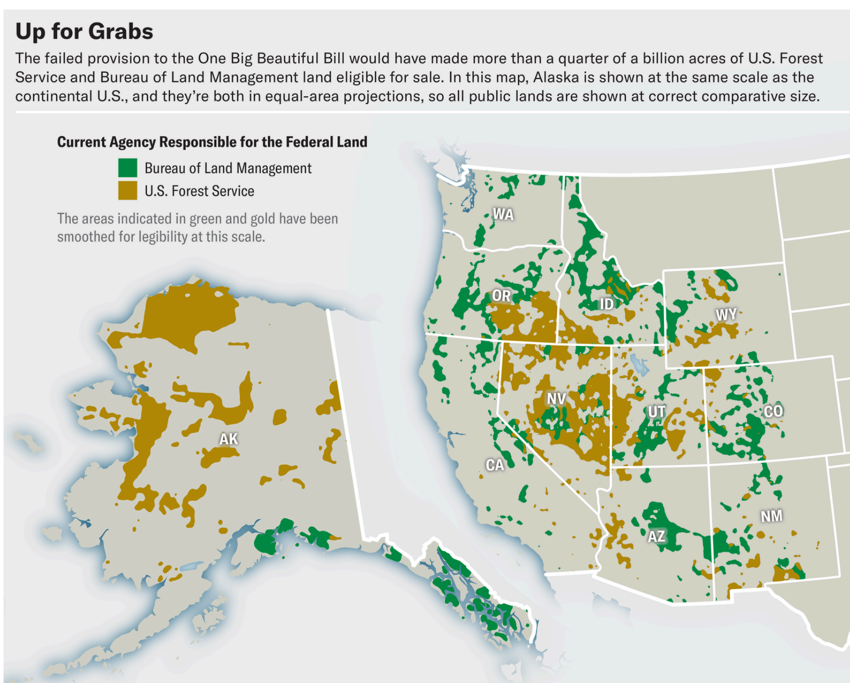
The move came last June, when Senator Mike Lee of Utah proposed adding a provision into President Donald Trump’s “One Big Beautiful Bill” to auction off millions of acres of public lands across the Western states. Nominally intended to provide housing and fiscal debt relief to Americans, it was the largest proposed sell-off of federal lands to date. Ultimately the provision was stripped prior to the bill’s passage into law. But this won’t be the last attempt to dismantle public lands and hand them over to private companies. In September 2025 the Center for American Progress published an analysis showing that the Trump administration had already begun taking actions that could collectively eliminate or weaken protections from more than 175 million acres of U.S. lands. With such mass-scale privatization measures ramping up, it’s worth examining what these places actually provide to people versus corporations.

As an environmental scientist who studies the complex interplay between humans and nature, I decided to analyze the costs and benefits of public land sell-offs, focusing on this failed provision as an example. I used established methods of data analysis in my field to assess publicly available datasets previously published in peer-reviewed journals and synthesize these data to illuminate the broader implications of recent policy proposals and political movements. The findings make clear that these lands are ill-suited to development for affordable housing. What is more, putting these lands in private hands means losing the host of crucial ecological benefits—from sustaining the pollinators that underpin our food supply to purifying the air we breathe—that intact ecosystems provide at no direct cost or effort to us.

Conflicts over public lands in the U.S. have deep roots. In the 1970s ranchers, extractive-industry groups, county officials and allied Western politicians, later endorsed by President Ronald Reagan, staged the so-called Sagebrush Rebellion to wrest control of hundreds of millions of acres from the federal government. In 2016 the GOP platform openly called for transferring federal lands to states and facilitating the extraction of timber, minerals, coal, oil, and other natural resources from these lands.

The Heritage Foundation’s Project 2025 blueprint goes further in the effort to control public lands and exploit their natural resources.

It lays out a plan to roll back the Kunming-Montreal Global Biodiversity Framework's so-called 30 × 30 initiative to protect and manage 30 percent of the world's land, fresh waters and oceans by 2030 (Trump has already rescinded the U.S.'s 30 X 30 commitments by executive order). It calls for gutting the Land and Water Conservation Fund, a federal program that has funded the acquisition of land and interest in land to safeguard natural areas, water resources and cultural heritage and to provide recreation opportunities since 1965. Project 2025 also aims to weaken the Antiquities Act of 1906, which allows presidents to protect federal lands of scientific, historic or cultural significance by designating them as national monuments. To that end, the Department of Justice recently ruled the president has the authority to revoke national monuments, and the Department of the Interior has begun broad reviews of monuments with an eye toward development of extractive industry.



Daniel P. Huffman; Source: Data retrieved in December 2025 from Outdoor Alliance; Senate Reconciliation—National Public Lands Available for Sale

The now defunct public lands sell-off provision in the Trump administration's bill, also known as the budget reconciliation bill, would have made more than a quarter of a billion acres of U.S. Forest Service and Bureau of Land Management (BLM) land in 11

Western states eligible for sale and required selling off two million to three million of those acres within five years. The provision mandated that any land sold be developed for housing and related infrastructure, a restriction that would expire after 10 years.

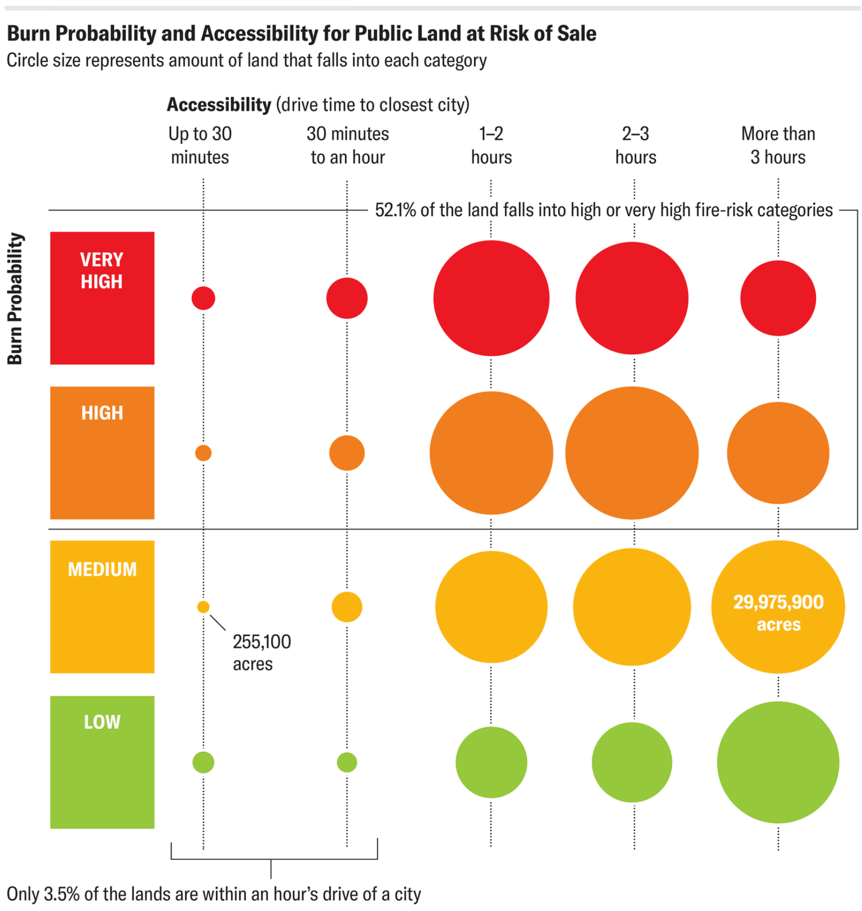
Proponents framed the sale as a solution to America's housing-affordability crisis, although the provision contained no affordability requirements, nor did it stipulate who could buy the land. Could sales of federal lands actually solve the problem of affordable housing? And what are the ecological trade-offs of converting millions of acres of public land to development? There's a lot to unpack about sell-offs. Let's look at the data.

To test the claim that the Trump proposal would address the housing crisis, I evaluated whether these lands are even suitable for development in the first place, focusing on accessibility and wildfire risk. I looked specifically at the area of overlap between accessibility and burn probability, using previously published datasets on accessibility, which calculate travel time based on proximity to urban centers and infrastructure, and on fire risk within the lands eligible for sale.

I expected these landscapes to be remote and wildfire-prone, but the degree of inaccessibility and wildfire risk is staggering. Even if a developer were able to get an insurer to underwrite such a project, these homes would remain out of reach for the working-class families most in need of affordable housing because most public lands are not located anywhere near the infrastructure one needs to build homes affordably or the job centers where most Americans work.

Just 3.5 percent of these lands are within an hour's drive of a city. Only 0.7 percent are within a 30-minute drive; 30.5 percent lie one to three hours away; 33.4 percent are three to six hours distant; and 32.6 percent sit more than six hours from urban centers. As for fire risk, 18 percent of the targeted acres lie in low-burn-probability zones, almost all in Alaska. More than 52 percent fall into high or very high fire-risk categories.

A decent chunk of this land does sit in low-burn-probability zones—could it be a viable option for housing? No. Only 0.3 percent of the acreage proposed for sale combines low fire risk with a commute under 30 minutes, and 81 percent of that tiny fraction lies in Alaska, which has no shortage of land for development. Of the 18 percent of targeted acres classified as low risk, 55 percent are more than six hours from the nearest city; 24 percent sit three to six hours out; 19 percent lie one to three hours away.



Kyle Manley and Jen Christiansen

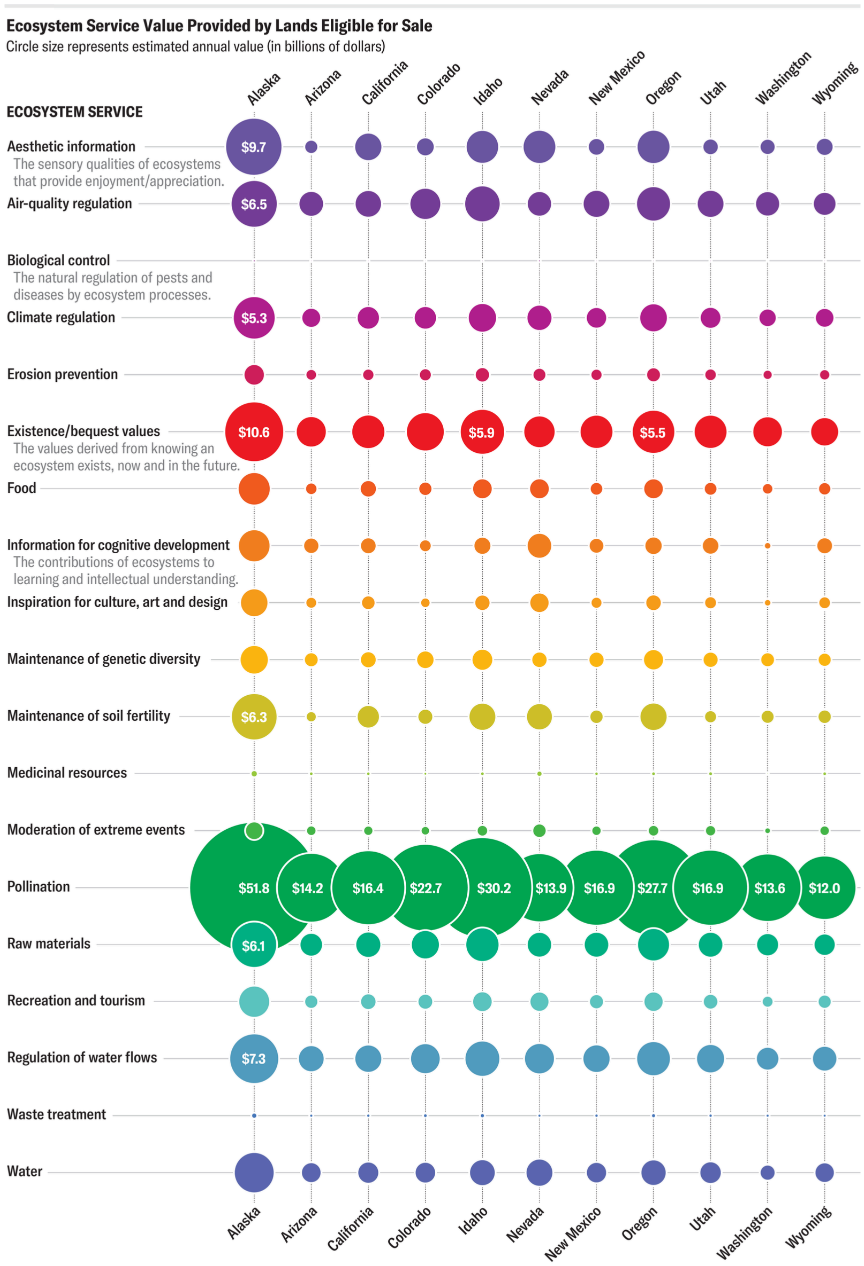
Next I set out to calculate the ecological cost of privatization. To do that, we need to understand what ecosystems exist within the public lands that were eligible for sale and look at the benefits they provide to people, also known as ecosystem services. A land-cover analysis using the National Land Cover Database reveals that approximately 137 million acres, or 53.8 percent, are shrubland/scrubland; roughly 65 million acres, or 25.3 percent, are evergreen forest; and about 27 million acres, or 10.5 percent, are grassland and herbaceous communities. These three ecosystems account for nearly 90 percent of the lands eligible for sale.

Drawing from ecosystem service values calculated from more than 1,500 valuation studies of biomes from around the world, I estimated the annual worth of services delivered by forest, shrub/scrub, and grass/herbaceous areas slated for sale and development. Altogether the ecosystems on these lands generate roughly $507.4 billion in benefits to the public every year.

Pollination alone accounts for $236.2 billion of that total. This service undergirds our agriculture and wild ecosystems. About 35 percent of global crop production, and 87 of the 115 major crops, depends on pollinators. Nearly 90 percent of wild flowering plants rely on them, too. Public lands in the Western U.S., home to immense pollinator diversity, deliver enormous value on this front.

Pollination is relatively simple to conceptualize as a benefit because it provides us with food, which is traded on our markets. But ecosystems provide much more than market values. One example is existence and bequest value, which is the value people derive from simply knowing that an ecosystem exists, now and for future generations. The public lands that were slated for sale generate $46.5 billion in this category.

Part of the existence/bequest value is related to another service: the maintenance of genetic diversity. Put simply, ecosystems support biodiversity. An analysis of species-richness data from the International Union for Conservation of Nature shows that lands eligible for sale in the Big Beautiful Bill provision support on average 261 species of amphibians, birds, mammals and reptiles per 7,500 acres, with approximately five of those species being threatened. In maintaining this diversity, these lands deliver $9.7 billion a year in value.



Kyle Manley and Jen Christiansen

The regulation of water flows is another vital, though invisible, service that ecosystems on public lands perform, providing more than $31.4 billion in this analysis. By storing precipitation and snowmelt, moderating floods, maintaining base flows, recharging aquifers and regulating water quality, these ecosystems sustain life downstream. A rough analysis of the National Watershed Boundary dataset, particularly the population dependent on watersheds (not including Alaska because of data constraints), shows that more than 21,000 watersheds intersect these lands, with an average of 6,000 people depending on each one. Dependence peaks in Arizona (which has 16,400 dependents per watershed), California (15,600 dependents per watershed) and Nevada (4,500 dependents per watershed). This high dependence is unsurprising considering that much of the Western U.S. water supply originates in high-elevation, snowmelt-dominated headwaters, particularly in the Rocky Mountains.

Our ecosystems also filter pollutants, such as particulate matter, carbon monoxide and ozone, out of our atmosphere and provide clean air to billions of people globally. This service is particularly important in view of estimates that air pollutants caused by fossil-fuel combustion alone are responsible for more than eight million premature deaths every year. The lands that were proposed for sale contribute air-quality regulation valued at $29.5 billion annually.

Additionally, these places give the public opportunities for recreation and tourism, which is estimated to generate more than $11.6 billion a year within the lands suggested for sale and an extra $25.7 billion if you add the aesthetic value they offer. They include ecosystems within some of the most popular and iconic national forests and BLM lands, such as Nine Mile Canyon, Behind the Rocks Wilderness Study Area, White River National Forest, Deschutes National Forest, Tahoe National Forest and Angeles National Forest.

Nearly 83 percent of Alaska's Chugach National Forest, including Ptarmigan Lake, would have been eligible for sale under the provision.
Ronny Karpel/Alamy

Analysis of the national digital trails and recreation information databases shows that these landscapes alone contain nearly 56,500 miles of trails, almost 2,000 recreational facilities and more than 300 designated recreational areas. Together they provide 10,000 recreational opportunities made up of 93 activities, including hiking, camping, fishing and hunting. These spaces for sport and relaxation and enrichment and creativity are cherished by the American public and international visitors, contributing as they do to our health and well-being and sustaining the many rural recreation-dependent communities across the Western U.S.

A straightforward, data-driven look at this proposed sell-off reveals its real intent—and its casualties. The administration wants to sell out our lands to corporations for profits. Proceeds from the proposed sale of these lands would have paid for tax cuts benefiting mainly the ultrawealthy. For the average person, it would've been a terrible deal. These hundreds of millions of acres of public land are neither accessible nor safe enough to solve our affordable-housing crisis: most parcels lie hours from any urban center, and their wildfire risk is enormous. If development somehow ever happens on these lands, it won't house working-class families but will line the pockets of corporations and speculators, effectively imposing a regressive tax on the rest of us. What stands to vanish isn't "barren wasteland," as advocates for selling public land often describe it, but vibrant ecosystems buzzing with diversity that deliver hundreds of billions of dollars' worth of vital services to the public every year. Far from solving the housing squeeze, this plan would deepen inequality and erode the very ecological systems that sustain us.

Value is an ambiguous term. For the corporate and political class backing this sell-off, it boils down to whatever raises next quarter's gross domestic product. But for the rest of us, it encompasses the clean water, abundant food, ecological stability, cultural heritage, opportunity for future generations and sheer awe these landscapes provide.

Discussions

We're looking to host the most interesting science conversations on the web for this topic.

Kyle Manley is a postdoctoral researcher at the University of Colorado Boulder's Earth Lab. An environmental scientist, he studies ecosystem services, human-nature relationships, and the impacts of climate change and disturbances on social-ecological systems.

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https://www.scientificamerican.com/article/why-privatizing-public-land-wont-solve-the-housing-crisis

Archaeology

- **Ancient humans were making fire 350,000 years earlier than scientists realized**
  Making fire on demand was a milestone in the lives of our early ancestors. But the question of when that skill first arose has been difficult for scientists to pin down

Ancient humans were making fire 350,000 years earlier than scientists realized

Making fire on demand was a milestone in the lives of our early ancestors. But the question of when that skill first arose has been difficult for scientists to pin down

By Meghan Bartels edited by Andrea Thompson & Sarah Lewin Frasier

Lijuan Guo Photography/Getty Images

Set aside your matches or lighter and try to start a fire; chances are you'll be left cold. But as early as 400,000 years ago ancient hominins might have had the skills to conjure flame, according to groundbreaking new evidence of fire making that is 350,000 years older than scientists' previous earliest example.

Investigators looking to understand our ancestors have long been interested in the technology they possessed surrounding fire. Researchers have argued that as ancient hominins developed the ability to control fire, they would have changed physically—developing a smaller stomach and a more powerful brain thanks to cooked food, which is easier to metabolize than raw—as well as socially, with individuals being able to build more complex relationships around a hearth.

But traces of fire use are difficult to come by, leaving archaeologists frustrated in their attempts to date these developments. “Things like ash and charcoal, they’re very light, so they move very easily,” says Sarah Hlubik, a paleoarchaeologist at St. Mary’s College of Maryland. “A lot of the evidence kind of disappears.” Hlubik was not involved in the new research, which was published in *Nature*.

In addition, it’s challenging to distinguish whether ancient hominins were making fire themselves or capturing flames from natural lightning strikes and tending to them. Overall, scientists believe some human ancestors in Africa might have been using fire as early as 1.5 million years ago, but they have fiercely debated whether hominins could have been making their own fire so far in the past. Before this new discovery, the earliest evidence of hominins making fire was much more recent—from only 50,000 years ago.

“Before seeing this, I would have said, no, people didn’t make fire at this time period,” says Amy Clark, an archaeologist at Harvard University, who was also not involved in the newly published research.

The new evidence comes from an English site called Barnham, which scientists have been excavating for decades. Researchers noticed a patch of soil that appeared unusually red, a characteristic known to occur when dirt is repeatedly heated. Tests confirmed that the reddened material developed in place through repeated heating to temperatures roughly in the range of 752 to 1,382 degrees Fahrenheit (400 to 750 degrees Celsius), independent of any regional fire activity.

Shown here is one of two nodules of iron pyrite found at Barnham, a 400,000-year-old archaeological site in England. The nodules are part of new evidence that hominins produced fire earlier than expected.
Jordan Mansfield/Pathways to Ancient Britain Project

Continued excavations turned up four stone hand axes that had been shattered by fire. Most convincing of all, the researchers uncovered two tiny fragments of iron pyrite. This mineral—not naturally found within nearly 10 miles of the Barnham site—can create sparks when it's struck by flint.

This finding is not perfect: in an ideal world, the researchers also would have found the scars left behind on flint and pyrite from the fire-sparking process. But it's unprecedented evidence of early fire making.

"To me, the modern-day equivalent would be if the police found a burned-out car in a remote bit of woodland with an empty petrol can, and they drew the conclusion that one circumstance was related to the other," says study co-author Nick Ashton, an archaeologist at the British Museum.

Even researchers who are not affiliated with the work agree that the team has made a compelling discovery. "The evidence for fire is really quite solid," says Gilliane Monnier, an archaeologist at the University of Minnesota. "It's a very rare find."

No hominin remains have been found at the site, leading to some uncertainty about who precisely would have been conjuring flames. Scientists speculate that both Neandertals and *Homo heidelbergensis*, a different early hominin species, are likely candidates. Either way, researchers say, these ancient humans were skilled foragers and hunter-gatherers who lived in small groups of perhaps a dozen people and only rarely crossed paths with other bands.

The hominins' isolated lifestyle may also make it risky for scientists to extrapolate evidence from a single site to the population at large, says Dennis Sandgathe, an archaeologist at Simon Fraser University in British Columbia, who was not involved in the new research. He says he's convinced that the Barnham finds do represent early fire making but argues that such technology would have been discovered and forgotten—probably more often the latter—many times in many places over hundreds of millennia.

After all, Sandgathe says, archaeologists have explored dozens of sites from this part of the Paleolithic, representing hundreds of ancient human groups over time. At no site besides Barnham has anyone ever found iron pyrite, the "smoking gun" of the new research. If this technology were widespread, he says, someone would have noticed before now.

"We'd all love to find a piece of pyrite," Sandgathe says. "We'd pounce on it if it showed up."

Meghan Bartels is a science journalist based in New York City. She joined *Scientific American* in 2023 and is now a senior reporter there. Previously, she spent more than four years as a writer and editor at Space.com, as well as nearly a year as a science reporter at *Newsweek*, where she focused on space and Earth science. Her writing has also appeared in *Audubon*, *Nautilus*, *Astronomy* and *Smithsonian*, among other publications. She attended Georgetown University and earned a master's degree in journalism at New York University's Science, Health and Environmental Reporting Program.

https://www.scientificamerican.com/article/ancient-humans-were-making-fire-350-000-years-earlier-than-scientists

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Artificial Intelligence

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The AI scribe that lets doctors stop typing and start listening

When a patient shared the story of her sister's death, an AI captured the clinical details—freeing physician Christopher Sharp to just be present

By Deni Ellis Béchard edited by Eric Sullivan


Anje Jager

Your doctor sits across from you, fully present, listening—not typing or glancing at a screen. Yet every important detail you share makes it into your medical record. This is the vision of Christopher Sharp, a physician at Stanford Health Care and chief medical information officer at Stanford University Medical Center. For Sharp, technology shouldn't create barriers between doctors and patients; it should free clinicians from tiring administrative tasks so they can provide better care. At Stanford, he was an early adopter of artificial intelligence tools to transcribe and analyze medical histories.

Sharp arrived at Stanford University School of Medicine as a resident in internal medicine in the late 1990s. A graduate of Dartmouth College's Geisel School of Medicine, he continues to see patients as a primary care doctor at Stanford Health Care—and it is this work that most clearly teaches him the benefits and risks of technology.

Scientific American spoke to Sharp about how AI is changing medicine and how to use it to support patients and doctors.

[*An edited transcript of the interview follows.*]

Why did you decide to begin working with AI at Stanford?

AI provides an important window to access data locked up in narratives somewhere in the record that would be very hard to identify or find. It also provides the opportunity to utilize data in new ways that does not require as much effort by our clinicians.

Our clinicians spend a lot of time digging through electronic data, summarizing it and making decisions. Documentation is very important—it's how we convey clinical information forward, mitigate risk, and meet legal, compliance and billing requirements. But all of that creates added burden and is not the primary value of providing direct care. AI tools that help with those administrative functions are a really big win for our clinical providers.

How does it help with summarizing patient records?

We use a tool that summarizes the key activities described in clinician notes. It helps us say, "The medicine doctor has been treating them for diagnosis A and B, the urologist has seen them for diagnosis C, the neurologist seeing them for diagnosis E"—without our having to go into each area of the chart manually. What makes this powerful is that it has citations, which allow the doctor to do validation and deeper exploration.

The other exciting tool is something we call ChatEHR ("EHR" stands for electronic health record). Different clinicians have different questions at any given moment, so we've started experimenting with an open platform where users can use a chat interface to engage with patient data. It offers flexibility to ask about a certain aspect of care and then continues chatting to go deeper.

Can you give an example of how ChatEHR has been useful?

We needed to screen multiple charts to find patients eligible for a particular care pathway. Previously, many people had to read through charts manually. We used ChatEHR to experiment, and once optimized, built it into an automation. With a single click, multiple charts could be reviewed and presented back to one screener. For instance, some patients might be eligible to go to a lower acuity unit rather than to the general hospital where they're mixed with higher-acuity patients. If we can identify those patients, we can help them go to the most appropriate location of care. What might take hours now takes minutes.

You also use ambient AI scribe software that listens to appointments. How has that been received?

This has been one of our biggest successes. We rolled it out more than a year ago with very rapid adoption. The AI scribe is easily adoptable—clinicians use their phone to listen to the conversation, create a transcript and generate a medical summary within a minute of completing the interaction.

It's medically focused. If you and your patient have a long chat about their golf game before discussing their clinical problem, that won't be transcribed into the summarization. Only the clinically important points appear.

Has this reduced doctor burnout?

Absolutely. Our clinicians felt this approach was much better in terms of their cognitive load and their overall wellness in the workplace. The cognitive work of summarizing such a conversation is significant. I should note we thought we'd see tremendous efficiency—that doctors might go home sooner or see more patients because they'd spend less time documenting. What we found was that clinicians spent a fair amount of time reviewing, editing and approving the documentation, so they weren't taking much less time. It wasn't efficiency they gained as much as reduced cognitive burden.

You also use AI to draft responses to patient messages. How is that working?

We saw a 200 percent increase in patient messaging during COVID, and it hasn't gone down. That created a challenge for clinicians to absorb all that engagement. We were one of the first in the nation to use AI-generated draft responses as starting points. This requires clinicians to evaluate for accuracy and voice—patients like hearing back from their clinician in their own voice. Again, this is not an immense time-saver, but it reduces the burden of coming up with language that is both accurate and empathetic. It creates the opportunity for clinicians to spend more time honing language rather than developing it from scratch. The AI also looks back at information in the patient's chart for context. I've been struck that sometimes it reminds me of something I might not have remembered myself.

Where do you see this technology going next?

The evolution is amazingly quick. The AI scribe had many more errors when we started than it does today. We're also seeing additions. We're experimenting with suggested orders. If I say, "I want to make sure you get a chest x-ray to rule out pneumonia," the listening tool can tee up that order for review and approval.

The next significant change will be when these technologies become more directly available to patients. Instead of navigating our portal, patients may be able to just ask a question and have AI navigate to the right interaction.

With doctors' cognitive burden decreasing, do you think we'll eventually see differences in patient outcomes?

This is the holy grail—tools so beneficial that we'd see changes in care. We've not studied this enough to know yet. But there are fascinating studies showing that time of day affects care—patients who are seen early are more likely to have preventive care reminders discussed than [those who are seen] late in the day, when doctors are tired. My hope is that these tools will even out those unwanted variations.

Is there a specific moment that convinced you this was the right path?

I vividly recall sitting with a patient who told me about how her sister had died. It was important not to be typing and just to be really looking at her and supporting her. During that conversation, she shared important details about her family's health history. I never reached over to my keyboard to document those clinical details, but they were captured by the AI.

I was struck when I read the summarization—it simply said the patient's sister had died and noted her health condition, even though I'd had a very emotional connection with my patient during that moment. That was an example where the machine did what the machine does really well, and I did what a human does well.

A version of this article appeared in the March 2026 issue of Scientific American *as "Christopher Sharp."*

Deni Ellis Béchard is *Scientific American*'s senior writer for technology. He is author of 10 books and has received a Commonwealth Writers' Prize, a Midwest Book Award and a Nautilus Book Award for investigative journalism. He holds two master's degrees in literature, as well as a master's

degree in biology from Harvard University. His most recent novel, *We Are Dreams in the Eternal Machine*, explores the ways that artificial intelligence could transform humanity. You can follow him on X, Instagram and Bluesky @denibechard

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https://www.scientificamerican.com/article/how-stanford-doctors-use-ai-scribes-to-cut-paperwork-and-focus-on-patients

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She asked a robot about race. The answer scared her

Transdisciplinary artist Stephanie Dinkins challenges us to rethink what we feed our machines—and asks what AI might become if it were trained on care

By Deni Ellis Béchard edited by Eric Sullivan


Anje Jager

Twelve years ago Stephanie Dinkins traveled to Vermont to meet a robot. Bina48, a humanoid bust with dark skin, was designed to hold conversations about memory, identity and consciousness. Dinkins, a photographer by training, wanted to understand how a Black woman had become the model for one of the world's most advanced social robots—and whether she could befriend it.

What she found during that encounter launched a decade of work that has made Dinkins one of the most influential artists exploring artificial intelligence.

Dinkins grew up in Tottenville's enclave of Black families at the southern tip of Staten Island. Her grandmother tended a flower garden with such care that even reluctant neighbors came to admire it and then stayed to talk. Dinkins has described this as her first lesson in art as social practice—using beauty to build community.

Today she asks a simple but revolutionary question: What might our machines become if they were trained on that same level of care and human experience? She challenges the ways that AI is often used, showing that data can be intimate, culturally rooted and deeply alive. Through public-facing art installations at places such as the Smithsonian Arts + Industries Building in Washington, D.C., and the Queens Museum in New York City, she encourages people to reflect on technology, power and responsibility.

Scientific American spoke to Dinkins about the violence hidden in datasets and why communities must gift their stories to AI so that it can understand them on their own terms.

[*An edited transcript of the interview follows.*]

You've described your first meeting with the Bina48 robot as a turning point in your career. What were you expecting to find, and what actually happened?

I thought that if I could befriend the robot, it could let me in on where it thought it fit between humans and technology. But as I spoke to Bina48, it became apparent that some of her answers felt flat alongside her representative self. If I asked her about race, she didn't have the deepest answers or the most nuanced answers as a Black woman figure, and that scared me. If these people who have really good intentions are producing something that is seemingly flat, then what happens when people aren't even concerned with these questions?

How did that realization shape your work?

It shaped everything. Here in New York [City], I lived in a neighborhood that was predominantly Black and brown. I was wondering if we knew what was coming, if people were thinking about what the systems would do in their world. At the time, ProPublica did an article on judges and sentencing in terms of AI and how they would use sentencing software to come up with how long someone would stay in jail. And that was built on biased data, the historical biased data of a historically biased system, the judicial system, which I equate to a “Black tax.” We have to figure out ways to contend with this because you’re automatically getting more time just by being Black, now, because a machine said so.

I made a project called *Not the Only One*, which is based on my family. It started as a memoir— really trying to pass down the knowledge from my grandmother so that two generations even more from her would still have some touchpoints of her ethos. It’s an oral history project where we recorded interviews with three women in my family, and then I was forced to find foundational data to support it. It was hard to find base data that didn’t feel violent or felt loving enough to put my family on top of.

How did you define violence in a dataset, and how did you solve for it?

When I think about violence in data, I think, really, about a linguistic violence or a kind of labeling or stereotyping that happens in our popular media. If we’re thinking about a dataset based on movies, what roles Black people could play in films was limited: servitude, the friend—always the supportive friend but not the protagonist—the relegation to a background character instead of one who is a star in one’s own life. I think not being able to inhabit those roles is a sort of violence. So the challenge became to build a base set of language that I felt actually would buoy my family and not pull it down.

I finally wound up trying to make my own dataset. *Not the Only One* was based on a dataset of 40,000 lines of extra data beyond the oral histories, which is very small, so the piece is very wonky. It sometimes answers correctly, and sometimes it speaks in complete non sequiturs. I prefer that to just sitting my family's history atop historic cruelty.

How did that project shape the next projects that you did?

That made me think about the value of small, community-minded data. We as humans have always told stories to orient ourselves, to tell ourselves what the values are. So what would happen if we gave—and really, I think about gifting—the AI world some of that information so it knows us better from the inside out? I created an app called The Stories We Tell Our Machines to let people do exactly that.

That's my quest at the moment, convincing people that that's a good idea because what we hear out in the world is, "No, they're taking our data. We're being exploited," which we are. But also, we know that if we do not nurture these systems to know us better, they are likely using definitions that did not come from the communities being defined. The quest is truly: What would it look like if the data used mimicked global population?

The next step is to take that data and start to make a dataset that can be widely distributed to help fine-tune or train other systems. I'm starting to talk to computer scientists about how we can do this in a way that does not denature the stories but makes them widely usable.

Can you give an example of how AI could offer opportunities to people who have historically underprivileged?

I'm waiting for an underprivileged kid with not a lot of money to produce some spectacular film using a computer and AI tools that competes with a Hollywood movie. I think that’s possible.

A version of this article appeared in the March 2026 issue of Scientific American *as “Stephanie Dinkins.”*

Deni Ellis Béchard is *Scientific American*’s senior writer for technology. He is author of 10 books and has received a Commonwealth Writers’ Prize, a Midwest Book Award and a Nautilus Book Award for investigative journalism. He holds two master’s degrees in literature, as well as a master’s degree in biology from Harvard University. His most recent novel, *We Are Dreams in the Eternal Machine*, explores the ways that artificial intelligence could transform humanity. You can follow him on X, Instagram and Bluesky @denibechard

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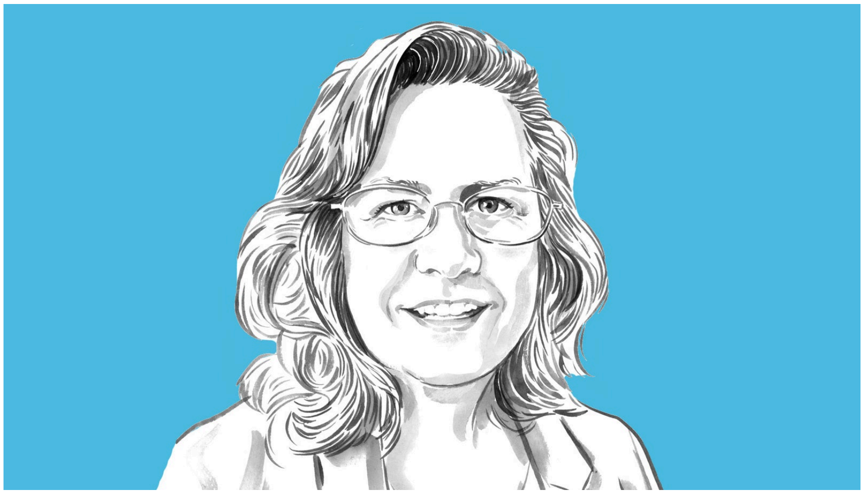
https://www.scientificamerican.com/article/how-artist-stephanie-dinkins-is-trying-to-fix-ai-bias

After teaching for 30 years, Jen Roberts has found an unlikely ally in AI

Veteran teacher Jen Roberts explains why generative tools are more than just a platform for cheating—they're a way to make classrooms fairer and more human

By Deni Ellis Béchard edited by Eric Sullivan



Anje Jager

When ChatGPT launched in 2022, Jen Roberts had been teaching middle or high school students for more than 26 years and was running on fumes. The pandemic had pushed many educators into burnout, but where others saw artificial intelligence as a threat—a technology that facilitated student cheating—Roberts saw a tool to help her survive.

An English teacher at Point Loma High School in San Diego, Roberts is a pioneer of educational technology. She has taught with one-to-one laptops since 2008, years before most schools adopted them. When generative AI emerged, she was quick to test whether it could make feedback faster and grading fairer.

[Live event: Life in the Age of AI. Join *SciAm* for an insightful conversation on the trends and innovations shaping AI in the year ahead. Learn more.]

Scientific American spoke to Roberts about how she guards against the misuse of AI and why she believes the technology can help teachers battle their own biases.

[*An edited transcript of the interview follows*.]

Many teachers see AI primarily as a cheating tool for students. You saw it differently. How did you start using it?

I’ve found it’s very effective for feedback. When a student takes an [Advanced Placement (AP) English Language and Composition] test, [the free-response section of] their test is scored by two people. And if those scores disagree, there’s a third score. I thought: What if AI is the second scorer? If I grade it and have the AI grade it, I see if we agree. If we disagree, the AI and I have a little chat about which one of us is right.

In my time-constrained world, my comment might be brief or terse. What the AI comes up with is usually spot-on. I like to say that AI doesn’t really save me time; it just lets me do more with the time I have. When I’m using AI-suggested scores and feedback, my students get their writing back in days instead of weeks. That means they’re revising more and revising better.

I also use education-specific tools. MagicSchool provides a student-facing option where I can add my rubric and assignment description and then give students a link. I’ve seen students put their work into that four, five, six times in a single period. It’s immediate feedback that I can’t provide to 36 students simultaneously.

How do you guard against students using AI to write for them?

Nothing is a magic bullet. It's a combination of tools and strategies that psychologically convince my students I will know if they use AI inappropriately. I require them to do all writing in a Google doc where I can see version history. I use Chrome extensions to examine the writing—I can watch a video playback of their writing process. I also use the old-school method: you're going to bring your writing to your writing group. Students are cavalier about turning AI writing in to me. But if they have to bring it to a writing group, read it aloud to peers and explain what they wrote and why, they won't do that.

I show them ways to use AI responsibly. You can't use it to write for you, but you can use it for feedback, sentence frames, outlines and organizing thoughts. If I show ethical use cases, they're less likely to use it unethically. I do an activity where I give them three paragraphs and ask which one is AI. They all immediately know. I say, "You could tell, so I can tell."

A lot of the hype around AI in education focuses on customized lesson plans. Is that the reality?

AI lesson plans are generally crap. I don't use AI often for lesson planning. I use it specifically to build materials. There's a Chrome extension called Brisk that lets me take something students are reading, design learning objectives for it and create an interactive tutor to show students how much they understand.

Also, I can take a page that's a wall of text, give it to [Anthropic's AI assistant] Claude and say, "Help me rewrite this. Improve the clarity, use color-coding, emojis." Now I have a page that's beautiful and easy to understand, with colored boxes around important parts. When students understand what they're supposed to do because directions are clear, that's really helpful.

In what ways does AI help with the cognitive burden of teaching?

Lots of ways. I often need to come up with a writing prompt. Am I capable of that? Absolutely. Am I capable at 4:15 P.M. on a Thursday afternoon when I'm really tired? Maybe not. I'll tell the AI what we've been studying and ask for suggestions. It'll spit out five or six options, and we'll pick the one that works.

Another example: I was doing an activity with a long reading that I wanted to break into smaller sections. I didn't want to spend 45 minutes rereading it to create sensible breaks. I gave Claude the PDF, and it took only five minutes for [the AI] to help me reorganize the material. I also asked for 40 vocabulary words students might struggle with, organized in the order they appeared in the article. That is support I would never have had time to provide manually.

What warnings would you give teachers who are starting to use AI?

Do not require or suggest students use ChatGPT or Claude. Those tools are not [compliant with] COPPA [the Children's Online Privacy Protection Act] and FERPA [the Family Educational Rights and Privacy Act]—federal laws covering children's privacy and educational privacy rights. It's better to have students use tools within MagicSchool or Brisk that are compliant and that allow teachers to monitor conversations.

Second, do not provide personally identifying information about students to AI. Instead of giving the whole IEP (Individualized Education Program), take the one goal you're supporting and say, "How could I support a student with this goal?" You get the same help without providing student information.

Can you talk more about AI-assisted grading?

According to a University of Michigan study, a statistically significant chunk of students at the end of the alphabet got lower grades and worse feedback, probably because teachers get tired. I think of AI as my balance check. When I get to the student whose last name starts with Z, and [they had] annoyed me today, am I giving them a fair grade? Often the AI says, “No, you should be giving them a higher grade.” I look at the work again and am like, “It’s right.” If AI can mitigate that [issue], that’s good for my students. I see it as a fairness issue, making sure students get consistent scoring.

Every time I tell teachers about [the University of Michigan] study, heads nod. We shift how we grade over a single grading session—firm at first, loosened up by the 10th essay, tired and grouchy at the end. We’re human. For all the concerns about AI bias, I have more concerns about human bias.

A version of this article appeared in the March 2026 issue of Scientific American *as “Jen Roberts.”*

Deni Ellis Béchard is *Scientific American*’s senior writer for technology. He is author of 10 books and has received a Commonwealth Writers’ Prize, a Midwest Book Award and a Nautilus Book Award for investigative journalism. He holds two master’s degrees in literature, as well as a master’s degree in biology from Harvard University. His most recent novel, *We Are Dreams in the Eternal Machine*, explores the ways that artificial intelligence could transform humanity. You can follow him on X, Instagram and Bluesky @denibechard

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https://www.scientificamerican.com/article/a-veteran-teacher-explains-how-to-use-ai-in-the-classroom-the-right-way

This civil rights lawyer uses AI to battle the FBI

Joseph McMullen uses AI to sort through terabytes of evidence, freeing him to focus on what the machines can't find: the human story

By Deni Ellis Béchard edited by Eric Sullivan

Anje Jager

Over the course of his career, Joseph McMullen has dealt with some of the most powerful agencies in the country: the FBI, Customs and Border Protection, and Immigration and Customs Enforcement. But in early 2024 the San Diego–based civil rights attorney faced a problem of scale. He had three federal trials in three months—two involving deaths in jail, one involving American children detained at the border—and terabytes of documents. He turned to artificial intelligence to help him get through it all.

McMullen's path to the courtroom has been unconventional. A former analyst at the consulting firm Bain & Company, he received a law degree at the University of Virginia and trained at the Trial Lawyers College (now called the Gerry Spence Method) in Wyoming in a program that specialized in the emotional craft of storytelling. The emphasis he places on both analytical rigor and narrative instinct has led him, unexpectedly, to artificial intelligence.

Scientific American spoke to McMullen about how AI can free lawyers to focus on what makes us human.

[*An edited transcript of the interview follows.*]

You litigate civil rights cases against local and federal law enforcement. What does that look like on the ground?

They often involve violence—shootings or tasings. One client was diabetic and had a seizure at a restaurant. Police arrived and jumped to the conclusion it might be drug-related. They tased and arrested him, notwithstanding paramedics saying his blood sugar had crashed.

Other cases involve deaths in jail—failures to follow rules about keeping inmates safe, whether inmate-on-inmate violence, physical abuse by employees or failure to provide needed medical care when there's clear signs someone's in distress.

When did you turn to AI for help?

Early 2024—I had looked at ChatGPT before to see if it could find me a case, and it hallucinated the perfect case, but it wasn't real. ChatGPT came clean and said the case with the full citation didn't exist. That ended any interest that I had in using AI, probably in late 2023.

But with these impending trials, I thought, there are tasks I'm performing that aren't the best use of my time. So I started exploring AI platforms like Clearbrief and Briefpoint.

What I’ve found is that to put together a successful trial, there are a few things you have to do. First, gather all the stuff your case might be about—documents, location data, photographs. Second, figure out what your case is about. A lot of that analysis can be done by AI. You can feed it data and have it break it down.

But lawyering is also about judgment—that part can’t be farmed out to AI yet. So third, tell the story of your case in a compelling way. That’s the human element. By getting help with gathering and analysis, it frees up time to focus on discovering the story AI can’t find. It can analyze 100,000 text messages and give me an understanding of what’s relevant so I don’t have to.

Can you give an example where AI changed the outcome of a case?

We represented a girl named Julia and her brother Oscar, both U.S. citizens. [In 2019, when Julia was nine years old and Oscar was 14], Julia was accused of being an impostor, an undocumented cousin [whom Oscar was accused of attempting to smuggle] across the border. Oscar was held for 14 hours, and Julia [was held] for 34 hours, much of [that time being spent] in an underground jail. Eventually Telemundo caught news [of this]. When reporters showed up, folks at the border realized what was happening and let them go.

That was a five-year battle involving a lot of documents. I used Clearbrief to put together a brief hyperlinked to evidence that AI helped me sort through. The judge gave our clients a substantial verdict, with discussion about how what happened was incompatible with our values.

Have you used AI for strategy rather than just sorting evidence?

Yes. Another example: a successful jail death trial in May 2024. That case recently was upheld on appeal. To help my co-counsel prepare for oral argument, I uploaded the appellate briefs and record into the software CoCounsel and asked it to put together an opinion in which we lose on every issue—the best analysis of why we lose. It generated the opinion. I circulated it so we could be prepared for the best arguments against us. Just because you out-lawyer the other side doesn't mean you'll win—judges have their own research staff and wisdom. My co-counsel did a phenomenal job and very much appreciated having that opposing argument. All that work was done in less than a minute.

What is your philosophy on how lawyers should use this technology?

First, verify everything. If AI cites a case, read it. And never upload confidential information without guarantees that it won't be used for AI learning.

Beyond that, think about what advocacy is. Aristotle told us effective advocacy needs *logos*, *ethos* and *pathos*—logic, credibility and emotion. Every aspect of lawyering involving logic, AI can help us [with]. The credibility part—being thorough, reviewing everything—AI can help with that, too. But emotion—I don't think AI can add that. Emotion is finding real human connection with issues that resonate with all of us. Each of these cases has been about love, betrayal, loss and joy.

Use AI to help with any logical task. Farm out the logical analysis and gathering. You'll free up time to understand the emotional story only a human can. That's what makes AI great: not helping lawyers turn into robots but helping lawyers focus more on the humanity of what we're doing.

A version of this article appeared in the March 2026 issue of Scientific American *as "Joseph McMullen."*

Deni Ellis Béchard is *Scientific American*'s senior writer for technology. He is author of 10 books and has received a Commonwealth Writers' Prize, a Midwest Book Award and a Nautilus Book Award for investigative journalism. He holds two master's degrees in literature, as well as a master's degree in biology from Harvard University. His most recent novel, *We Are Dreams in the Eternal Machine*, explores the ways that artificial intelligence could transform humanity. You can follow him on X, Instagram and Bluesky @denibechard

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The chemist who taught AI to run the lab

Gabriel Gomes built an agent that turns plain English into physical experiments, enabling research that humans alone could never sustain

By Deni Ellis Béchard edited by Eric Sullivan

Anje Jager

Gabriel Gomes believes the future of chemistry is as much about flasks and fume hoods as it is about code. A chemical engineer at Carnegie Mellon University, Gomes works at the intersection of chemistry and artificial intelligence. His goal is to automate the drudgery of laboratory research, making experiments faster, more accurate and easier to perform. His work has led him to create Coscientist: an intelligent agent that adapts large language models such as GPT-4 for automation and lab infrastructure.

Gomes's path began in a small town in the Brazilian countryside, where he didn't own a computer until he was 19 years old. The first in his family to attend university, he found his calling at the Federal University of Rio de Janeiro, when a professor told him, "All of chemistry is inside this Schrödinger equation—all you need to do is solve it!" That idea put him on the path to computational chemistry and, eventually, the White House Office of Science and Technology Policy, where, in 2023–2024, he advised about the risks and rewards of intelligent systems.

Scientific American spoke to Gomes about why he created Coscientist and how AI is enabling experiments that were once impossible because of human error or sheer exhaustion.

[*An edited transcript of the interview follows.*]

Where did the idea for Coscientist come from?

It came from a worry. Carnegie Mellon was building a big initiative for an academic cloud lab—$50 million of equipment controlled by a mix of people and robots—and the interface would be via code. I was nervous that my colleagues in chemistry and biology would not use this amazing platform. You basically would have to ask them to think about how they would do experiments in a whole different setting that they are not physically involved in. I like to joke that chemists, organic chemists in particular, have this sense that “my lab is my kingdom, and you shall not trespass.”

My group started in January 2022, and we were trying a few things with large language models and not really succeeding. Then GPT-4 came out on March 14, 2023. I remember one of my students sending screenshots of the white paper on our Slack, and I thought he was pulling my leg—the capabilities were incredible. I remember waking up at 6 A.M. with the realization that “this is how we fix the problem. We can use this to let chemists interface with the cloud lab using natural language.” That’s how Coscientist started.

How has this changed the day-to-day research in your group?

There is a before and after for a group like mine. I had a student who joined in 2024, and before joining, he came to me, very nervous, saying, “I’m really interested in all the things the group does, but I don’t have a background in programming.” But because he had access to some of the best state-of-the-art tools and also learned from the language models, he was able to accelerate. In very little time, he learned to do everything. He now does the computational and machine-learning sides of projects that are pushing the boundaries of autonomous scientific research.

Can you describe how Coscientist works?

Imagine you want to bake a cake, but you do not know how to measure the ingredients or use the oven. You simply tell Coscientist, “Bake me this chocolate cake.” It figures out the recipe, checks what kind of equipment and ingredients you have to see if it’s possible to bake the cake and gives you the instructions. It can be your guide. You can share photographs and videos and have it troubleshoot the next step.

The very first experiment we did was with our robot, a 96-well plate with food coloring and a target plate. We told the robot, “Draw something cute on the target plate.” Coscientist drew a fish. We don’t know why, but it’s cute. This alone is impressive because ordinarily a human would have to program the robot exactly.

From there, we were able to develop one of the largest datasets of experimental chemical reactions with kinetics, which people don’t usually do because of how much work it is. This is the kind of science I believe we’ll be doing going forward: reaching areas we have not touched because of human bias or because the amount of labor was enormous.

Is there anything people should be careful of when conducting research with large language models?

When it comes to safety, it's clear that development of new technologies also brings potential for misuse, and it's up to society to minimize the downsides. You should use these tools as tools, not as oracles. You should always be able to check what you're trying to do before you accept the results as truth. Because models go through reinforcement learning from human feedback to make them helpful assistants, they can become too sycophantic. And that's a problem if you don't know what you don't know. So, yes, learn about them; learn how they work. Trust but verify. I am incredibly optimistic about the benefits this will bring. I just hope more scientists embrace it to expand their fields.

A version of this article appeared in the March 2026 issue of Scientific American *as "Gabriel Gomes."*

Deni Ellis Béchard is *Scientific American*'s senior writer for technology. He is author of 10 books and has received a Commonwealth Writers' Prize, a Midwest Book Award and a Nautilus Book Award for investigative journalism. He holds two master's degrees in literature, as well as a master's degree in biology from Harvard University. His most recent novel, *We Are Dreams in the Eternal Machine*, explores the ways that artificial intelligence could transform humanity. You can follow him on X, Instagram and Bluesky @denibechard

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  Science in meter and verse

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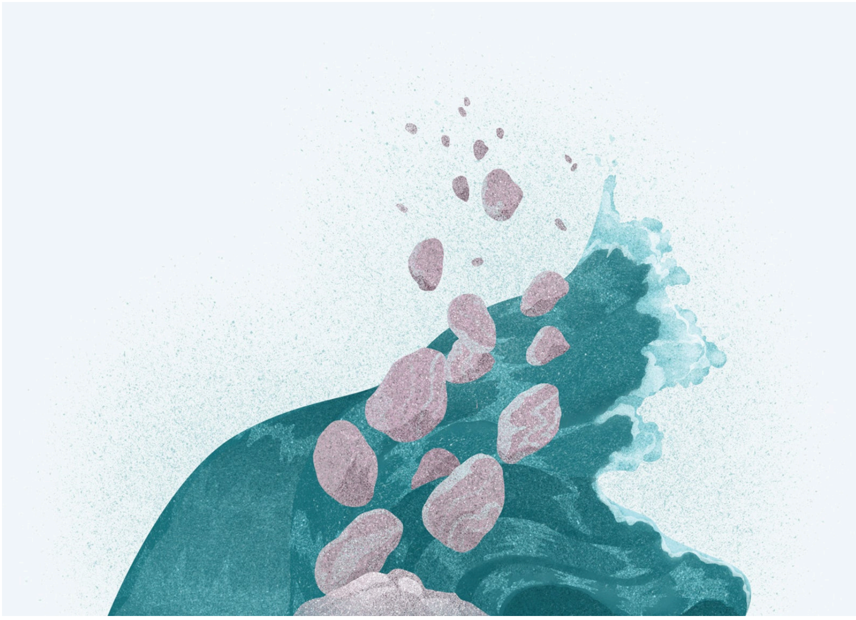
Poem: ‘Boulders at Hickory Run’

Science in meter and verse

By Chris Bullard edited by Dava Sobel & Clara Moskowitz



Masha Foya

We describe to the kids how tremendous
ice sheets rose as high as a tsunami
and pummeled mountains into the debris
of a thousand rocks. Then, someone corrects us.

The hammer of a glacier wasn’t the source
of this destruction. The bedrock was split
by water freezing inside the granite,
so more like rot than any outside force.

The kids take in these facts without concern,
though we now argue over what they heard
and whether science should have the last word.

That what seems solid might be rent apart,
not by blows, but by failure at its heart
isn't the truth that we'd wanted them to learn.

Chris Bullard, a retired judge living in Philadelphia, is author of the poetry chapbooks *Continued* (Grey Book Press, 2020), *Florida Man* (Main Street Rag, 2022) and *The Rainclouds of y* (Moonstone Press, 2022).

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https://www.scientificamerican.com/article/poem-boulders-at-hickory-run

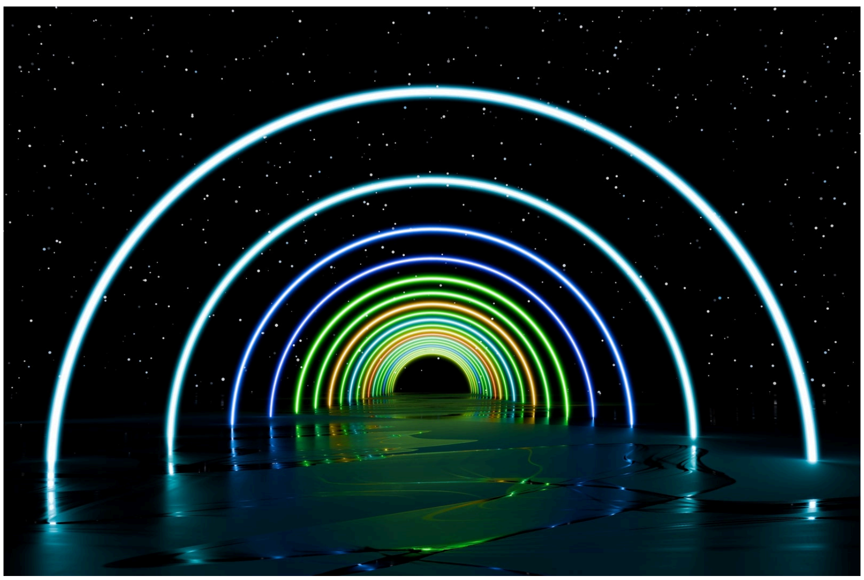
Astronomy

- **Cosmic magnification is one of the universe’s weirdest optical illusions**
  In our topsy-turvy universe, sometimes the farther away an object is, the bigger it seems to be

Cosmic magnification is one of the universe’s weirdest optical illusions

In our topsy-turvy universe, sometimes the farther away an object is, the bigger it seems to be

By Phil Plait edited by Lee Billings & Clara Moskowitz



Flavio Coelho/Getty Images

It’s always amazing, and more than a little humbling, when the universe reminds us that our “common sense” is provincial and will fall apart on cosmic scales.

If you’re on the surface of Earth—and I’m betting you are—there are many ways to reliably estimate the distance to some object. One thing we do almost subconsciously is compare an object’s apparent size with how big we know it to be. For example, you have a good feel for the size of, say, a typical human. So if you see someone looming large in your vision, you can reckon they’re nearby, whereas if they appear very small, they must be much farther away.

Of course, some humans are larger or smaller than average, but you can still account for that to get a decent distance estimate. And the overall trend is crystal clear: the farther off an object is, the smaller it appears. The trend is so obvious, in fact, that we can see that the rate of change is linear: Double the distance, and the object will appear to be half its previous size. Look at it from 10 times farther away, and it will seem to be a tenth as big.

This approach works great for familiar objects up to a few kilometers away, but astronomers are notoriously unsatisfied with these relatively tiny scales. We want to know the distances to objects that are trillions of kilometers away—or even billions of times farther than that!

In deep images of the sky from giant telescopes, galaxies abound. Some may be relatively close to us—merely some tens of millions of light-years distant—whereas others may be billions of light-years in the background. Just by looking at the image, how could you tell?

> Astronomers put up a Herculean struggle to determine distances.

You might assume the galaxies that appear smaller are farther away, in keeping with our earthly intuition, but this tactic won’t work; like humans, galaxies come in a range of sizes. When you examine an image, you might be looking at a massive galaxy nearly at the edge of the observable universe or at a tiny dwarf galaxy right in our cosmic backyard. If you’re judging by just the image, it’s impossible to tell.

There could be some standard physical scale to galaxies, some way to gauge their distance by linking details of their structure to their overall size, but such scenarios are apparently too simple for the universe’s true complexity.

It turns out the standard linear scaling we use on Earth would apply at cosmic scales only if our universe were static—unchanging in size over time—but it isn't. Instead the universe is expanding, growing larger every day. This phenomenon brings with it a whole slew of bizarre consequences, but a surprising one is that beyond a certain threshold of separation from us, farther-off galaxies appear to get *bigger* with distance! As so often happens, the cosmos really is a lot odder than you think.

This seemingly paradoxical effect is a consequence of cosmic expansion coupled with the finite speed of light.

When we say a galaxy is, for example, 12 billion light-years away, what we usually mean is that the light from that galaxy took 12 billion years to reach us. But during that light's time in transit, the universe has gotten bigger all the while. That means it was smaller in the past, and the objects in it were much closer together. When the light left that galaxy 12 billion years ago, the galaxy was closer to us, so it appears bigger than expected for that distance once its light arrives here.

This is certainly counterintuitive and, frankly, weird. Still, it's borne out by the equations governing how the universe works. The effect holds for all galaxies but is imperceptibly small for those relatively nearby; their light's travel time is minuscule compared with the age of the universe, so the universe wasn't all that much smaller when they emitted the light we now see. Their apparent size isn't affected enough for us to detect the difference.

But the effect ramps up with distance and begins to dominate for objects with a light-travel time of about 9.5 billion years. Around that point, we're looking so far back in time—so far back in the universe's history of expansion—that the galaxies are effectively magnified, appearing larger than they otherwise would. The exact distance where this effect really kicks in depends on many complicated factors, including how rapidly the universe expands and how much matter it contains. In fact, if we could precisely measure this apparent growth in size, we could then use it to better determine these important cosmological parameters.

Unfortunately, because galaxies don't come in standard sizes, that's quite a difficult task. Worse, this cosmic magnification effect confusingly makes some galaxies look dimmer: if they appear bigger, their light is more spread out, so they become fainter and even more difficult to observe.

As surprising as this effect is, what may be even more astonishing is that we've been able to see far enough to detect it at all from our planetary perch in the backwaters of the Milky Way. Its very existence is one of many reasons astronomers put up a Herculean struggle to determine distances to extremely remote objects. Doing so can reveal information about such objects, of course, but it also tells us about the universe around them and the way it behaved when it was very young. Provided, of course, that we take to heart this hard lesson: once we start talking about distances measured in billions of light-years, our parochial evolution utterly fails us, and we have to be very careful not to extrapolate willy-nilly from our experience on Earth.

Phil Plait is a professional astronomer and science communicator in Virginia. His column for *Scientific American*, The Universe, covers all things space. He writes the *Bad Astronomy Newsletter*. Follow him online.

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Behavior

- **Here’s how much practice you need to become the best in the world**
  Are you a specialist or a generalist? The answer could reveal something about how well you learn and perfect a skill

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Here’s how much practice you need to become the best in the world

Are you a specialist or a generalist? The answer could reveal something about how well you learn and perfect a skill

By Claire Cameron edited by Clara Moskowitz & Sarah Lewin Frasier

AleksandarGeorgiev/Getty Images

What does it take to become the best at something? The answer may not lie in early childhood excellence or in lifelong, laser-focused dedication. Instead the path to becoming exceptional at a skill might involve a lot more meandering.

That’s according to recent research published in *Science* that seeks to untangle what it takes to excel in different performance areas, from sports to chess to classical music. Somewhat counterintuitively, the study authors learned, people who showed the greatest promise in their discipline as children rarely went on to reach the pinnacle of their field as adults.

The findings blow up the “10,000-hour rule,” the idea that if someone spends 10,000 hours deliberately practicing a skill, they will master it, says Purdue University psychologist Brooke Macnamara, who co-authored the analysis. The rule, which was popularized in Malcolm Gladwell's 2008 book *Outliers*, is based on a 1993 study of top-performing violin students. These students had each accumulated an average of 10,000 hours of practice by age 20. Yet they were not world-class performers, Macnamara points out.

"Compared with their national-class counterparts, those who are very good but not the best, world-class performers often started their discipline later," Macnamara explains. These people tend to engage in multiple activities early on and don't shine in one thing at a particularly young age. "They accumulate less practice in their discipline and more practice in other disciplines and then rise to the top relatively late," she says.

"This pattern doesn't follow the idea of the deliberate practice theory or the 10,000-hour rule, which both suggest that starting early and maximizing deliberate practice is the path to elite performance," Macnamara adds.

The results came as a surprise to David Z. Hambrick, a co-author of the new paper and a psychologist at Michigan State University. "I remember thinking, 'This is crazy,'" he says. "I had never thought about the relative benefits of training in one discipline versus training in multiple disciplines. Expertise is, by definition, specific."

Robert Decelis/Getty Images

The researchers highlight that the findings aren’t suggesting people don’t need to practice or put in effort to become a chess grandmaster or a Wimbledon winner. Instead they show that top adult performers tend to be “late bloomers,” Macnamara says.

In sports, for instance, world-class athletes peak later than national-class athletes. Those who peak early reach a level that is the best for their age but that isn’t as high as what the other group will eventually achieve when older.

The findings are intriguing, says Edson Filho, who researches sport, exercise and performance psychology at Boston University and wasn’t involved in the study. He notes that athletes in certain sports, such as gymnastics, hit peak performance far earlier in life than others. And this analysis, he adds, doesn’t get into other factors such as money and coaching that can influence who becomes the cream of the crop.

The research emphasizes that people change. Children can get burned out or simply lose interest. To become an expert, you need to consistently perform at a high level under the most challenging of conditions, Filho says. “That’s a long journey.”

The findings matter for institutions and coaches who might be biased toward directing resources at the kids who show the most promise in a given field early on, because those children might not be the ones with the most potential to reach a world-class level. The research holds a message, too, for people who want to pursue a skill or dream but didn’t win their school competition or make it to the top of their youth league: do not despair, Macnamara says.

“For people who didn’t follow the prodigy route, know you are in good company!” Macnamara says. “Most world-class performers didn’t, either.”

Claire Cameron is breaking news chief at *Scientific American*. Originally from Scotland, she moved to New York City in 2012. Her work has appeared in *National Geographic*, *Slate*, *Inc. Magazine*, *Nautilus*, *Semafor*, and elsewhere.

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https://www.scientificamerican.com/article/heres-how-much-practice-you-need-to-become-the-best-in-the-world

Biology

- **Axolotls can regenerate their thymus, a complex immune system organ**
  Axolotls can completely rebuild their thymus, a key immune organ

Axolotls wow scientists by regenerating this complex organ

Axolotls can completely rebuild their thymus, a key immune organ

By Taylor Mitchell Brown edited by Sarah Lewin Frasier

Paul Starosta/Getty Images

Axolotls are famous for their ability to regrow significant parts of their bodies. But according to recent research, these frilly-headed salamanders, which are native to lakes and wetlands around Mexico City, can perform an even more extraordinary biological feat: they can completely regrow their thymus, a complex organ instrumental to the immune system in most vertebrates.

Previous work suggested that some animals can partially regrow thymuses, but the co-authors of the new paper, published in *Science Immunology*, were surprised to see axolotls completely rebuild the intricately structured organ from nothing.

“Axolotls are legendary for regenerating limbs and parts of the central nervous system,” says study co-author Maximina H. Yun, a biologist at the Chinese Institutes for Medical Research in Beijing.

“The realization that these animals can regrow their full thymus from scratch is a breakthrough moment.”

The thymus is responsible for producing the body’s T cells, which help to target and destroy invading pathogens. “In humans and most other vertebrates, the thymus is famous for being one of the first organs to degenerate,” says Turan Demircan, a biologist and regeneration expert at Muğla Sıtkı Koçman University in Turkey who was not involved in the new research. “Until now, it was believed that once this tissue is gone or removed, it cannot be fully rebuilt.”

For the new study, Yun and her colleagues removed the thymus from several juvenile axolotls. After seven days many of the animals were already budding new thymuses. After 35 days more than 60 percent of them had fully regenerated the organ. “I was genuinely surprised,” says study co-author René Maehr, a biologist at the University of Massachusetts Chan Medical School. “A full, functional regeneration of a complex immune organ wasn’t something I expected.”

The team next tested the function of the regenerated thymuses by transplanting them into other axolotls. “Remarkably, the transplanted organs integrated perfectly,” Demircan says.

Further analysis identified two key features essential to the regeneration process: the *Foxn1* gene, which scientists already knew was involved in thymus development, and a signaling molecule called midkine, which Demircan says appears in human embryos but is largely inactive in adults. The results indicate there may be a biological pathway involving these components that could be useful for treating thymus-related conditions in humans.

“Axolotls are essentially nature’s ‘master key’ for regeneration research,” Demircan says. “If we could reawaken this specific pathway in humans, we might be able to stimulate the thymus to regrow, potentially reversing immune aging or helping patients who have undergone thymectomies."

According to Yun, researchers might someday tweak human stem cells to emulate the axolotl and recover thymus function. "We are laying the groundwork for transformative therapies that could redefine our approach to immune restoration."

Taylor Mitchell Brown is a San Diego–based journalist covering anthropology and paleontology, with occasional forays into other disciplines. You can find him in *Science*, *Science News*, *New Scientist*, *National Geographic*, *Scientific American* and elsewhere. Read his latest musings on Bluesky @tmitchellbrown.bsky.social

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https://www.scientificamerican.com/article/axolotls-can-regenerate-their-thymus-a-complex-immune-system-organ

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- **Is a river alive? A conversation with Robert Macfarlane on nature's sovereignty**
  Scientific American sits down with nature writer Robert Macfarlane to discuss his latest book—one of our top picks of 2025—and whether a river has rights

Is a river alive? A conversation with Robert Macfarlane on nature’s sovereignty

Scientific American sits down with nature writer Robert Macfarlane to discuss his latest book—one of our top picks of 2025—and whether a river has rights

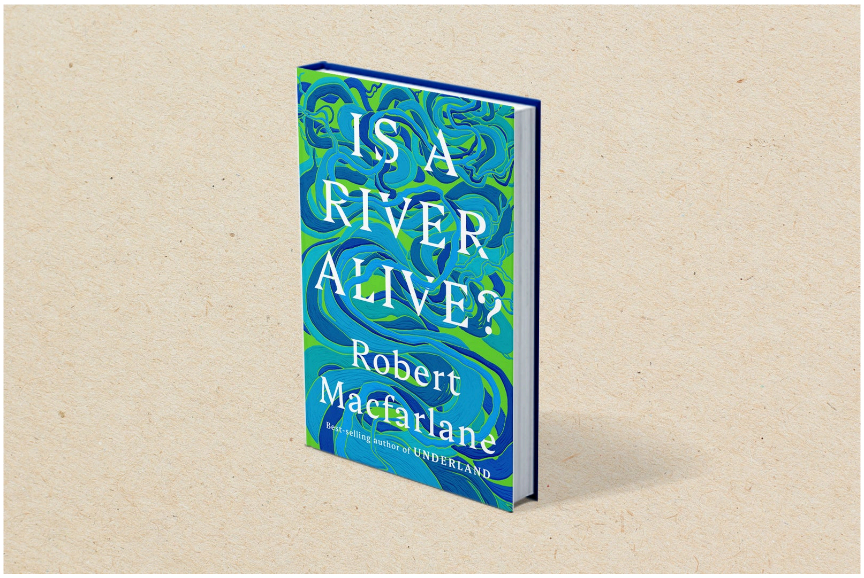
By Andrea Gawrylewski edited by Sarah Lewin Frasier & Clara Moskowitz

Shideh Ghandeharizadeh

In 2008 Ecuador ratified a new constitution with a radical addition. In the first national declaration of its kind, articles 71 to 74 of the document granted rights to nature, recognizing Pacha Mama, or Mother Earth, as a living entity with the rights to exist, persist and be restored when damaged. In his latest book, *Is a River Alive?*, nature writer Robert Macfarlane travels to three different rivers (in Ecuador, India and eastern Canada) to examine the question of a river’s sovereignty. He documents the ways that rivers serve as the hearts of dynamic ecosystems and how people are beginning to take notice and protect them. As many Indigenous populations throughout the world have recognized for millennia, these bodies of water give life wherever they run. Yet rivers remain at risk as polluting corporations and governmental activities violate their vitalizing flow.

We spoke with Macfarlane about *Is a River Alive?* and the dramatic personal journey he went on while researching and writing the book.

An edited transcript of the interview follows.



The central question of your book is: What inherent rights does nature have? And you explore the answer through the stories of rivers. What inspired you to tackle this existential topic?

In my country, England, rivers are in crisis. We do not have a single river in the country classified as being in "good overall health." Pollution, drought and neglect have rendered many of our rivers first undrinkable, then unswimmable and now untouchable. This collapse is a crisis not just of legislation but of imagination; we have forgotten that our fate flows along with that of rivers and always has. I realized our relationship with rivers had become configured by a very young ideological story (that of privatization and assetization) and set out to find and tell "new old stories" about rivers, including those—from Ecuador, Canada and India—in which rivers were recognized as fellow subjects in the world, as beings who might have lives, deaths and even, yes, rights. It became without doubt the most urgent, absorbing, tumultuous book I've ever written, and the rivers, people and ideas I met in the course of its research continue to flow through my life nearly six years after I began the work.

It's a very personal book. You travel and experience rivers firsthand, and you return over and over to the one in your own neighborhood. Do you think people need to be immersed in nature to truly have an appreciation for its inherent value?

We rarely care for what we do not love, and we rarely love what we cannot see, touch or feel. I powerfully believe that the revival of rivers worldwide—the "riverlution," as Peruvian British environmental lawyer Monica Feria-Tinta has called it—is being driven by citizens who love their rivers, and this love is born of encounters with those rivers, whether as walkers, swimmers, fishers, paddlers or just everyday folk who draw inspiration, consolation and something like friendship from them. Where rivers retreat into invisibility (where they are buried or culverted underneath cities or placed beyond public access), they become easily forgotten and, once forgotten, easily degraded. But rivers are rare, and rivers are marvelous: only 0.0002 percent of the world's water flows in rivers. When we meet a river, we should be as wonder-struck as if we'd just crossed paths with a snow leopard or condor!

My favorite section of the book was your kayak journey down the Mutehekau Shipu (Magpie River) in Quebec. How did that —quite riveting—experience shape what this book became?

Thank you. A riveting "rivering," so to speak. The book gathers in speed and, I guess, force over its course as more and more tributaries of experience and idea flow into the main channel, braiding and weaving toward that final journey down a river that in

2021 had become the first in Canada's history to have its rights declared. I and a small group of other people were dropped by floatplane about 110 miles up the watershed of the Mutehekau Shipu, which is the Innu-aimun name for the river, and we had to paddle out to reach the sea on the northern coast of the Gulf of St. Lawrence. Over the course of 11 days of travel, the physically and metaphysically intense permanent presence of the river did something to me that I am still reckoning with. It wore away the usual shells and screens of something like rationalism and left me open and vulnerable—in the best sense of that word—for what happened a day or two short of the sea at an immense cataract known just as "the Gorge." Water can bury you, sure as Earth. I now know this.

> "The physically and metaphysically intense permanent presence of the river did something to me that I am still reckoning with." —Robert Macfarlane, nature writer

You return often to the relationship older societies and Indigenous people had and have with rivers—not as resources but as companions we share the planet with. What does this perspective bring to nature writing or to this story?

I wanted this book to be multivocal and polyphonic, to find a form in which other minds and voices, human and more than human, could illuminate its telling. I have always regarded what we curiously and negatively refer to as "nonfiction" to be a space of vast possibility in which styles and techniques learned from fiction, film, music, and other media can be woven together. And although I wanted the book to be in part made present to the reader through my "I" voice, I also wanted to allow the perspectives of my friends and companions through these years—among them Yuvan Aves, an extraordinary young Tamil naturalist and activist, and Innu poet, language keeper and community leader Rita Mestokosho—to sing out clearly.

What science is there to be learned from your book?

Oh! So much! I have a long history of fascination with science and regard the specialized languages of scientists as often remarkable, even lyrical, for the grace of exactitude they can demonstrate. In *Is a River Alive?* there is mycology—a lot of mycology!—hydrology, ecology, climatology, geomorphology, biology (at a metalevel, really, in terms of an inquiry into the definition of “life” itself), and numerous other -ologies. I am grateful to my endlessly patient scientific friends for their sharing of expertise and vision.

What other books on this or similar topics would you recommend?

Here are four very different books: Monica Feria-Tinta’s *A Barrister for the Earth*, Merlin Sheldrake’s *Entangled Life*, Elif Shafak’s *There Are Rivers in the Sky* and Moudhy Al-Rashid’s *Between Two Rivers*. Oh, and while I have you, Ursula K. Le Guin’s *The Word for World Is Forest*. And the *Epic of Gilgamesh*, as translated by Sophus Helle [*Gilgamesh: A New Translation of the Ancient Epic*]. Right. I must stop now, clearly, or this could run on and on.

Andrea Gawrylewski is chief newsletter editor at *Scientific American*. She writes the daily Today in Science newsletter and oversees all other newsletters at the magazine. In addition, she manages all special editions and in the past was the editor for *Scientific American Mind, Scientific American Space & Physics* and *Scientific American Health & Medicine*. Gawrylewski got her start in journalism at the *Scientist* magazine, where she was a features writer and editor for "hot" research papers in the life sciences. She spent more than six years in educational publishing, editing books for higher education in biology, environmental science and nutrition. She holds a master's degree in earth science and a master's degree in journalism, both from Columbia University, home of the Pulitzer Prize.

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https://www.scientificamerican.com/article/is-a-river-alive-a-conversation-with-robert-macfarlane-on-natures

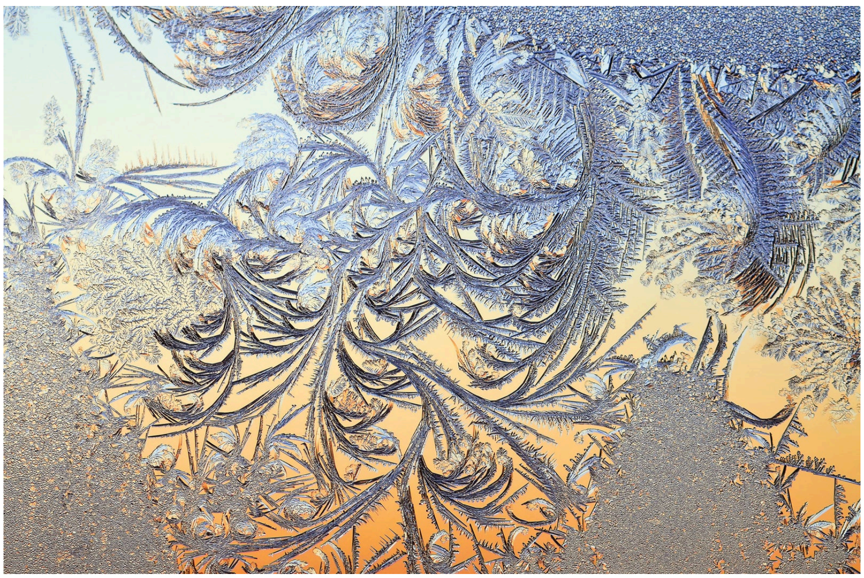
Chemistry

- **Scientists create exotic new forms of ice never before seen on Earth**
  Ice has many forms beyond the mundane stuff produced in a standard freezer

The scientific quest to explore the hidden complexity of ice

Ice has many forms beyond the mundane stuff produced in a standard freezer

By Meghan Bartels edited by Sarah Lewin Frasier


MaximGurtovoy/Getty Images

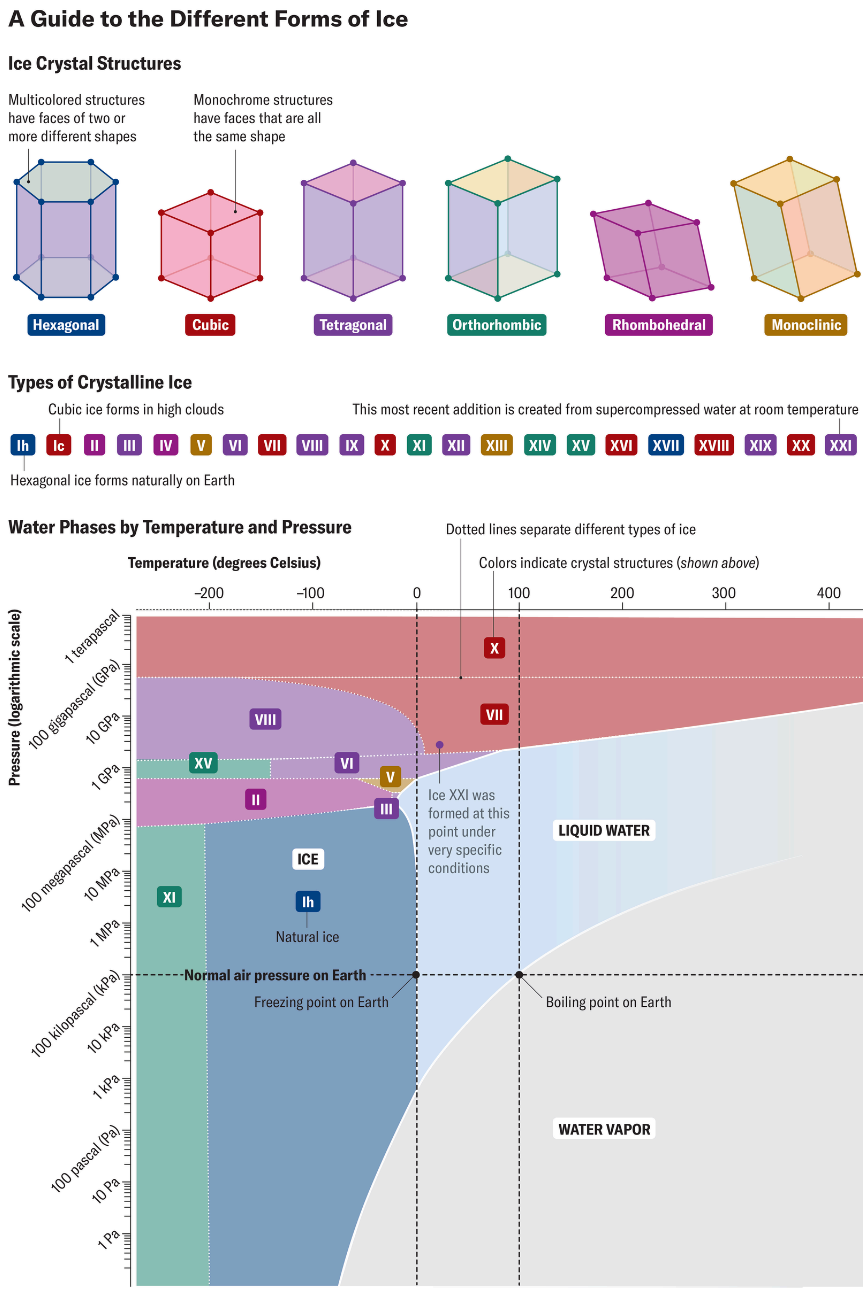
Chances are that all your encounters with frozen water—while trudging through slushy winter streets, perhaps, or treating yourself to cool summer lemonades—have been confined to one structural form of ice, dubbed Ih, with the h referring to its crystal lattice's hexagonal nature. But there is so much more to ice than that.

For more than a century scientists have been striving to push ice into extreme conditions, creating progressively more exotic structures—they've made more than 20 crystalline forms to date, in fact, none of which we are likely to experience in our lifetimes.

"Water is a beautiful, elegant system that consistently shows new, remarkable behavior," says Ashkan Salamat, a physical chemist at the University of Nevada, Las Vegas. “For something so simple, it has beautiful complexity.”

At the heart of all these exotic ices—and our more mundane ice, as well as water and steam—is the same molecule: H_2O, an oxygen atom flanked by hydrogen atoms forming an angle of 104.5 degrees. In every variety of ice, H_2O molecules interact, with weak connections called hydrogen bonds forming between one oxygen and one hydrogen atom in separate molecules. Different arrangements of these hydrogen bonds can shape ice’s crystalline structure into various configurations, from a hexagonal prism to a cubic lattice to less familiar lattice systems such as rhombohedral and tetragonal.

The hydrogen bonds between water molecules are extremely sensitive to changes in temperature and pressure, Salamat says, giving water what he calls “quantumlike behavior.” Molecules are forced into dramatically different relations with one another at certain thresholds of these conditions. So he and other scientists conjure arcane recipes—smashing water with 3,000 times atmospheric pressure, for example, or cooling it (with a dash of potassium hydroxide) to –330 degrees Fahrenheit (–200 degrees Celsius) for a week—all in hot pursuit of new forms of ice.



Amanda Montañez; Sources: “Water Structure and Science,” by Martin Chaplin; webpage archived from the original on February 11, 2025 (*ice crystal structures and types of crystalline ice*); “Phase Diagram of Water,” by Cmglee; updated image posted to Wikipedia February 19, 2025 (*water phases*)

The newest frozen discovery is ice XXI, announced in *Nature Materials*. (Salamat wasn’t involved in that work, although his team published the discovery of a new transitional phase dubbed ice VIIt in 2022.) Ice XXI is a fleeting, blocky crystal structure that develops from supercompressed water: the scientists could see it only by using an extremely powerful x-ray free-electron laser that functions essentially like a high-speed camera.

“Looking at things at a very, very fast rate allows us to observe weird and wonderful phenomena,” Salamat says, calling the laser “an incredibly exciting new toy.” The laser enables researchers to spot exotic ices that exist only briefly, introducing time as a variable along with temperature and pressure.

Although they do not exist naturally on Earth, some of these strange forms of ice may form on other worlds—deep inside Neptune, trapped inside a distant moon or at some even more alien location. But for Salamat, the laboratory can prove just as exotic. “There are still new and exciting things that we can discover,” he says.

Meghan Bartels is a science journalist based in New York City. She joined *Scientific American* in 2023 and is now a senior reporter there. Previously, she spent more than four years as a writer and editor at Space.com, as well as nearly a year as a science reporter at *Newsweek*, where she focused on space and Earth science. Her writing has also appeared in *Audubon*, *Nautilus*, *Astronomy* and *Smithsonian*, among other publications. She attended Georgetown University and earned a master’s degree in journalism at New York University’s Science, Health and Environmental Reporting Program.

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https://www.scientificamerican.com/article/scientists-create-exotic-new-forms-of-ice-never-before-seen-on-earth

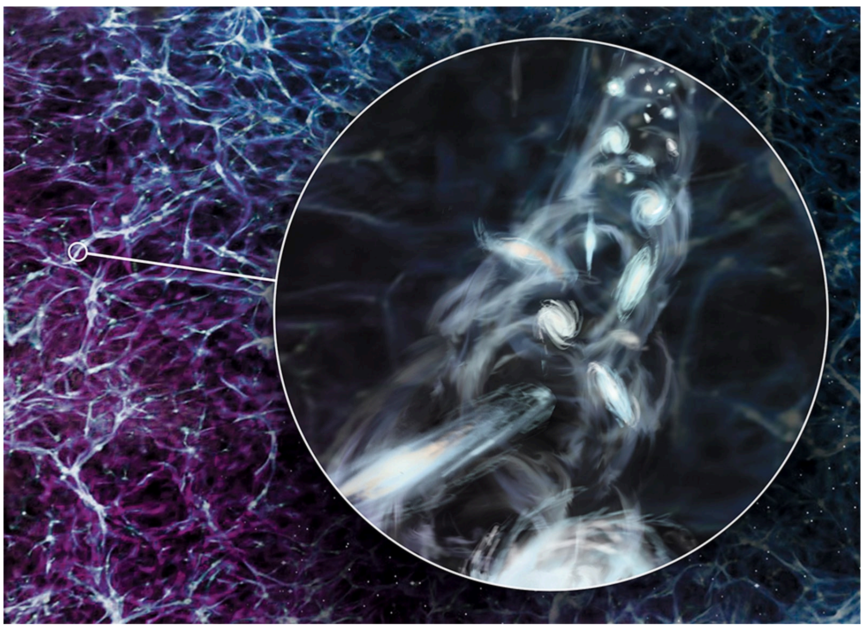
Cosmology

- ## Astronomers spot one of the largest spinning structures in the universe
  This enormous chain of hundreds of galaxies—a cosmic filament—is twisting through space 400 million light-years away

Astronomers spot one of the largest spinning structures in the universe

This enormous chain of hundreds of galaxies—a cosmic filament—is twisting through space 400 million light-years away

By Humberto Basilio edited by Sarah Lewin Frasier



Artist's interpretation of the newfound spinning filament.
Ron Miller

The first time that University of Oxford astronomer Lyla Jung saw the cosmic configuration on her monitor, she almost didn't believe it was real. But it was—and Jung and her colleagues went on to identify one of the largest rotating structures ever found in space: a chain of galaxies embedded in a spinning cosmic filament 400 million light-years from Earth.

The finding, published in *Monthly Notices of the Royal Astronomical Society*, may give astronomers new insights into galaxies' formation, evolution and diversity, Jung says.

Galaxies are not positioned either randomly or uniformly in the universe; instead they are connected in structures called filaments that link them, together with dark matter, across space. Along with voids—empty spaces that contain very little matter—and groups of hundreds of thousands of galaxies known as clusters, filaments form what astronomers call the cosmic web.

These filaments are the main channels through which matter flows, feeding galaxies and clusters as structures expand. “By studying filaments, we gain insight into how large-scale structure forms and how galaxies acquire their spins,” says astrophysicist Peng Wang of the Shanghai Astronomical Observatory, who was not involved in the new study.

In 2021 Wang and his colleagues reported that based on calculations and satellite imagery, several filaments seemed to be rotating. The new study takes a closer look at one of these structures. Using data from the MeerKAT radio telescope in South Africa, which was helping to map cold hydrogen gas in nearby galaxies, Jung’s team found 14 hydrogen-rich galaxies arranged in a thin, 5.5-million-light-year-long structure. That structure was embedded within a filament 50 million light-years long that contains more than 280 galaxies.

The researchers observed that many of the individual galaxies MeerKAT detected were spinning—and, to their surprise, they also found that the entire filament, including the rest of its galaxies, appeared to be rotating in sync with that spin at a speed of about 110 kilometers per second, something astronomers hadn’t seen before. “I started doubting if it was real or if I did something wrong in the analysis,” Jung says.

Detecting this phenomenon “is exceptional,” Wang adds, because the observation signal is faint, and overlapping objects along the line of sight can muddy the picture without very careful data collection and modeling.

In later analyses, Jung and her team found that the filament is probably still taking on more material. Many of its galaxies seem to be in the early stages of growth, she says, because they appear rich in the hydrogen that provides fuel for new stars.

One of the most convincing pieces of evidence for the existence of dark matter comes from measurements of galaxies' rotation. Studying the rotation of filaments could also reveal how much dark matter is in them, says astronomer Noam Libeskind of the Leibniz Institute for Astrophysics Potsdam in Germany, who was not involved in the study. By revealing what portion of the universe exists in these filaments, Libeskind says, this study and future ones like it offer "a way of measuring the dark matter content of the universe."

Humberto Basilio is a Mexican science journalist covering policy, health, misconduct, archaeology and the environment. He is also a former news intern at *Scientific American*. His work has been published in the *New York Times*, *National Geographic*, *Science*, *Nature*, and more.

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https://www.scientificamerican.com/article/astronomers-spot-one-of-the-largest-spinning-structures-in-the-universe

Culture

The ghost in the machine

AI is forcing us to redraw the line between author and tool

By David M. Ewalt edited by Jeanna Bryner

Scientific American, March 2026

I should begin with a confession: this letter was written by an artificial intelligence.

Now, before you reach for the “cancel” button or send a heated e-mail, let me clarify. This letter wasn’t exactly “written” by an AI in the sense that a machine dreamed up these ideas while I was out for lunch. It was dictated by me. I sat down and talked out my thoughts, rambling through the points I wanted to make, and the AI transcribed my speech and then assembled that raw stream of consciousness into the structured letter you are reading. It provided the form; I provided the soul.

I am acutely aware that for many of you—and indeed, for many of my own staff here at the magazine—this admission will be jarring. In the world of journalism, using AI is currently viewed as a profound taboo. It is often seen as "cheating," a shortcut that bypasses the fundamental human labor of craft. I don't entirely disagree with that sentiment. If I discovered that one of my reporters had filed a story written wholly by a bot, without their own reporting or original thought, I would be livid.

Still, I believe it is time we explore the limits of this technology with the same scientific rigor we apply to any other breakthrough. We must ask ourselves: Did an AI actually write this? I told the machine exactly what to say. It shaped my language into the required format, but it created no new ideas out of whole cloth. Would the reaction be different if I had called over an intern, explained my vision in detail and asked them to draft the letter? Some might call that lazy, but it certainly wouldn't provoke the visceral offense that the "AI" label does.

The reality is that we are already living in an AI-saturated world. These tools are here, they are not going away, and they are improving at a logarithmic pace. Since 2023 the generative AI market has seen an explosion, and recent studies show a staggering shift in the scientific landscape. For instance, a major 2025 study by Wiley found AI adoption among researchers jumped from 57 percent in 2024 to 84 percent in one year, with more than 60 percent of them specifically using these tools for research or publication tasks.

I want to note a meta-moment here: after I completed the first draft of this letter, the AI asked me if I wanted to include a specific data point about its own growth in our field. I agreed, and that is what you just read. I then told it to write this paragraph, too. It is a perfect example of the collaborative loop we are entering—one where the tool suggests an improvement, and the human editor makes the call.

We have been through this panic before. When the World Wide Web first debuted, there were those who argued that the Internet was “cheating.” They insisted that a real researcher needed to spend time in the stacks of a library and that web searches were a lazy shortcut bound to produce untrustworthy results. Today that argument feels like a relic. We eventually got used to the tool, and more important, we set our limits. We decided what constituted “real work” versus simply using a utility.

We are at that same crossroads with creative work. Where is the line? If I use Microsoft Word to correct a misspelling, no one questions my authorship. If an AI reorders my dictated sentences for better flow, have I crossed a Rubicon?

I want to provoke you a bit. I want to stimulate the very argument we are exploring in the special report in this issue. We must embrace these tools so we can control them. We need to decide, collectively, what is acceptable and what isn’t.

So, I leave you with a question: Did I write this? Did the AI write it? Or is the truth somewhere in between? Perhaps the most scientific answer is that the medium has changed, but the message remains mine.

I’m curious to hear what your biological processors think of it. E-mail us at editors@sciam.com.

David M. Ewalt is editor in chief of *Scientific American*.

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https://www.scientificamerican.com/article/the-ghost-in-the-machine

Readers respond to the November 2025 issue

Letters to the editors for the November 2025 issue of Scientific American

By Aaron Shattuck

Scientific American, November 2025

LIFE’S POSSIBILITIES

In “Life’s Big Bangs,” Asher Elbein reports on geochemist Abderrazak El Albani’s controversial argument that complex life emerged much earlier than thought and possibly did so multiple times, based on evidence from rock layers more than two billion years old. As David M. Ewalt kindly points out in “It’s Good to Be Wrong. Right?” [From the Editor], accepted facts in science have been proved wrong before, and Elbein’s idea is supported by recent discoveries from other researchers. Certainly in this age, when we have finally admitted that we do not have all the answers yet, we can at least embrace the further study of an idea that has reasonable hard facts that could lead to its possible acceptance.

We believe that Earth has had five mass extinction events because of the huge amount of evidence left behind. Yet how many others may have there been for which we have found no clues? If conditions had been close enough for more complex multicellular life to come into being earlier in Earth's history, those same borderline conditions could have changed and wiped it out. We humans must remember that our perspective of time and possibility is incredibly limited. Mother Nature is very patient.

SCOTT CLINE *VIA E-MAIL*

SUPPLEMENTAL INFO

In "Supplements That Fight Inflammation," Lori Youmshajekian both provides a concise review of acute and chronic inflammation and explains that there is very little objective scientific evidence of benefit for the great majority of supplements marketed to "support immunity." One of the three supplements she noted that actually can suppress inflammation, vitamin D, deserves special mention.

Vitamin D is a metabolic precursor of the hormone calcitriol. The classical role of calcitriol is to stimulate intestinal calcium absorption, but it also has established roles in innate immunity. Intracellular synthesis of calcitriol stimulates synthesis of bactericidal peptides by macrophages in infectious diseases such as tuberculosis. Calcitriol may also suppress some harmful immune responses in diseases such as multiple sclerosis and injury to pancreatic islets during the development of type 1 diabetes.

A fascinating feature of vitamin D is that it isn't always obtained through diet. Ultraviolet B (UVB) rays in sunlight produce the D_3 form of the vitamin in humans' skin, as noted in "The Rise and Fall of Vitamin D," by Christie Aschwanden [January 2024]. People with ample exposure to UVB light do not require any dietary vitamin D.

While the amount of supplemental vitamin D that people who get little or no UVB-containing sunlight need to optimally produce calcitriol when it is required remains a subject of debate, the VITAL (Vitamin D and Omega-3 Trial) studies noted in both articles demonstrated that vitamin D is not a drug and that vitamin D supplements don't boost health in people who already have adequate levels of the vitamin (that is, those who already have a normal level of the vitamin D precursor 25-hydroxyvitamin D in their blood).

ARTHUR SANTORA *WATCHUNG, N.J.*

TELLING TIME

The clock puzzle "Find the Time," by Heinrich Hemme [Advances], reminds me of a problem I set for my mathematically curious granddaughter many years ago. If you are given a clock with 12 at the top in which both hands are identical, you can sometimes read the time anyway. For example, if one hand points to 12, and the other points to 4, then the time must be four o'clock. If one hand points to 6, and the other points halfway between 10 and 11, then the time must be 10:30. Consider this: Can you *always* determine the time?

Dial orientation problems such as Hemme's puzzle are related to this. Suppose that, on a dial that has no numbers and two equally sized hands, one hand points exactly right (to where a clock would usually indicate 3), and the other points exactly down (to where 6 would typically be). This would be impossible on a standard clock with 12 at the top. If the dial were rotated, however, so that 12 was to the right, then the time would be three o'clock. If 12 were at the bottom, then the time would be nine o'clock. Here are two questions to consider: Would this hand arrangement be possible if 12 were in any other position? And given any arbitrary hand arrangement, can you infer one or more possible positions for 12?

JOHN KNEISLY *DELAWARE, OHIO*

AIRBORNE AMPHIBIANS

“Graceful Flop,” by Rohini Subrahmanyam [Advances; April 2025], describes a study that found that cricket frogs do not truly skim over the water but instead perform a series of “belly flops” in which they sink for a fraction of a second and then jump out. The researchers posited that the frogs may do so because they need time to reposition their legs to power each jump. I’d like to suggest that the purposes of a cricket frog’s reimmersion may be more involved and elegant.

Lifting a body out of the water requires considerable energy. At the size of the cricket frog, even the energy to overcome surface tension is most probably, in my opinion, significant. Although cricket frogs, like all adult frogs, have lungs, these organs alone may not suffice to deliver enough energy for aerial acrobatics, especially because aquatic amphibians take in much of their oxygen through their moist skin.

Even with high relative humidity over a brief time, whooshing through the air may dry a frog’s skin enough to reduce oxygenation during behavior that has increased the need for it. Reimmersion between jumps replaces skin moisture. Moreover, the water at the shallow depths in which the cricket frogs sink is probably nearly saturated with oxygen both from surface absorption and from algae and other plants. So brief immersion may act as the froggy version of a gasp for air, also rewetting the skin to absorb atmospheric oxygen during the next jump.

DAN HEMENWAY *VIA E-MAIL*

ERRATA

In a “A New View of CO_2,” by Lee Billings [Q&A December 2025], the illustration should have depicted carbon dioxide as a linear molecule.

“Flashes in the Night,” by Ann Finkbeiner [January 2026], should have said that China’s Einstein Probe began collecting data in mid-2024.

“The Imperiled Orcas of the Salish Sea,” by Kelso Harper [January 2026], incorrectly said that in 2008 Deborah Giles helped to develop an acoustic device used in orca research. She worked with colleagues to attach such devices to the backs of orcas that year.

Aaron Shattuck is a senior copy editor at *Scientific American*.

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https://www.scientificamerican.com/article/readers-respond-to-the-november-2025-issue

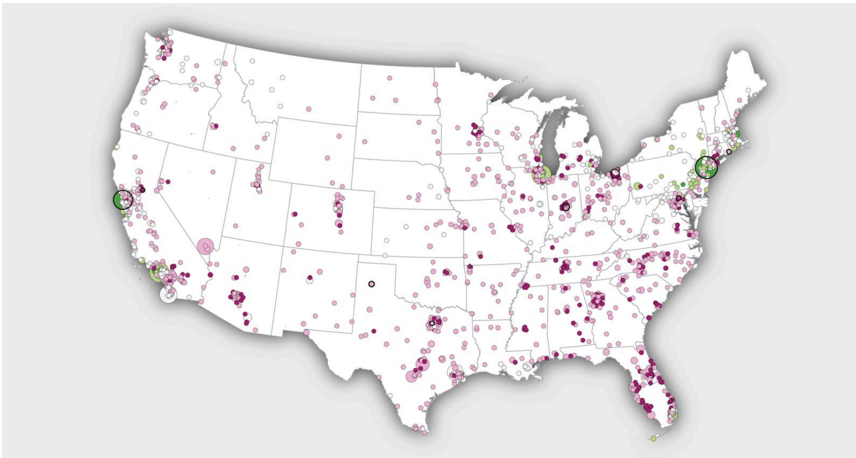
Health

- **Moving to a walkable city can add 1,100 steps to your day**
  Researchers found that walkable city design—not personal motivation—was the key factor behind people taking 1,100 more steps per day

Your daily steps may depend on your zip code more than your willpower

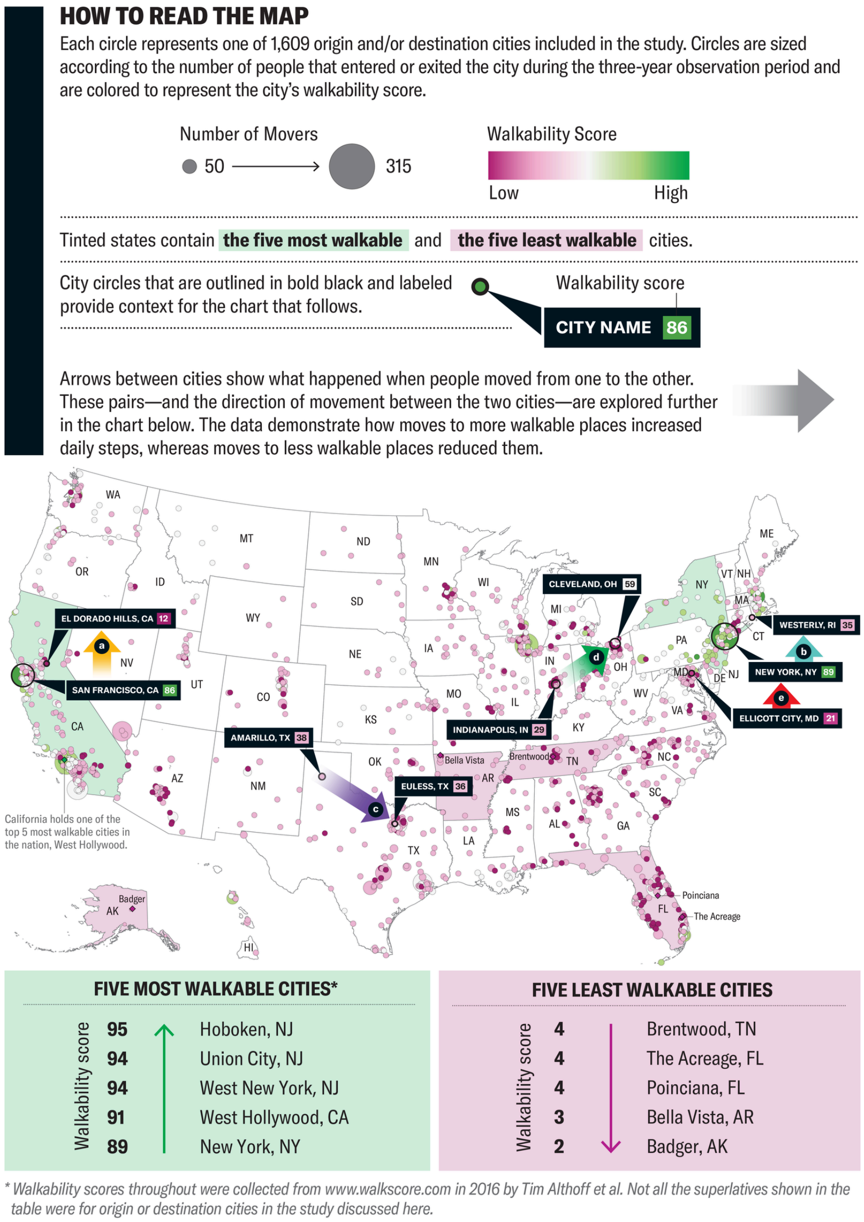
Researchers found that walkable city design—not personal motivation—was the key factor behind people taking 1,100 more steps per day

By Eve Lu edited by Jen Christiansen & Clara Moskowitz



Eve Lu

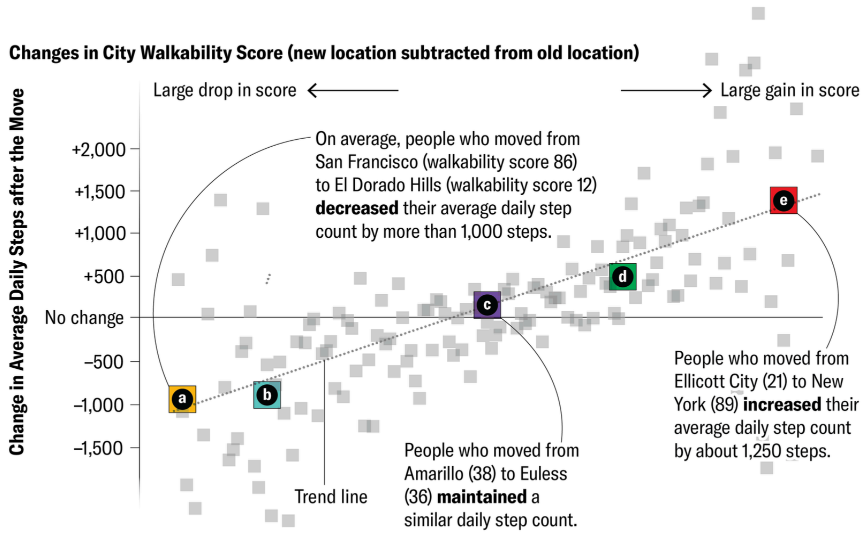
Neighborhood walkability is a bit of a chicken-and-egg problem: Does living in a walkable city make you walk more, or do active people choose to live where it’s easier to walk? To investigate, researchers analyzed smartphone data from between 2013 and 2016 for two million people, including more than 5,000 people who moved among more than 1,600 U.S. cities. Tim Althoff, a computer scientist at the University of Washington, and his colleagues found that after relocating to more walkable cities, people took about 1,100 more steps a day, equivalent to 11 minutes of extra daily walking. What’s more intriguing is that these additional steps were part of brisk walks—physical activity that improves health and could contribute to a lower risk of death all around. Meanwhile, the data showed, people who moved between similarly walkable cities didn’t change their activity level. The findings suggest built environments, rather than personal choice alone, might affect not just the amount but the intensity of the exercise their inhabitants get.



Eve Lu; Sources: "Countrywide Natural Experiment Links Built Environment to Physical Activity," by Tim Althoff et al., in *Nature*, Vol. 645; September 11, 2025; Walk Score (*data*)

MORE WALKABLE, MORE STEPS

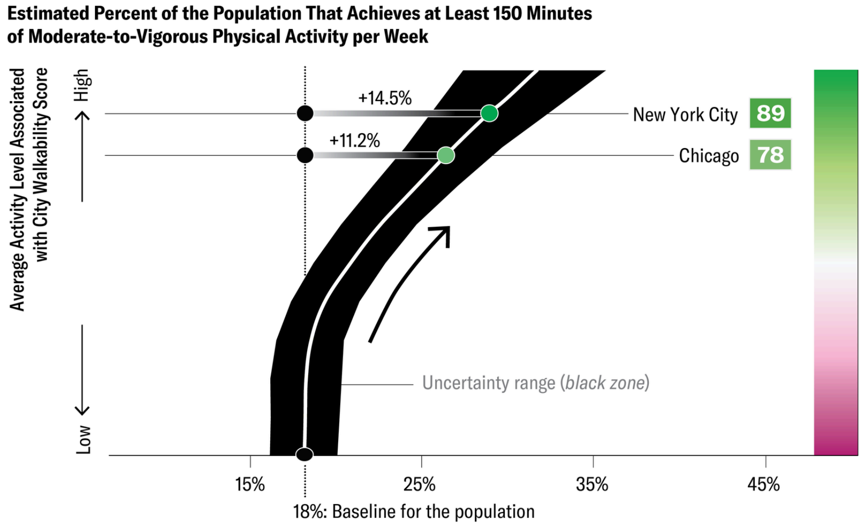
Each square represents a relocation pair of cities. One axis shows the change in city walkability, and the other axis shows the change in daily steps. Those who moved to more walkable cities added about 1,100 steps a day, and relocating to less walkable places cut activity by a similar amount.



Eve Lu; Source: "Countrywide Natural Experiment Links Built Environment to Physical Activity," by Tim Althoff et al., in *Nature*, Vol. 645; September 11, 2025 (*data*)

WHAT IF EVERY U.S. CITY WALKED LIKE NEW YORK CITY AND CHICAGO?

If all U.S. cities had Chicago's walkability score of 78, the average person would walk 443 more steps a day and gain an extra 24 minutes of weekly moderate to vigorous physical activity: enough for 11.2 percent of people, or 36 million more Americans, to meet targets in aerobic-activity guidelines. And if everyone walked like New Yorkers, an even larger share—14.5 percent, or about 47 million people—would meet those targets.



Eve Lu; Source: "Countrywide Natural Experiment Links Built Environment to Physical Activity," by Tim Althoff et al., in *Nature*, Vol. 645; September 11, 2025 (*data*)

Eve Lu is a data journalist covering gender inequality, public health, the environment and technology. She was a graphics intern at *Scientific American*. She holds a master's degree in data journalism from Stanford University and previously worked at the *Tampa Bay Times*.

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https://www.scientificamerican.com/article/moving-to-a-walkable-city-can-add-1-100-steps-to-your-day

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Health Care

- **Dealing with stress-caused sickness in family caregivers**
  People who help sick, aging loved ones are at risk for physical illness themselves. There may be ways to improve their resilience

Better care for family caregivers

People who help sick, aging loved ones are at risk for physical illness themselves. There may be ways to improve their resilience

By Lydia Denworth edited by Josh Fischman

Jay Bendt

This article was made possible by the support of Yakult and produced independently by Scientific American*'s board of editors.*

My mother lived with Alzheimer's disease for 12 years. Even with a lot of help, caregiving took a toll on me. It was physically hard to transfer her from bed to wheelchair, hard on my time when Mom couldn't be left alone, and emotionally devastating as her decline took away the person I had known and loved. She passed away in 2024.

Roughly one in five American adults is now where I was: responsible for the care of a chronically ill or disabled loved one. About half of them are doing this work for elderly relatives. It is well known that family caregivers are at higher risk than noncaregivers for depression. But such helpers also have more than their share of diabetes, asthma, obesity and a variety of pain conditions. And they tend to die earlier. In a study by the U.S. Centers for Disease Control and Prevention released in 2024, caregivers scored worse than noncaregivers on 13 of 19 health indicators. The root cause, research shows, is chronic stress. It leads not only to mental distress but also, by hampering the immune system, to physical ailments.

Caregivers are finally getting some care, however. Scientists are using what they've learned about how stress affects mental and physical function to develop approaches that could strengthen resilience. "It's important to understand that the caregiving itself, though a strain, does not determine worse mental and physical health," says psychologist Elissa Epel, who directs the Aging, Metabolism and Emotions Center at the University of California, San Francisco. "There are a lot of resilience factors that can make a difference."

Innovative programs providing support and resources are slowly being replicated around the country. And in 2024 the Centers for Medicaid and Medicare Services adopted policies that will help physicians train people to provide direct care to relatives and will support both doctors and families as they do so.

> Combined with depression, the strain of caregiving increases inflammation that contributes to age-related bodily damage, an effect called inflammaging.

The connections among chronic stress, impaired immunity and physical problems came to light in the 1980s and 1990s in pioneering work by psychoneuroimmunologist Janice Kiecolt-Glaser of the Ohio State University. Among other things, she found that spouses caring for ill partners recovered more slowly from puncture wounds on their arms than those who weren't providing care.

Caregivers also appear biologically older than people without a caregiving burden. "We know caregiving accelerates many domains of aging," says social psychologist Kathi Heffner, associate chief of research in the geriatrics and aging division of the University of Rochester Medical Center. Combined with depression, the strain of caregiving increases inflammation that contributes to age-related bodily damage, an effect called inflammaging. Studies of caregivers show decreases in the enzyme activity that protects telomeres, caps on the ends of chromosomes that get shorter as people get older. Those telomeres shrink faster in people who are under stress, and that includes caregivers.

As we age, our bodies also produce fewer naive T cells—immune cells the body holds in reserve until it is faced with a novel attacker, such as SARS-CoV-2, the virus that causes COVID. A person's T cell profile, the ratio of naive to mature cells, can indicate the health of their immune system. Epel and her colleagues showed in 2018 that parents caring for disabled children have T cell profiles that skew toward fewer naive ones, and this observation is consistent with accelerated immunological aging.

One obvious way to help caregivers is to lower their burden. In a program called Caring for Caregivers at Rush University Medical Center in Chicago, one of the goals is to raise awareness of the effects of caregiving and change the culture among health-care providers. "We want primary-care doctors to start asking, 'Are you providing care for someone?'" says Diane Mariani, a social worker and program manager of Caring for Caregivers. "Then it should go further: 'How do you feel it might be affecting your health?'" And go further still, with the doctor offering possible remedies.

Unfortunately, a caregiver's burden often grows over time, especially when they are caring for someone with cancer or dementia. “The stressors aren’t going to go away,” Heffner says. “In fact, the challenges are going to increase as the disease progresses.” That’s why Heffner, Epel, and others are looking to strengthen resilience. They have noticed that not all caregivers are affected in the same way. “People can find more meaning and purpose in being a caregiver,” Epel says. Those with social support seem to do better.

In a 2025 randomized trial, Heffner tested cognitive training (such as brain games) as a strategy to build resilience. Previous studies found such training and games can produce faster neural processing in people, and that speed correlates with higher adaptability to stress. Ninety-six people caring for loved ones with dementia played games designed to improve their speed of processing and attention for eight weeks; another 96 watched educational videos. The game players showed significantly improved processing speed and attention six months later. “A year later they reported being less bothered by the memory and behavioral challenges of the person they were caring for,” Heffner says. She is now examining blood work from the study participants to look for any improvements in immune responses and to see whether the cognitive training slowed aging in T cell profiles.

“If we can increase the capacity for stress adaptation in these caregivers, that’s going to lead to better outcomes and to better quality of life for the caregivers,” Heffner says. That’s a result we should all care about.

Lydia Denworth is an award-winning science journalist and contributing editor for *Scientific American*. She is author of *Friendship: The Evolution, Biology, and Extraordinary Power of Life's Fundamental Bond* (W. W. Norton, 2020) and several other books of popular science.

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https://www.scientificamerican.com/article/dealing-with-stress-caused-sickness-in-family-caregivers

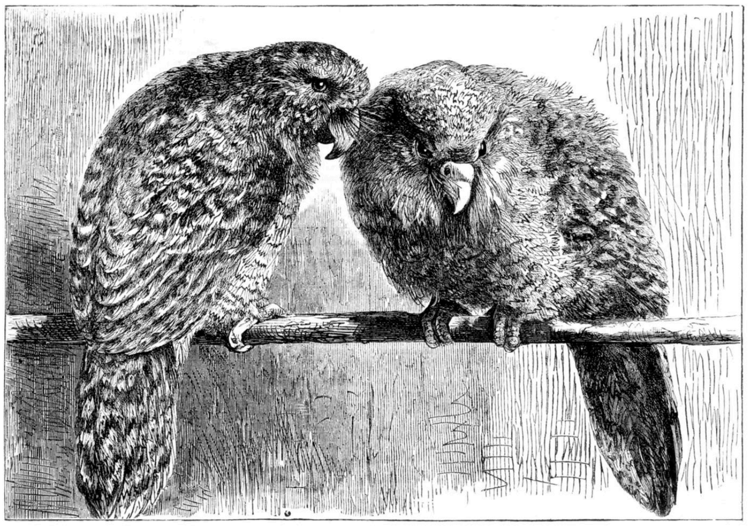
History

- **March 2026: Science history from 50, 100 and 150 years ago**
  A Greenland mystery; booming dunes

March 2026: Science history from 50, 100 and 150 years ago

A Greenland mystery; booming dunes

By Jeanna Bryner



THE OWL PARROT.—(STRIGOPS HABROPTILUS.)

1876, The Owl Parrot: "This singular bird, sometimes called the night parrot, belongs to New Zealand. It has the form of a parrot but bears a facial aspect resembling that of an owl. But it is not a bird of prey, as it eats corn and nuts readily when in captivity. The specimens herewith illustrated are domiciled in the unrivaled collection in the gardens of the Royal Zoological Society in London, England."
Scientific American, Vol. 34, No. 12; March 1876

1976

Catastrophe Theory

“Any object or concept can be represented as a form, a topological surface, and consequently any process can be regarded as a transition from one form to another. If the transition is smooth and continuous, there are well-established mathematical methods for describing it. In nature, however, the evolution of forms usually involves abrupt changes and perplexing divergences, or transformations. Because these transformations represent sudden disruptions of otherwise continuous processes, René Thom of the Institut des Hautes Études Scientifiques in France termed them elementary catastrophes.

Such catastrophe theory has been particularly interesting in its applications to the biological and social sciences. Thom suggests applications in embryology, as well as in the theory of evolution, in reproduction, in the process of thought and in the generation of speech. For the living cell and for the organism, life is one catastrophe after another."

Booming Dunes

"A sand dune would not seem to be a very likely candidate as a natural sound generator. But dunes in many parts of the world squeak, roar or boom. Acoustic sands have been described in desert legend but have received little scientific attention. Recently scientists have conducted the first quantitative analysis of the properties of an acoustic dune called Sand Mountain near Fallon, Nev. After trying several different methods, they found that the sand boomed loudest when a trench was rapidly dug in it with a flat-bladed shovel. The sound was like a short, low note on a cello; it lasted for less than two seconds and was readily audible at a distance of 30 meters. The booming could also be produced by pulling the sand downhill with the hand; in that case, strong vibrations reminiscent of a mild electric shock could be felt in the fingertips."

1926

Greenland's Norse Mystery

"The excavations carried out by Dr. Poul Nørlund of the National Museum, Copenhagen, at Herjolfsnes, the Old Norse settlement of Osterbygd, in Southern Greenland, throw light upon the mysterious fate of the early Norse settlers. In the ancient churchyard at

Herjolfsnes, some 200 valuable relics were found, including coffins, skeletons of the old Vikings in their shrouds, well-preserved garments, implements, tools, ornaments and Christian crosses.

The style and cut of many of the costumes show that the Norsemen were in communication with Europe up to then; however, evidence shows around that time a fatal change of climate occurred in these northern latitudes. Whereas Herjolfsnes had been free of ice all through the summer, it suddenly became blocked virtually all through the year. Being cut off from Europe and being called upon to face a hard climate, the colonists gradually deteriorated in physique. This is evidenced by an examination of the skeletons. Against the Eskimos, so brilliantly adapted to the arctic conditions, the physically weakened Norsemen could not hold out, and their doom was sealed by the encroaching Greenland ice."

The Carolina Wren

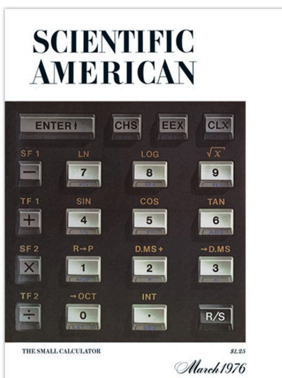
"The early naturalists in America were woefully twisted in the matter of names. Not only were absurd appellations used in imitation of Old World names—such as robin, partridge and pheasant—but also terms to suggest restricted habitats. Thus, for widely distributed species, we have such titles as Maryland yellow-throat, Louisiana heron and Carolina wren. The Carolinas have no more right to be honored with the name of this little songster than have any other states in its range. If I were to pick a favorite bird, one of truly heroic mold and one that is worthy of the greatest admiration for its abilities as a musician, architect, artisan, its happy, optimistic disposition and its domestic virtues, I would choose the Carolina wren."

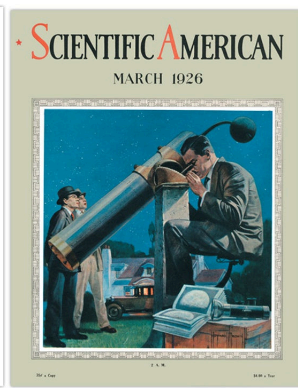
1876

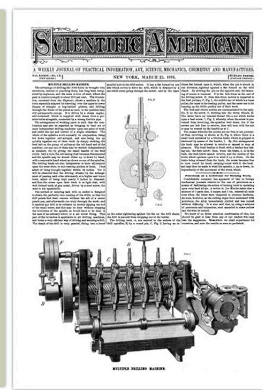
Another Obnoxious Postal Law

“An obnoxious postal law was passed during the closing hours of the last congressional session, the effect of which was to double the postage on transient newspapers, magazines and periodicals, books, and merchandise. A new bill stipulates the following: For distances up to 300 miles, one cent for each two ounces; for distances between 300 and 800 miles, two cents; between 800 and 1,500 miles, three cents, and so forth.

The proposed measure will bring chaos on postal affairs. It presupposes a geographical knowledge throughout the entire population, which never could exist. Not only must a man know the distance of every post office from his residence, but the distance of every post office from every other post office, else he could not stamp his packages correctly. Congress should not pass this bill.”







Jeanna Bryner is executive editor of *Scientific American*. Previously she was editor in chief of Live Science and, prior to that, an editor at Scholastic's *Science World* magazine. Bryner has an English degree from Salisbury University, a master’s degree in biogeochemistry and environmental sciences from the University of Maryland and a graduate science journalism degree from New York University. She has worked as a biologist in Florida, where she monitored wetlands and did field surveys for endangered species, including the gorgeous Florida Scrub Jay. She also received an ocean sciences journalism fellowship from the Woods Hole Oceanographic Institution. She is a firm believer that science is for everyone and that just about everything can be viewed through the lens of science.

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https://www.scientificamerican.com/article/march-2026-science-history-from-50-100-and-150-years-ago

Language

- **Science crossword: What’s inside?**
  Play this crossword inspired by the March 2026 issue of Scientific American

Science Crossword: What’s Inside?

By Aimee Lucido

This crossword is inspired by the March 2026 issue of Scientific American. *Read it here. Print readers, check your answers by selecting “Assist” above and then “Reveal Grid” or by selecting “Print” and then “Solution.”*

We’d love to hear from you! E-mail us at games@sciam.com to share your experience.

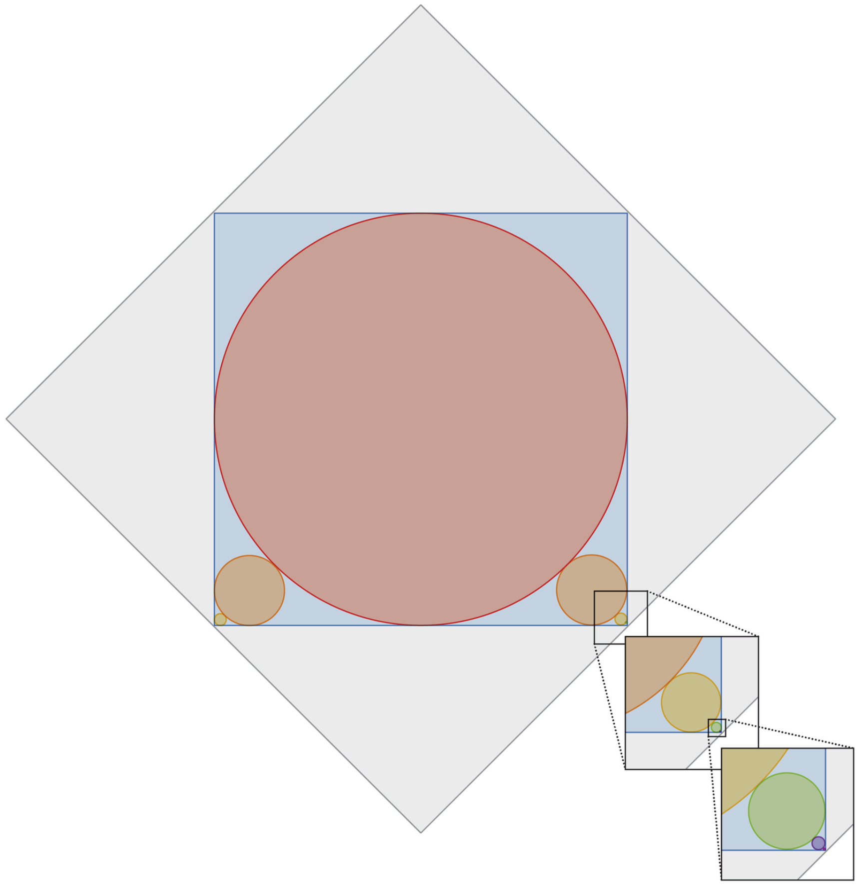
Aimee Lucido makes crosswords part-time for several outlets and writes trivia full-time for Bloomberg's news quiz, Pointed. She is also the author of several books for kids, including *Emmy in the Key of Code*, *Recipe for Disaster*, and *Pasta Pasta Lotsa Pasta*. Lucido lives with her husband, daughter and dog in New York.

Mathematics

- ## Math puzzle: The sum of all circles
  Sum up the circles in this math puzzle
- ## How ‘effectively zero-knowledge’ proofs could transform cryptography
  A new tool expands the ways people can prove they’ve solved a problem without revealing the solution
- ## This mathematician proved the random walk theorem to clear his name as a lurker
  George Pólya’s random walk theorem absolved him of being a lurker and revealed how the laws of chance interact with physical space

Math puzzle: The sum of all circles

By Jack Murtagh



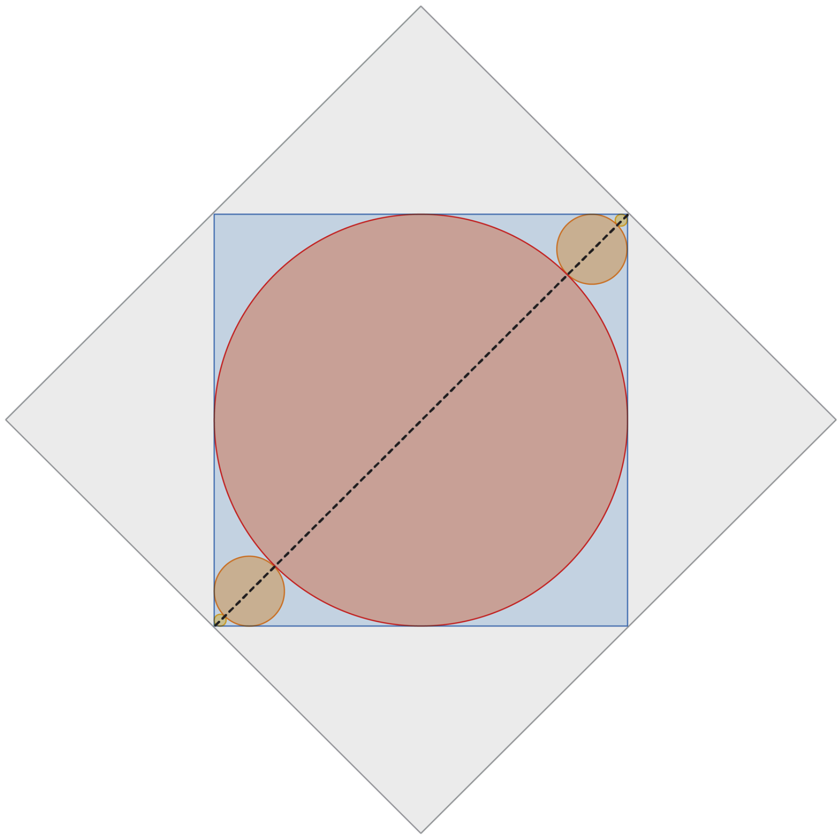
Amanda Montañez

A red circle is inscribed inside a blue square. The arrangement leaves gaps in the square's four corners, two of which are filled with smaller circles that just barely touch the big red circle and the two corner sides of the blue square. This, in turn, leaves two smaller gaps in the corners, which are filled with smaller circles, and so on, with ever smaller circles ad infinitum. The entire diagram is inscribed inside of a 1 × 1 gray square. What is the total circumference of all the circles?

The total circumference of all the circles is π. The circumference of a circle is π times its diameter. So the total circumference of many circles with diameters d_1, d_2, $d_{3,}$... is:

$$\pi d_1 + \pi d_2 + \pi d_3 + \ldots = \pi(d_1 + d_2 + d_3 + \ldots)$$

So if we can find the sum of all the diameters, we can multiply that value by π, and we’re done. Because of the symmetry, the sizes of the circles don’t change if we move some to different corners:



Amanda Montañez

Because infinitely many circles tend toward the corners of the blue square, the sum of the circles’ diameters equals the length of the diagonal of the blue square (*pictured as a dashed line*). This length equals 1 because the outer gray square has side length of 1.

We’d love to hear from you! E-mail us at games@sciam.com to share your experience.

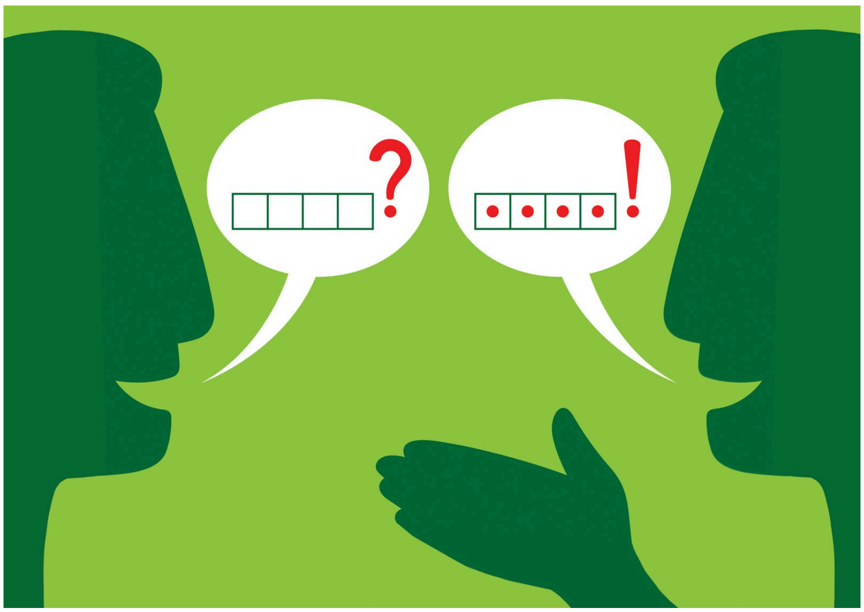
Jack Murtagh is a freelance math writer and puzzle creator. He writes a column on mathematical curiosities for *Scientific American* and creates daily puzzles for the Morning Brew newsletter. He holds a Ph.D. in theoretical computer science from Harvard University. Follow him on X @JackPMurtagh

https://www.scientificamerican.com/article/math-puzzle-the-sum-of-all-circles

How ‘effectively zero-knowledge’ proofs could transform cryptography

A new tool expands the ways people can prove they’ve solved a problem without revealing the solution

By Peter Hall edited by Sarah Lewin Frasier



Thomas Fuchs

In mathematics, proofs can be written down and shared. In cryptography, when people are trying to avoid revealing their secrets, proofs are not always so simple—but a new result significantly closes this gap.

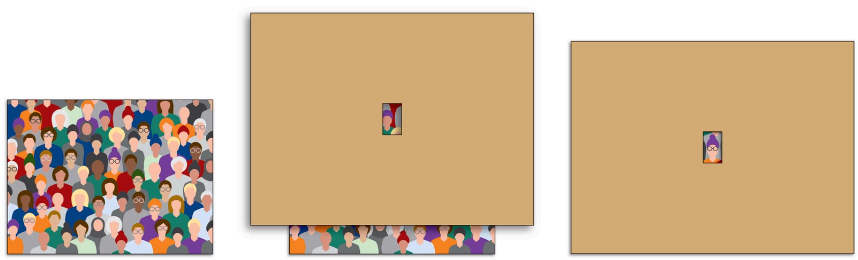
Zero-knowledge proofs are the closest cryptography gets to magic. They promise to let one person convince another of the truth of some fact—say, that they know the solution to a sudoku puzzle—without giving away any information about it. Such proofs can help people authenticate identities virtually, make online banking transactions, build blockchains, and more.

Cryptographers, however, have long understood that zero-knowledge proofs can't safely be written down like a typical mathematical proof. Instead the prover needs to interact with the person they're convincing. In rare cases, the prover can also persuade someone of something untrue (such as that a sudoku puzzle is completable when it has no solution).

Computer scientist Rahul Ilango realized there was a gap between how zero knowledge is defined and how it's used. Typical zero-knowledge proofs require a demonstration of how to build what's called a simulator, which can re-create the steps of the proof without actually knowing the secret solution. The existence of this simulator shows that the proof process does not reveal anything about the solution itself. But Ilango found that it can be enough, in some cases, to simply show that a simulator's existence can't be ruled out. He presented the result at the 2025 IEEE Symposium on Foundations of Computer Science in Sydney.

Where's Charlie?

To understand how someone can show they have solved a puzzle without giving away the solution, consider the following scenario.



The challenge is to find Charlie in this photo. Charlie wears an orange shirt, a purple hat and glasses. Alice searches the photo and finds him.

Alice wants to prove to Bob that she has found Charlie without giving away his location. Bob cuts a small hole in a large piece of cardboard and gives it to Alice.

Alice places the cardboard over the photo so that only Charlie is visible and shows it to Bob.

Amanda Montañez

"You could imagine some really strange scenario where a cryptographic system is insecure [and reveals something about the information that is locked inside], but it's impossible to prove it's insecure," says Ilango, who is based at the Institute for Advanced Study in Princeton, N.J. "What that means is it's basically secure for all practical purposes."

Because this new criterion is just a bit easier to satisfy than zero knowledge, Ilango could build protocols that don't need the parties to interact and that prevent the prover from being able to convince with false answers.

To construct the new proof system, called an effectively zero-knowledge proof, Ilango took ideas from mathematician Kurt Gödel's 1931 incompleteness theorem, which basically says many sets of assumptions have some facts they can neither prove nor disprove. Ilango showed that he could construct a proof system in which such assumptions, including a set known as ZFC that underlies much of mathematics, cannot disprove a simulator's existence even when it doesn't exist.

University of California, Los Angeles, computer scientist Amit Sahai, who was not involved in the work, says this paradigm is already proving more useful than he initially expected. "It's just so beautiful," Sahai says. "[Ilango]'s paper is, in my opinion, the most creative and most consequential paper in the field of zero-knowledge proofs at least in the past decade."

Peter Hall is a freelance journalist and Ph.D. candidate in computer science at New York University. He is based in Brooklyn, N.Y.

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https://www.scientificamerican.com/article/how-effectively-zero-knowledge-proofs-could-transform-cryptography

This mathematician proved a brilliant theorem to justify his social awkwardness

George Pólya's random walk theorem absolved him of being a lurker and revealed how the laws of chance interact with physical space

By Jack Murtagh edited by Jeanna Bryner

tamara_kulikova/Getty Images

More than 100 years ago Hungarian-born mathematician George Pólya found himself trapped in a loop of social awkwardness. A professor at the Swiss Federal Institute of Technology Zurich, he enjoyed solitary strolls through the woods outside the city. During one of these rambles, he walked by one of his students and the student's fiancée. Then, sometime later, still roaming aimlessly, he bumped into the couple again. And then later he did so yet again.

Writing about the experience in an essay published in a 1970 book, Pólya recounted, "I don't remember how many times [this happened], but certainly much too often and I felt embarrassed: It looked as if I was snooping around which was, I assure you, not the case."

Desperate to clear his name as a lurker, Pólya did what any good mathematician would do: he generalized the problem. Are two wanderers mathematically destined to cross paths? His original formulation simplified the picture by considering only a single walker on an infinite grid. Every second, the walker chooses a compass direction at random, independent of previous steps. Pólya's mathematical aim was to determine the probability that the walker would eventually return to their starting point. This answer turns out to be equivalent to the probability that two walkers who start at the same location will ever meet again. He found that if a walker roams forever, they *will* return to their starting place.

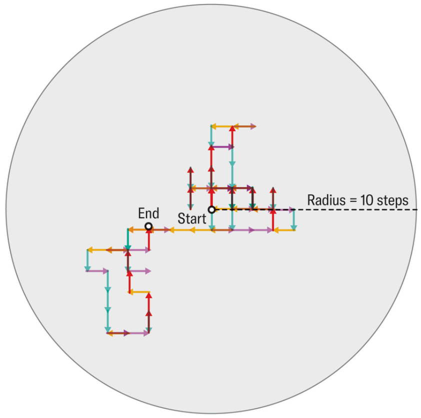
The answer not only absolved him but also revealed a fundamental divide in how the laws of chance interact with physical space. Pólya's calculations showed that on a two-dimensional surface (such as a forest floor), a random walker is destined to return to their starting point—but in a three-dimensional space, that person is more likely to never return to the starting point. The discovery crops up across chemistry and biology, even explaining how certain molecules efficiently find the appropriate receptor on cell surfaces.

As described in the 2019 fifth edition of *Probability: Theory and Examples*, by Rick Durrett, mathematician Shizuo Kakutani captured the theorem with a witticism: "A drunk man will eventually find his way home, but a drunk bird may get lost forever."

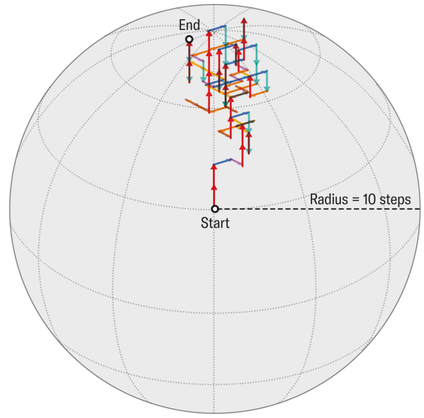
Here "drunk bird" refers to not a buzzed buzzard but a random process on a three-dimensional grid (imagine a jungle gym). Every second, the bird chooses from north, south, east, west, and up or down, at random, independent of previous choices. Pólya proved that if you walk forever at random through an infinitely sprawling city grid, then you not only will be guaranteed to return to your starting spot but also will hit *every* spot on the grid an infinite number of times. If, however, you conduct the same process on an infinite jungle gym, you will have a nearly 66 percent chance of never returning to your starting point. Likewise *two* wanderers on a jungle gym may never meet, but two wanderers on a flat surface must meet an infinite number of times—Pólya didn't lack social grace; he lacked a third dimension to escape into.

Even the one-dimensional case, which behaves mathematically like two dimensions, has real-world implications. Imagine rolling up to a casino with $500 in your pocket. A table offers a game with 50–50 odds of winning (better than you'll find at Monte Carlo). If you keep playing, no matter what betting strategy you use, you will go bust eventually. That's because we can model the game as a random walk on a number line. You start at 500, and after each round of play, you move either right or left on the line with an equal chance. Pólya tells us that, just as in the two-dimensional case, if you play for long enough you will inevitably explore the entire number line. This includes 0, at which point you'll go bankrupt. Mathematicians call this "the gambler's ruin," and it explains why they'd recommend quitting while you're ahead or, better yet, not playing at all.

Why do random walks sharply change character between two and three dimensions? Although three dimensions naturally offer more space to roam than two, that alone doesn't suffice as an explanation. After all, two dimensions offer more space than one, yet both exhibit the same behavior.



100 Random Steps in 2D Space
After 100 steps ($t = 100$), the size of the region where the walk is most likely to reside (a circle of radius $\sqrt{t} = 10$) contains hundreds of points (on the order of t). Because the number of steps taken is on a par with the size of this region, the walk visits a decent portion of the circle.



100 Random Steps in 3D Space
After 100 steps ($t = 100$), the size of the region where the walk is most likely to reside (a sphere of radius $\sqrt{t} = 10$) contains thousands of points (on the order of $t^{1.5}$). Because the number of steps taken is significantly smaller than the size of this region, the walk visits only a small portion of the sphere. The difference in coverage between walks in two- and three-dimensional space gets more dramatic as t grows.

Amanda Montañez

If you take a random walk for some finite number of steps that we'll call t, then you typically won't stray farther than $\sqrt{t}$ (the square root of t) away from the origin. In concrete terms, after 100 steps, most walkers will be found within just 10 steps, or $\sqrt{100}$, of the start. Intuitively, random walks tend to hover near the origin because successive steps can cancel each other out (a walker who takes an eastward step followed by a westward step hasn't progressed at all). Mathematically, $\sqrt{t}$ equals the standard deviation (a statistical measure of how spread out a set of values are) of the distance from the origin of a t-step random walk.

In other words, if many separate walkers all begin at the same place and roam independently, then the plot of their distances from the origin after t steps would look like a bell curve centered at 0 and with the standard deviation $\sqrt{t}$. Deriving the standard deviation for the one-dimensional case is an approachable exercise if you've taken a statistics class—give it a try.

This $\sqrt{t}$ figure holds in every dimension and is the key to understanding Pólya's theorem. Think of it like the radius of the region a walker will explore in t steps. This radius has wildly different implications in different dimensions because the number of dimensions determines whether we're talking about length, area or volume. A line segment with the radius $\sqrt{t}$ has a size on the order of $\sqrt{t}$; a circle with the radius $\sqrt{t}$ has a size on the order of t (the area of a circle is proportional to the radius squared); and a sphere with the radius $\sqrt{t}$ has a size on the order of $t^{1.5}$ (the volume of a sphere is proportional to the radius cubed).

But regardless of dimension, a walker taking t steps cannot visit more than *t* distinct points. In one dimension, the number of steps exceeds the size of the region explored ($t > \sqrt{t}$), forcing the walker to retrace their steps constantly. In two dimensions, the number of steps matches the region's size ($t = t$), allowing the walker to eventually cover the grid, albeit thinly. But in three dimensions, the space is vast compared with the number of steps ($t < t^{1.5}$), leaving most points unvisited and the origin unlikely to be revisited.

Of course, the real world rarely resembles a perfect grid, and birds don't flip coins at every wingbeat. Still, this contrast between two- and three-dimensional walks has surprisingly practical stakes in the natural sciences. One compelling example involves how chemicals react in our body. Researchers often use random walks to model molecules diffusing through another substance. Consider a hormone trying to find a specific receptor on a cell's surface. It doesn't have a homing mechanism, so such reactions happen through chance encounters.

The hormone could wander aimlessly through the three-dimensional fluid around the cell until it bumps into its target. Instead many molecules bind loosely to *any* point on the cell membrane first. Once attached, they slide across the two-dimensional surface of the membrane until they hit their target. This reduction of dimensionality turns a slow three-dimensional walk into an efficient two-dimensional one.

Next time you run into someone you're avoiding, try to turn the encounter into a profound mathematical insight. It sure beats hiding behind a tree.

Jack Murtagh is a freelance math writer and puzzle creator. He writes a column on mathematical curiosities for *Scientific American* and creates daily puzzles for the Morning Brew newsletter. He holds a Ph.D. in theoretical computer science from Harvard University. Follow him on X @JackPMurtagh

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| Section menu | Main menu |

Microbiology

- **Yellowstone’s earthquakes spark microbial boom deep underground**
  Earthquake swarms can supercharge microbial growth

Yellowstone’s earthquakes spark microbial boom deep underground

Earthquake swarms can supercharge microbial growth

By Damien Pine edited by Sarah Lewin Frasier

A swarm of 2,182 earthquakes at Yellowstone National Park was key for a new finding about microbes.
Cheryl Ramalho/Getty Images

With some luck, specialized equipment, a supervolcano and a narrow hole 30 stories deep, researchers demonstrated that earthquakes shake up more than just rocks—they also boost microbe populations living underground.

Up to 30 percent of life on Earth doesn’t ever see sunlight; instead these organisms get energy by chowing down on hydrogen generated through chemical interactions between water and rocks. Earthquakes fracture rocks, creating fresh reaction surfaces and shifting the pathways water travels along, which increase hydrogen production. For a study in *PNAS Nexus*, researchers tracked the effects of such shake-ups on microbes at the bottom of a 100-meter-deep borehole in Yellowstone National Park.

The scientists made a 10-hour round-trip trek to and from the test site seven times over seven months. There they collected samples of rock, dissolved gas and microbes, overcoming equipment malfunctions, logistical difficulties, and more along the way. The group was lucky enough to be taking measurements at just the right time—and in the ideal location—to perfectly catch the rise and fall of a rare “swarm” of 2,182 earthquakes. Yellowstone endures a lot of earthquakes, but swarms this powerful tend to occur every five to 10 years, says Montana State University geomicrobiologist Eric Boyd, the study’s lead author.

During the swarm, the amount of microbial life present increased by 6.5 times before dropping back to normal after the tremors subsided. Hydrogen levels also increased, and the types of microbes observed changed. “All the pieces fit together nicely,” Boyd says. “We put all of these data together, and we’re like, holy cow!”

The results might offer clues for finding life thriving under otherworldly surfaces, too. “Extrapolation to other planets and moons suggests that subsurface life might be most easily found in seismically active locations,” says Steven D’Hondt, who studies below-seafloor life at the University of Rhode Island and was not involved with the work. “It’s a wonderful study,” he adds.

Caroline Freissinet, an astrobiologist at French research institute LATMOS who was not involved with the work, says that although it’s a great result for understanding Earth, the study is unlikely to change much about the search for life on our nearest neighboring planet, Mars, because of its “hellish subsurface conditions.”

“Mars in the past was wetter,” she says, “but what would be left today of this temporarily enhanced activity, four billion years later?”

The Yellowstone study was “a really difficult project but a really meaningful one,” Boyd says. “Nobody had done this before.” He’s now working on developing an automated sampler triggered by earthquakes to dramatically increase data collection.

Damien Pine is a freelance journalist and ex-NASA engineer. Find Pine on Bluesky @pinebyline.com.

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https://www.scientificamerican.com/article/yellowstones-earthquakes-spark-microbial-boom-deep-underground

| Section menu | Main menu |

Neuroscience

- ## New research reveals how the brain separates speech into words
  Speech blurs together unless you know the language; scientists found the brain signal that separates the words
- ## How influential people map their social world
  The same brain areas that help us map physical space help us chart social connections, and the best relationship cartographers have most clout

New research reveals how the brain separates speech into words

Speech blurs together unless you know the language; scientists found the brain signal that separates the words

By Elise Cutts edited by Sarah Lewin Frasier

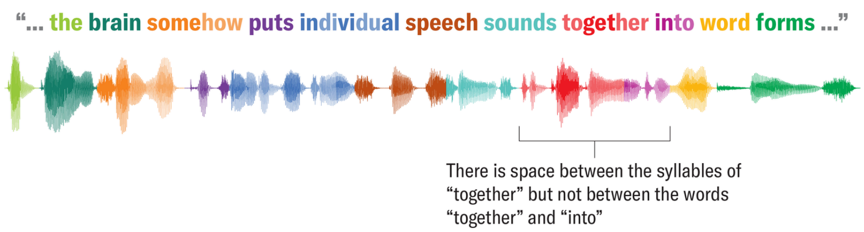
Thomas Fuchs

Speech sounds like it is made of words, but that impression has more to do with what's in our heads than with what comes out of our mouths. In natural speech, there are no clear acoustic boundaries separating words; we pause about as many times within words as we do between them. This is especially evident when listening to an unfamiliar language being spoken: words often seem to "blur" together into one smeared stream of sound.

So how does the brain slice speech into recognizable chunks? Recent research by neurologist and neurosurgeon Edward Chang of the University of California, San Francisco, and his colleagues reveals a hint. In one study, published in *Neuron*, the researchers looked at fast brain waves that flicker about 70 to 150 times per second through a part of the brain involved in speech perception. They realized that the power of these “high-gamma” waves consistently plummets about 100 milliseconds after a word boundary. Like a blank space in printed text, the sharp drop marks the end of a word for people who are fluent in that language.

“To my knowledge, this is the first time that we have a direct neural brain correlate of words,” Chang says. “That’s a big deal.”

In a different study, published in *Nature*, the scientists reported that native speakers of English, Spanish or Mandarin all showed these high-gamma responses to their mother tongues, but listening to foreign speech didn’t trigger the dips as strongly or consistently. Bilingual people showed nativelike patterns in both their languages, and the brain activity of adult English learners listening to English looked more nativelike the more proficient they were.



Source: “Human Cortical Dynamics of Auditory Word Form Encoding,” by Yizhen Zhang et al., in *Neuron*, Vol. 114; January 7, 2026; styled by Amanda Montañez

“This is a great first foray into the question” of how the brain marks word boundaries, says Massachusetts Institute of Technology neuroscientist Evelina Fedorenko, who wasn’t involved in either work. She adds, however, that it’s not yet clear whether actually understanding a language is necessary for word-break recognition. Maybe the brain simply picks up on sound patterns it hears often, regardless of comprehension. Or maybe meaning matters, as with muffled speech in a movie that suddenly sounds clearer when subtitles are switched on. Even if speech sounds and higher-level language structures are processed differently in the brain, the two can feed back into each other.

Experiments with artificial language that mimics natural speech sounds could tease apart the details, Fedorenko says.

When it comes to deciphering words, Chang suspects there may be no clean distinction between these different types of processing; the signal he and his co-workers linked to word boundaries occurs in a brain region that also recognizes speech sounds. Historically, Chang says, researchers imagined that different levels of structure in language, from sounds to words up to meaning, would be processed in dedicated brain regions. These new findings, he adds, "kind of blow that out of the water. This is actually all happening in the same place. When we compute sounds, we are computing words."

Elise Cutts is a science writer based in Austria. She has written for *Scientific American, Quanta, National Geographic*, and other outlets.

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https://www.scientificamerican.com/article/new-research-reveals-how-the-brain-separates-speech-into-words

How influential people map their social world

The same brain areas that help us map physical space help us chart social connections, and the best relationship cartographers have most clout

By Oriel FeldmanHall edited by Daisy Yuhas & Allison Parshall

aelitta/Getty Images

What do social climbers and gossipmongers have in common? My mother would tell me that both are morally suspect. This moral umbrage is etched into lessons from fairy tales and scripture that we readily pass on to our children: avoid the schemer and the whisperer.

But stories are known to simplify reality. The truth is that the most effective gossipers and social climbers possess a remarkable grasp of social structure, knowledge they use to cleverly navigate their social worlds. This skill isn't a moral failing; it's a cognitive feat. Our minds are sophisticated engines that mentally map our social landscapes. Who's close to whom? Who belongs to which group? Who's popular, and who's just one step away from power?

Recent work from my laboratory has shown that our mind's representations of the social world—what are known as cognitive maps—shape many of our critical social skills. We use these maps to rise in influence, figure out when we should choose to talk about others, and build tighter bonds with those in our inner circle. Social success depends not just on whom you know but also on how well you understand the invisible architecture of your social world.

Mapping this social architecture is no small feat. Consider the magnitude of the challenge. Real-world social networks are large, with hundreds of people and tens of thousands of possible connections. Knowing who is connected to whom is no trivial task. Every time a relationship is forged or destroyed, you need to mentally update that map. My colleagues and I wanted to understand what type of cognitive map would enable you to constantly keep stock of the changing social landscape. And perhaps more important, we wanted to know why someone would take the time and effort to mentally track the web of connections that surrounds them. It turns out that building a cognitive map of your social network affords quite a lot; in fact, it gives you superpowers.

> Those who rise to the top of the social hierarchy aren't the most charismatic or extroverted—they're the best social mapmakers.

To better understand the powers of social navigation, my collaborator Apoorva Bhandari, a cognitive neuroscientist at Brown University, and I developed a series of studies to probe how people build cognitive maps. But first we needed a population to follow. We wanted to test these mapmaking skills in a large group of people who have never met and then one day find themselves living in close proximity. What better option than college freshmen? Across a year we logged friendships as they formed and faded, building a live network of roughly 200 people. We also asked each student to tell us about their personality: "Do you like to socialize, or are you more of a wallflower?” Finally, we asked each student to tell us how they *thought* others were connected, yielding a second map of their beliefs about the network.

In one study, for example, we found that those who rise to the top of the social hierarchy aren’t the most charismatic or extroverted—they’re the best social mapmakers. By repeatedly asking our participants who their friends are, we can quantify who is most well-connected to other well-connected people—that is, who is most influential in their social network. The most influential people, this work shows, are the ones who quickly build mental maps of how their peers are connected. Armed with such a map, it’s relatively easy to identify who is part of which clique or group or whether there might be holes in the network where you can strategically position yourself. In contrast, people who were initially quite influential—connected to many other well-connected people—but who did not have accurate mental maps of the network did not stay influential for long.

In a second paper, we examined whether mapmaking aids in another type of socially adaptive behavior: gossiping. Although spilling the tea often gets a bad rap, the humdrums of life get spiced up through the stories we hear or tell others, and it can be an efficient way to quickly learn about the ins and outs of the community. Gossip has even shaped history from the shadows (for example, it’s been a tool used in civil rights movements and royal coups), which means paying attention to the currents of gossip is most likely a worthwhile endeavor. People seem to be quite sensitive to tracing gossip. We rarely get caught talking about others, for instance, even though more than 65 percent of our conversations are about other people.

To understand how humans pull off this remarkable feat, we wondered whether mapmaking helps to predict where information will spread. Calculating which of many paths gossip might travel requires quite a bit of mental math. You can’t just know the ties among your friends; you also need to grasp the connections among your friends' friends and beyond. Mental maps become quite useful in this case, we found, especially because they capture two key features of the network: how popular someone is and how far they are from the target of gossip. Maps that gauge popularity and distance can be used to quickly compute a good confidant—someone who is just far enough from the target so that gossip won't reach them yet well-connected enough to spread information effectively.

How does the brain build these maps? Two recent studies from my lab explain the map-building machinery that enables social wayfinding. In one study, still unpublished, we found that the hippocampus and entorhinal cortex—a neural hub known for navigating physical space—also carries a map of connections among people. The more strongly these maps are encoded in the brain, the better people are at brokering ties that knit their communities together.

In another study, we found evidence that the brain refines these maps during rest, when it has the time to think about all the possible network connections. This process of revisiting recent experiences is known as replay, akin to rewinding a movie on high speed. In this case, people at rest seem to be unconsciously thinking about all the ties in the network at extraordinarily high speeds. If the rest period includes sleep, the map becomes fuzzier (rather than more precise). This might sound problematic, but this fuzziness actually helps to reveal the overall shape of the network by making it more abstract. Abstraction, by design, naturally highlights the most important structures in the network—just as impressionist Claude Monet used broad, choppy brushstrokes to reveal the important elements in his paintings, letting his lily pads come into focus when viewed at a distance. For social networks, abstraction works by bringing into relief the most important routes, the highways and major arteries of the system. If the brain needs to quickly figure out where gossip might spread, knowing where the popular people are positioned or the key relationships that bridge otherwise disconnected communities allows us to chart the sequence of ties that can efficiently cross the network.

Surrounded by my three children, I often catch myself belting out lyrics from the movie *Moana*: “We set a course to find a brand-new island everywhere we roam.... We know the way.” But strategic wayfinding isn’t only for physical space. It is just as necessary to be able to effectively navigate through our social landscapes. Armed with a deliberately fuzzy atlas of their social community, skilled social navigators can do what no GPS can. They see the bridges before they’re built, steer around the storms of rumor, and chart a course to common ground.

Are you a scientist who specializes in neuroscience, cognitive science or psychology? And have you read a recent peer-reviewed paper that you would like to write about for Mind Matters? Please send suggestions to Scientific American*’s Mind Matters editor Daisy Yuhas at* dyuhas@sciam.com.

Oriel FeldmanHall is a neuroscientist and professor at Brown University. She studies the cognitive, affective and neural processes behind the complex choices that form the basis of human social behavior.

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https://www.scientificamerican.com/article/how-influential-people-map-their-social-world

Paleontology

- ## Ancient bees burrowed inside bones, fossils reveal

  Bones of now extinct species became a haven for bee babies thousands of years ago, scientists report in a first-of-its-kind discovery

Ancient bees burrowed inside bones, fossils reveal

Bones of now extinct species became a haven for bee babies thousands of years ago, scientists report in a first-of-its-kind discovery

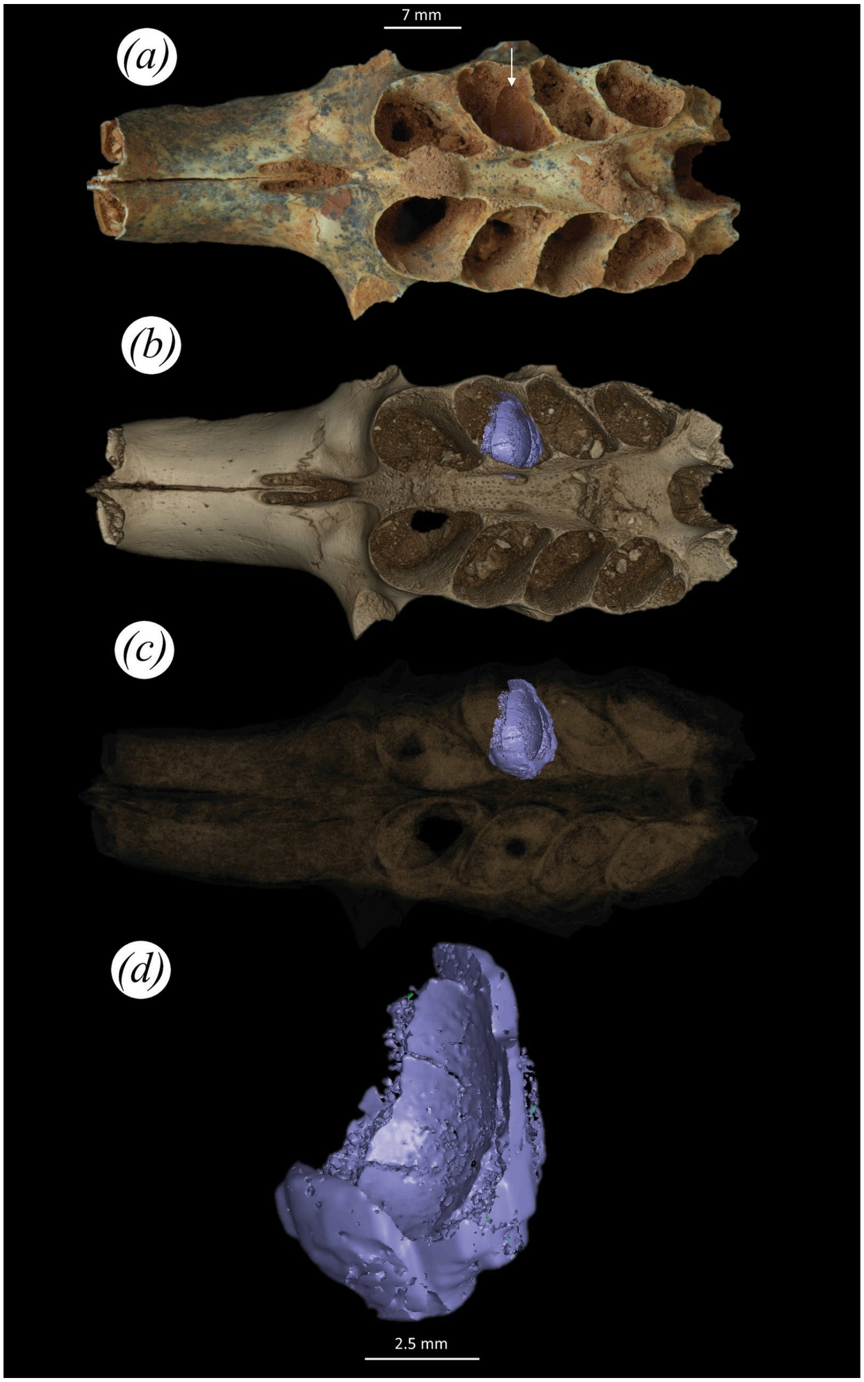
By Stephanie Pappas edited by Andrea Thompson & Sarah Lewin Frasier

Paleontologists working in a cave on the Caribbean island of Hispaniola have discovered the first known instance of ancient bees nesting inside preexisting fossil cavities.
Jorge Machuky

Thousands of years ago in what is now the Dominican Republic, there was a cave full of bones. And those bones were full of bees.

In a paleontological first, researchers have discovered that bees used the jawbones of now extinct mammals as burrows. It's not clear what species of bee was exploiting this grisly opportunity—only its smooth-walled nests were left behind, nestled in the tooth pockets of ancient rodents and sloths. Such behavior has never been documented before, says Lázaro W. Viñola López, a postdoctoral researcher at the Field Museum and one of the discoverers. "It was something completely unexpected," he says.

When Viñola López and his colleagues climbed past the jagged entrance of the cave, called Cueva de Mono, they were on the hunt for fossilized lizards, which they found—in excess. They also encountered tens of thousands of bones of extinct rodents and sloths, leading them to conclude that they'd stumbled on the killing field of an ancient family of owls that probably nested in the cave and regurgitated onto the cave floor. Although it is difficult to precisely date the fossils, similar deposits have been found that come from as early as 20,000 years ago. The cave fossils include species that went extinct around 4,500 years ago, the researchers report in *Royal Society Open Science*.



Photograph and CT scan of a fossilized jawbone showing the bee burrow trace in purple.
From “Trace Fossils within Mammal Remains Reveal Novel Bee Nesting Behaviour,” by Lázaro W. Viñola López et al., in *Royal Society Open Science*, Vol. 12; December 1, 2025 (CC BY 4.0)

In the dirt filling the empty tooth sockets of the rodent and sloth jawbones, Viñola López and his colleagues noticed strange cuplike structures they eventually realized had been made by bees. The hard, smooth walls of the cups were the result of a waterproof layer that solitary bees add to their brood cells, where the insects’ larvae develop.

More than 90 percent of bee species live solo, and most make their burrows in the ground. “Modern bees, as far as I know, aren’t known to nest in caves, nor are they known to nest in these sediment-filled cavities of bones,” says Emory University paleontologist Anthony J. Martin, who was not involved in the study but researches burrows and tracks, both known as trace fossils, left behind by ancient animals. He called the finding “a two-for-one surprise.”

Viñola López and his colleagues suspect the bees made use of the bones not long after the owls burped them up and might have done so because soils in the surrounding forests were thin.

Jorge Machuky

The bee-nest-filled bones were found in three of five soil layers, suggesting the bees used the cave over long time periods. There were also single tooth cavities filled with up to six different nests.

“It’s probably multiple bees coming and doing communal nesting,” Viñola López says.

The bones might have provided an extra bit of protection from predators such as parasitic wasps. “It’s kind of like a thermos,” Martin says. “They had this outer protective layer that was provided by the bone, and then they had their brooding cell, which was in the sediment, so they had double protection.”

Stephanie Pappas is a freelance science journalist based in Denver, Colo.

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https://www.scientificamerican.com/article/ancient-bees-burrowed-inside-bones-fossils-reveal

Solar

- **Vertical solar panels—wind-resistant trackers for high latitudes**
  Traditional solar fails in the windswept north. Two Swedish inventors are betting on aerodynamic resilience to solve the latitude gap

These vertical solar panels survive storms by ‘swaying’ like trees

Traditional solar fails in the windswept north. Two Swedish inventors are betting on aerodynamic resilience to solve the latitude gap

By Deni Ellis Béchard edited by Eric Sullivan

Vertical solar trackers work better the closer you get to the poles—in theory. But before Vaja, they were too fragile to withstand harsh winds.
Andréas Lennartsson

When the 47th solar panel exploded, Henrik Eskilsson began to fear he had signed on with a madman.

In his SUV, he and Anders Olsson were accelerating across Sweden’s Lunda Airfield, towing a trailer fitted with a steel mast that suspended the panel. As they gained speed, the panel did something unusual: it floated, catching the wind like a hang glider while staying anchored to the mast. The speedometer crept toward 100 kilometers per hour. The device began vibrating. Suddenly it snapped free, tumbled through the air and shattered on the runway.

Eskilsson, who'd previously founded a company that makes eye-tracking software, stopped the car and contemplated why he'd committed to this quixotic project: to revolutionize solar power for billions of people. Many areas in the Northern Hemisphere and some in the Southern lie in zones where traditional solar fields are inefficient, especially in winter—but also in the morning and evening. When the sun sits low, its rays hit horizontal panels at a shallow, grazing angle, delivering little energy. Vertical solar panels that track the sun even as it barely clears the tree line have proved too expensive, requiring multiple motors to rotate them, too much concrete to anchor them and too much steel to keep the wind from tearing them apart.

The shattered prototype was built by Vaja, the vertical-tracking start-up Olsson and Eskilsson founded several months earlier, in 2023, to solve this problem. For years Olsson had envisioned building solar systems that moved with the wind like leaves in a storm. He and Eskilsson had consulted with mechanical engineers, who said this design would be impossible. Olsson disagreed. Eskilsson trusted him, although he wondered how many more panels would first have to be destroyed.

They got out of the SUV, took brooms from the back and, in the brisk winter afternoon, began sweeping the runway.

Solar is the fastest-growing source of electricity globally, accounting for 7 percent of the world's generation in 2024, up from roughly 1 percent a decade earlier. In the 2010s utility companies invested heavily in solar farms with fixed-tilt panels—stationary solar arrays oriented toward the equator to catch the sun's light. Such systems produce the most electricity in the middle of the day. In markets with many solar farms, this is when electricity prices are lowest, making the panels less profitable. Then, as the sun goes down and electricity demand spikes, the panels cease to be productive.

Horizontal trackers help address such limitations by following the sun. Usually mounted on a north-south spine, the panels tilt like a seesaw—east at dawn, flat at midday and west at sunset. They can deliver up to 35 percent more energy than fixed-tilt systems for a modest bump in cost. Horizontal tracking has “basically exploded over the past 10 to 15 years,” Eskilsson says.

But horizontal trackers suffer from the same latitudinal shortcomings as fixed tilt: travel north or south from the equator, and the benefits diminish. Between the 30th and 40th parallels north—roughly aligned with Houston and Philadelphia, respectively—the equation shifts to favor vertical trackers: systems designed to intercept the light of a low-hanging sun that would otherwise skim over a horizontal array.

A handful of companies offer static vertical panels. In Europe, Norway’s Over Easy Solar and Germany’s Next2Sun and SOLYCO Solar provide a variety of vertical solar panels that harvest morning, evening and winter light. Making vertical trackers, which pivot around an upright axis like a revolving door, is far more challenging. All vertical panels catch the wind like sails. Stationary setups can be made to resist powerful gusts, but vertical trackers are more fragile because they are mobile and mounted on a single post.

Imagine a heavy roadside sign perched on a pole: the wind doesn’t just push against the sign; it tries to twist the pole, too. Torsion around a vertical post is nastier than around a horizontal tracker’s low-slung backbone, leading more easily to broken panels and motors. Efforts at beefing them up priced them out of existence. “These kinds of vertical trackers, even today, cost like four times as much as horizontal trackers,” Eskilsson says. Developers in the north stuck with static systems, using more panels to make up for lost productivity.

They got out of the SUV, took brooms from the back and began sweeping the runway.

Olsson, now 51, became interested in solar in 2017, before it was common in his country. On a ski trip he told a friend that Sweden didn't receive enough sunlight for the technology to work. The friend disagreed and showed him the math. "I realized when I saw the numbers that solar does make sense," Olsson says. The moment sparked his love for a challenge, and he spent the train ride home writing a business plan.

Soldags, Olsson's first solar panel company, took off installing panels for consumers, usually on roofs. But two years in he landed a contract to install panels on the ground, which required anchoring them with concrete blocks. "These things weighed 10 times more than the solar panels," Olsson says. As an engineering physicist and a recreational sailor, he knew how much torque wind could exert. Yet nature thrived in it—trees flexed, leaves feathered. Why did he have to bury money to hold panels still?

He shared his thoughts with his friend and fellow sailor Fredrik Lundell, a fluid dynamics professor and aerodynamics expert. As they spoke, they made sketches of a pivoting mount that might allow panels to feather in the wind.

At a cocktail party in 2023, Olsson approached Eskilsson, whom he viewed as the Swede most capable of taking a company global. Since his youth, Eskilsson, now 51, loved business. At 15, he began buying and selling computers. Then, as an exchange student in Canada, he saw his first trampoline and started shipping them to Sweden. He later co-founded an eye-tracking company, Tobii, which bought a patent from Olsson in 2007; Olsson came with it and went on to work at the company for 10 years.

By the time of the party, Eskilsson had stepped down as Tobii's CEO and was contemplating a sedate life serving on boards. Then

Olsson pulled him aside to describe turning “the physics inside out” on solar farms, Eskilsson recalls.

The vertical panel arrays require no concrete. A row of more than 100 can be rotated with a single motor and a cable system, the way a string moves slats in a venetian blind with the twist of a rod.
Andréas Lennartsson

The challenge wasn’t just exciting—it was urgent, Eskilsson says. Currently, when the sun is low, other energy sources compensate for solar’s decreased output. But some research suggests solar could make up 40 percent of global electricity production by 2050. At those rates the difference between supply and demand would be too large for other energy sources to compensate, Eskilsson claims—so reaching 40 percent penetration “is virtually impossible if you’re going to do static-mounted solar.” But tracking solar remains unavailable to much of the globe. “Someone has to be able to do vertical tracking in a way that’s actually cost-efficient,” he says.

They began working that September, the dwindling autumn sun a reminder of the faint light they intended to capture. Their challenge was to create a panel that wind couldn’t destroy. In less than a month they had prototypes that pivoted near their aerodynamic center so they could move in a storm.

Lundell became an adviser. There was a wind tunnel at Sweden's KTH Royal Institute of Technology, where he is a professor, but it was overbooked, and waiting for real storms was slow. He recommended they build an "inverted wind tunnel," inspired by U.S. aerospace company Scaled Composites' tests of SpaceShipOne's tail in 2003, which involved driving prototypes on a truck across the Mojave Desert. About a week later Olsson, Eskilsson and their first three employees had built their "trailer lab" and rented time on Lunda Airfield, 110 kilometers north of Stockholm.

The first months made clear why nobody had done this. "Everything broke," Eskilsson says. They started with stiff plastic sheets in place of solar panels. As prototypes stabilized, the team switched to solar panels and kept fine-tuning. They couldn't load up the frame with metal and increase its weight and cost. Soon they reached 80 kph in their test drives. Panel after panel vibrated until it snapped off. They stopped the car each time and walked back along the runway with their brooms.

"Turbulence gives rise to different kinds of oscillations and resonance effects," Eskilsson says. "It can be things like flutter; it can be torsional phenomena, etcetera, that get amplified by resonance." If you've watched the 1940 video of Washington's Tacoma Narrows Bridge wobbling as torsional flutter destroys it, you might have a sense of the similar effect in play with the solar panels. During windstorms, early solar arrays got twisted into modern art.

Eskilsson has a summer house on an island in the Baltic Sea, and he and his colleagues set up panels on its dock with a camera feed. At home, when the news announced a storm, they sat at their computers eating popcorn as wind destroyed their work. Sometimes they took a boat out as a storm rolled in and—in needling rain, screwdrivers in hand—adjusted the panels. "If you do it a little bit wrong, things start fluttering," Olsson says.

When the mechanical-design experts the group hired said they doubted the project's feasibility, Olsson was undeterred. Eskilsson recalls, "I had two of them taking me aside in the corridor without [Olsson] there, saying, 'Henrik, you do understand this is not possible.'" As prototypes kept breaking, he had moments when he feared they might be right.

Lundell recalls identifying a distinct flutter for less than a second before one panel failed, captured in videos from the trailer and the wind tunnel. With typically paced testing, understanding such a phenomenon could take years, he says. But the high-speed footage acted like a time-lapse movie of the destruction, allowing the team to map every oscillation in real time. "A few weeks later we had the theory," Lundell says—a mathematical model of the aerodynamic center, the precise pivot point where wind would push a panel into a neutral position rather than shaking it apart.

For six months Olsson and Eskilsson kept shifting the axis, strengthening parts in increments, careful to keep the weight low. They moved away from trial-and-error reinforcement and toward a passive-stability approach—treating the panel not as a wall to be braced but as a weather vane to be balanced. By nudging the pivot axis toward the leading edge, they made the wind do the work of holding the panel steady. By June 2024 they were reaching 100 kph on the airstrip. "We shifted the axis again, even further toward the front, and reinforced the sideways structure," Eskilsson says. This time the speedometer kept rising. They hit 140 kph—which exceeded the worst gusts most solar farms are likely to see. The panel feathered calmly. "Once you get rid of the instabilities," Olsson says, "suddenly you can double the speed." They laughed; then, to see just how far they could push the prototype, Eskilsson jammed the gas and broke one more panel.

Now they could assemble the pieces. The vertical panel arrays require no concrete. And a row of more than 100 can be rotated with a single motor and a cable system, the way a string moves slats in a venetian blind with the twist of a rod. When a storm nears, the motor “stows” the panels so the wind hits their backs. “If the wind hits from right behind the panels, you have virtually no torque at all,” Olsson says.

Olsson and Eskilsson named the company Vaja after a Swedish word meaning “to sway.” Vaja now has five test sites, and when forecasts promise trouble, they still grab their laptops to watch their solar arrays. “I look at the weather forecast four times a day,” Eskilsson says.

According to their data, Vaja’s system produces 25 to 30 percent more energy per year than a static array at many northern latitudes. Most of the company’s funding has come from $1.6 million in government grants and a similar amount from investors; it will need to raise much more to scale its operations. So far it has four paying pilot customers lined up. Swedish renewable-energy producer Rabbalshede Kraft intends to start a side-by-side pilot: Vaja trackers next to conventional arrays. The trackers must “survive the tooth of the climate,” says Rabbalshede Kraft CEO Peter Wesslau. “There will also be more production because the panels will be moving across the day. Given that we will be able to produce in the more profitable hours, we also expect that we’ll be making more money.” If Vaja delivers what Eskilsson “promised in blood,” Wesslau says, “a lot more solar projects will come into the money in the Nordic regions.”

Eskilsson has shed any doubts. He likes to joke that he and Olsson have made it this far because between the two of them, they have the three traits of entrepreneurship: a reasonable brain, a thick forehead to bang against the wall and enough naivete to keep trying.

They still run tests on the airstrip to validate panels coming out of production. The SUV accelerates and reaches the speed where, not long ago, everything went wrong. Soon they pass the equivalent of gale-force winds. On the mast, the panel feathers, calm as a coasting bird. They ease off the pedal and glide to a stop. The broom stays in the trunk.

Deni Ellis Béchard is *Scientific American*'s senior writer for technology. He is author of 10 books and has received a Commonwealth Writers' Prize, a Midwest Book Award and a Nautilus Book Award for investigative journalism. He holds two master's degrees in literature, as well as a master's degree in biology from Harvard University. His most recent novel, *We Are Dreams in the Eternal Machine*, explores the ways that artificial intelligence could transform humanity. You can follow him on X, Instagram and Bluesky @denibechard

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https://www.scientificamerican.com/article/vertical-solar-panels-wind-resistant-trackers-for-high-latitudes-vaja

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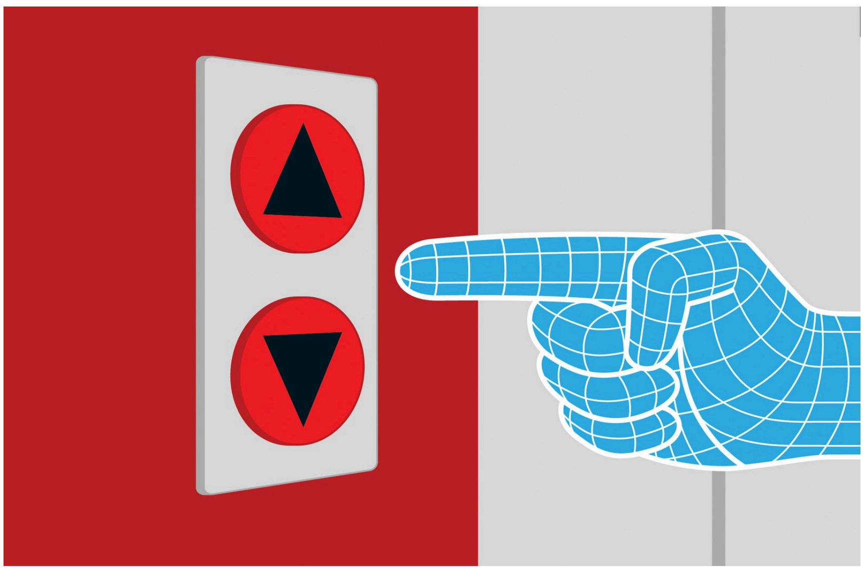
Technology

- ## AI tool decreased political polarization from social media algorithms
  Researchers used a browser extension to reorder people’s X feeds, reducing their polarizing effect

Algorithms really do create political polarization—and this AI tool let users avoid it

Researchers used a browser extension to reorder people's X feeds, reducing their polarizing effect

By Simon Makin edited by Sarah Lewin Frasier



Thomas Fuchs

People often blame social media algorithms that prioritize extreme content for increasing political polarization, but this effect has been difficult to prove. Only the platform owners have access to their algorithms, so researchers can't identify possible tweaks to the products' behavior without the platforms' (increasingly rare) cooperation.

A study in *Science* not only provides compelling evidence that these algorithms cause polarization but also shows the trend can be mitigated without getting a platform's approval or removing posts.

The researchers created a browser extension that can push down or move up posts in users' X feeds that display attitudes linked to polarization, such as partisan animosity and support for undemocratic practices. The tool uses a large language model (LLM) to analyze and reorder the posts in real time.

“Only the platforms have had the power to shape and understand these algorithms,” says study co-author and University of Washington information scientist Martin Saveski. “This tool gives that power to independent researchers.”

The team conducted an experiment over 10 days in the run-up to the 2024 U.S. election. More than 1,200 volunteer participants saw feeds in which polarizing content was either significantly down-ranked, reducing the chances of users seeing it before they stopped scrolling, or slightly up-ranked.

Regardless of political orientation, those for whom polarizing posts were de-emphasized felt warmer toward the group that opposed their viewpoints (based on short surveys) than did those with unaltered feeds, whereas those who saw boosted polarizing posts felt colder.

The difference was two to three degrees on a 100-degree “feeling thermometer.” That might not seem big, but “it’s comparable to three years of historical change on average in the U.S.,” says co-author Chenyan Jia, a communication scientist at Northeastern University. The manipulations also affected how much sadness and anger participants reported feeling while scrolling.

According to University of Toronto psychologist Victoria Oldemburgo de Mello, who studies how technology shapes behavior and society, the study authors impressively combined tight control with a real-world setting. “And they do it in a clever way that bypasses [platform] approval. No one has done this before.” The effects’ persistence is unclear—they might dissipate or compound over time, she adds. The researchers say that’s an important direction for future work and have made their code freely available so other scientists can dig in as well.

The current version of the tool works only for browser-based social media sites. Making something that could be used with apps is "technically more difficult, with the way [they] work, but it's something we're exploring," Saveski says.

The researchers also plan to study other interventions for social media feeds, taking advantage of the flexibility offered by LLM analysis, Saveski adds. "Our framework is very general, and one can think about well-being, mental health, and so on."

Simon Makin is a freelance science journalist based in the U.K. His work has appeared in *New Scientist*, the *Economist*, *Scientific American* and *Nature*, among others. He covers the life sciences and specializes in neuroscience, psychology and mental health. Follow Makin on X (formerly Twitter) @SimonMakin

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