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What Greenland's Ancient Past Reveals about Its Fragile Future

The collapse of the world's second-largest ice sheet would drown cities worldwide. Is that ice more vulnerable than we know?

By Jeffery DelViscio edited by Jen Schwartz & Seth Fletcher

Expedition members Caleb Walcott-George and Arnar Pall Gíslason use a hand drill to pull rock cores out of an outcropping, called a nunatak on the Greenland ice sheet in May 2024. The samples they extract could help solve a much larger climate puzzle: When was the last time that Greenland was green?
Jeffery DelViscio

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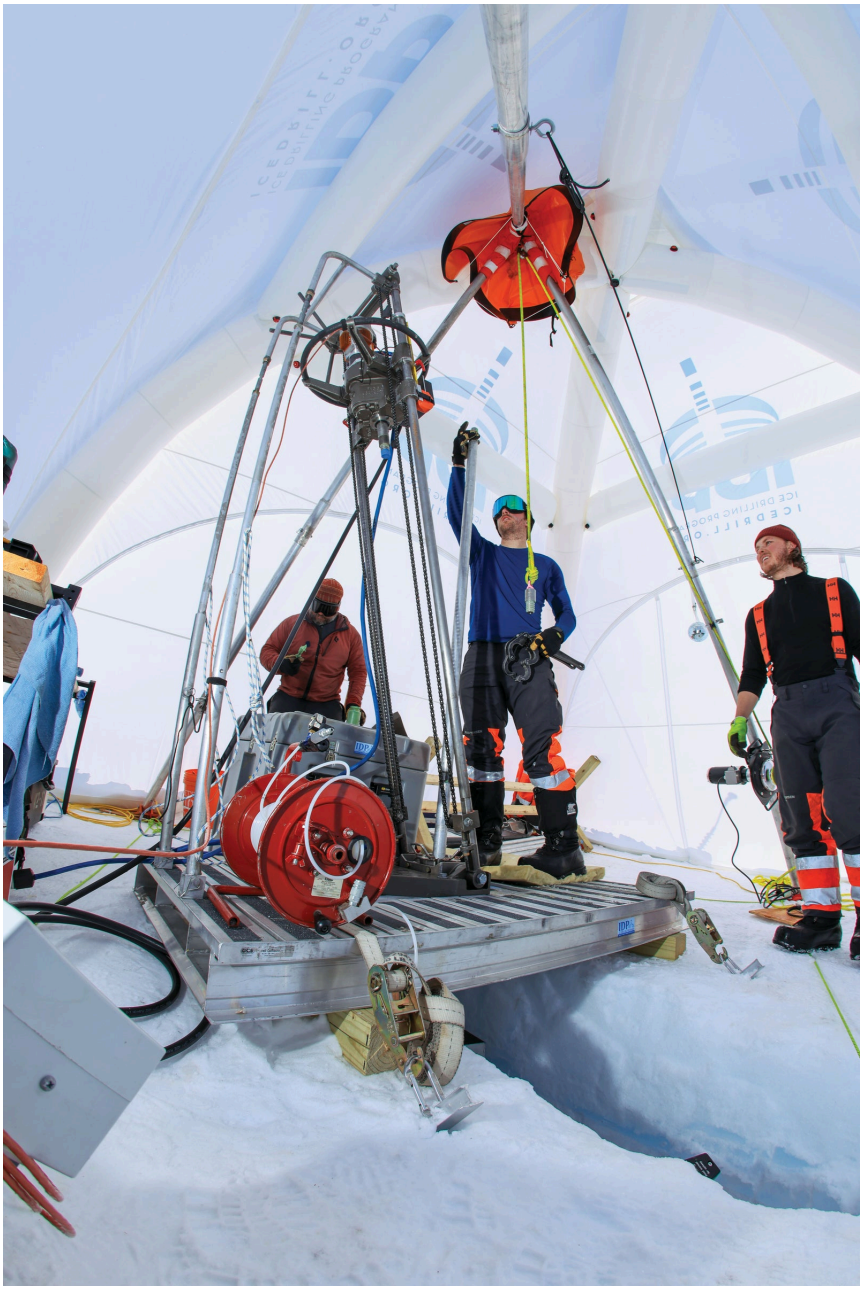
Inside a tent fastened to the surface of Greenland's ice sheet, the members of the GreenDrill expedition huddled around a drilling rig. The machine whined and shook as it spun. For days the drillers had been inching through ancient, solid ice to reach the rock below.

Outside, the sun burned down through a cloudless sky. The wind, having tumbled down 4,000 feet of elevation from the domed

summit of the ice sheet hundreds of miles to the west, charged over the surface in wavelike pulses. The tent shuddered like some mad bouncy house at the end of the world. The nine members of the expedition—ice and rock engineers, scientists, polar-survival specialists—knew they should be close to bedrock. But Forest Harmon, the driller working the handwheel, said he still couldn't feel the core break—the moment when the metal catcher inside the drill head separates the bedrock core from its earthly tomb.

The GreenDrill site sat on the frozen edge of the Northeast Greenland Ice Stream, or NEGIS, a massive, moving tongue of ice that drains 12 to 16 percent of the ice sheet into the ocean. Upended and laid atop the contiguous U.S., it would look like a flowing mountain range more than a mile and half tall at its highest point and 20 to 30 miles across, extending from Boston to Washington, D.C. If the entire Greenland ice sheet melted, global sea levels would rise by about 24 feet. The NEGIS is how a good deal of that planet-altering flood would enter the sea.

The sheet won't melt all at once, of course, but scientists are increasingly concerned by signs of accelerating ice-sheet retreat. A recent report showed that it has been losing mass every year for the past 27 years. Another study found that nearly every Greenlandic glacier has thinned or retreated in the past few decades. The NEGIS itself has extensively sped up and thinned over the past decade.



Team members Tanner Kuhl, Forest Harmon and Elliot Moravec (*left to right*) operate the Winkie Drill at the GreenDrill field camp. The drill is designed to cut through both ice and rock.
Jeffery DelViscio

Elliot Moravec, the mechanical engineer monitoring the drill-fluid pressure gauge, smiled, but only slightly. It seemed like something was about to go right, finally—in an expedition where almost nothing had before the team made it to the ice. So much in the weeks leading up to this moment had been uncertain. There were logistical delays and failed landings by military cargo planes. A more ambitious plan, which included a much larger drill and two different sample sites, had been scrapped. The project's two principal investigators were both forced to forfeit the field season

at the last minute. One of them had come all the way to Greenland only to have to turn around. The other made the painful decision to not even try to make it to the ice. The rest of the team was marooned for weeks in Kangerlussuaq, a staging location on Greenland's southwestern coast, about 850 miles from the drill site. Then it had taken more than 10 flights over seven days to get them and tens of thousands of pounds of gear onto the ice.

But at this moment, with just two weeks remaining in the expedition, their bit sat at the edge of discovery. The zone below was thought to hold within it a revelation: frozen in stone was a picture of this place but ice-free. Knowing the last time this area was actually green would help scientists answer a question of enormous consequence: Is the Greenland ice sheet even more fragile than we know?

Since President Donald Trump announced his administration's desire to "get" the world's largest island, Greenland has been the subject of sudden global attention. Climate change is exposing land formerly covered by ice, heightening political tensions on the island nation—and in the waters surrounding it as sea ice also disappears. But although the administration's plan to extract Greenland's natural resources is new, the American desire to occupy it, and pull value from underneath its frozen heart, is not.

In 1956 and 1957 the U.S. Army Corps of Engineers Snow, Ice and Permafrost Research Establishment, or SIPRE, recovered the first long ice cores from Greenland. Europeans and Americans alike had been trying to cross and dig into the ice sheet for decades before then. The "father of continental drift" himself, Alfred Wegener, is still entombed there. Wegener made four expeditions to study Greenland's ice in his lifetime. During his final expedition, in 1930, he died out on the ice. Just before he became a part of the ice record, he wrote: "We are approaching a new era of polar exploration characterized by the successful utilization of new

technologies in a rational manner. Everything that we want to and can measure must be measured on the ground."

In 1956 American scientists were doing exactly that, but the reason they were there at all had as much to do with the cold war as it did with the cold ice. The government's real mission was to build Arctic capabilities so it could both operate and listen from somewhere much closer to the Soviet Union. The location where SIPRE pulled those first deep ice cores from was called Site 2, and despite its public science mission, it was also a top-secret radar installation watching 24-7 for Soviet threats. But the tense geopolitics allowed a scientific discovery that, until then, had seemed impossible: the recovery of deep ice cores that kicked off an international race to recover and interrogate deeper and deeper ice. Those ice cores, and all that would be collected after them, became a kind of high-resolution climatological bedrock on which much of our understanding of rapid climate change rests.

Daniel P. Huffman

Although it is difficult to count the number of ice cores in existence, adding up the length of ice in just the freezers owned by Denmark (Greenland is an autonomous territory of the Kingdom of Denmark) and the U.S. gives you more than 21 miles of ancient ice. Researchers have dated them, measured the pressure of their enclosed air bubbles, characterized the structure of their snow, detected ancient volcanic cataclysms in their particulate content, and more. The results have given us an indirect way to track the timing of large and abrupt shifts in climate as far back as 123,000 years ago in the case of Greenland and 1.2 million years ago for ice extracted from Antarctica. “They are basically a backbone of climate science in terms of giving us these continuous, high-resolution climate records,” says Joerg Schaefer, GreenDrill’s co-principal investigator.

I have a personal 25-year history with one of these backbones. As an undergraduate researcher, I lived for a month on an oceanographic research vessel off Baja California. The mission was to collect sediment cores from the ocean floor. I spent hours and hours taking measurements—more than 30,000 of them—with my face pressed close to stinking, methane-rich mud.

Like ice cores, the sediment cores had visible horizontal bands. Ice cores’ bands come from seasonal variations in snowfall; in this marine mud, the winter sediment from above showed up one color, the summer sediment another. I used a measurement technique that allowed me to pull a climate signal out of the alternating light and dark bands. But to confirm that those climate wiggles were real, I had to try to match what I saw with other records that climatologists were really sure showed a strong connection to the hot and cold climate swings of the past; enter Greenland’s ice cores.

In 1999, when I was doing my research, the gold standards for such climate-record wiggle matching were ice cores from the Greenland Ice Sheet Project 2 (GISP2) or from the Greenland Ice Core Project

(GRIP). These two projects were a kind of friendly arms race between two different teams—one led by scientists in the U.S. (GISP2), the other by researchers in Europe (GRIP)—but without all the cold war skulduggery. Starting at nearly the same time (the Americans got a one-field-season jump on the Europeans), the two projects, less than 20 miles from each other near the summit of the Greenland ice sheet, raced to the bottom of the ice.

In July 1992 Europe won. That team reached the bed nearly 10,000 feet below the surface and stopped at the end of the ice. When the U.S. group finished a year later, not only did its core reach deeper than 10,000 feet, but the scientists were also able to collect a five-foot-long core of some of the rarest rock in the world—rock from under an ice sheet.

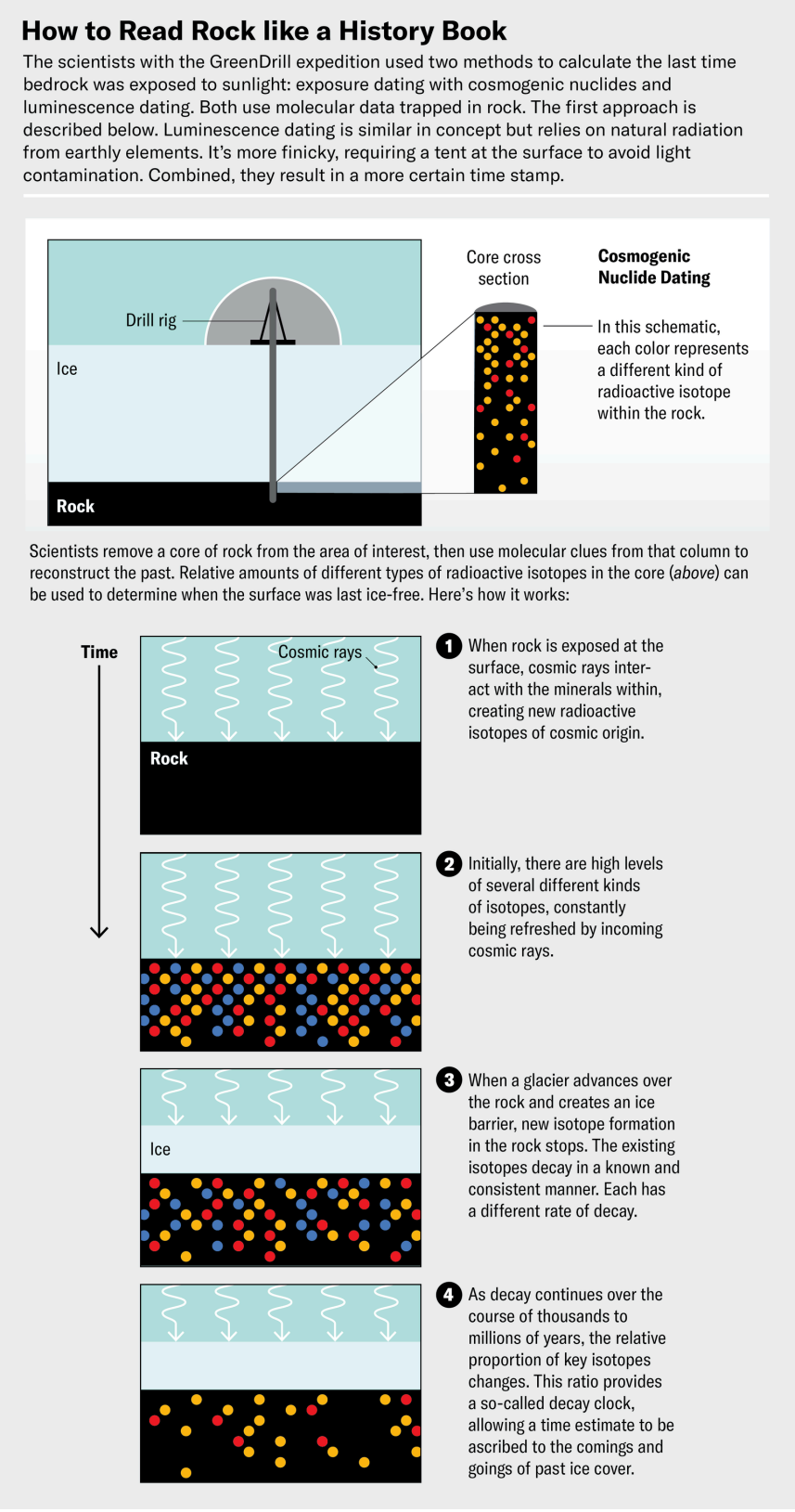
A drone’s-eye view of the windswept GreenDrill camp.
Jeffery DelViscio

These two deep climatic records became standards to benchmark other records against. My mud record stretched from the present back to about 52,000 years ago. I could take that record of wiggles from dark (cold world above) to light (warmer world above) and see whether the same temperature-related wiggles pulled from the ice core matched up. They did.

Many other climate researchers saw the same thing. In the three decades since these two cores were pulled from the ice sheet, tree rings, coral, cave deposits, other sediments and ice cores from across the world have all been successfully wiggle-matched to the records.

But in all the years researchers spent hunting for ice and finding out all they could about its nature, they mostly neglected to interrogate the stuff the ice is sitting on. That is a critical gap in our knowledge that is just waiting to be closed. “Those bed materials, whether it’s sediment or hard bedrock contained within it, are the words, the stories of the history of the ice sheet—it’s a book of information down there that we want to read,” says Jason Briner of the University at Buffalo, the other co-principal investigator of GreenDrill. “The bedrock under ice sheets is the least explored remaining zone on Earth’s surface,” Schaefer says. “These are moon rocks for us—the most rare and the most hard-to-drill surface rocks anywhere on Earth—and we have practically no direct observations.”

Schaefer and Briner have spent more than a decade fixated on this deep gap in climate science. What they have already found is sobering. “I have, for the first time ever in my career, datasets that take my sleep away at night,” Schaefer says. “They are so direct and tell me this ice sheet is in so much trouble.”



Jen Christiansen; Source: Jason Briner/University at Buffalo (*scientist reviewer*)

The data that terrify him come from the rock collected in 1993 under the GISP2 ice core. The ice core went off to be immortalized in thousands of research papers as a centerpiece of climate science. The bedrock went into cold storage in the U.S. ice-core repository

in Colorado. There it sat for almost two decades. In 2016 Schaefer, Briner and their collaborators exhumed the rock core and read it like a buried history book. They published a research paper in *Nature* entitled “Greenland Was Nearly Ice-Free for Extended Periods during the Pleistocene.”

The Pleistocene, a period that includes the last ice age, stretched from around 2.6 million to 11,000 years ago, when woolly mammoths, saber-toothed cats and the first modern humans roamed over earth and ice. From that one sub-ice rock core, the researchers learned that during that epoch there were periods—at least one, possibly many—when the ice sheet was completely gone or nearly so. “You do one data point, bedrock underneath the thickest part of the Greenland ice sheet, so you basically have to melt the entire ice sheet to make that spot ice-free,” Schaefer says. “Even there the bedrock was telling us, ‘Hell, yes, I was ice-free a lot over the last geological period.’”

“It started what some people like to call the fragile Greenland hypothesis,” says Paul Bierman, an author and geoscientist at the University of Vermont. Bierman and others have found additional evidence to support the worrying idea. In 2023 he and his colleagues published a study that showed “multiple lines of evidence” indicating much of northwestern Greenland was ice-free around 400,000 years ago. The concentration of carbon dioxide in the atmosphere then was less than 300 parts per million. Today we’re at 428 parts per million.

The GreenDrill team is preparing to publish new findings that are even more unnerving for humanity. Caleb Walcott-George, soon to be an assistant professor in the department of earth and environmental sciences at the University of Kentucky, was a graduate student during the first two field seasons of the project. At a recent academic conference, he presented solid evidence that an area in northwestern Greenland three times the size of New York City and currently covered by ice a third of a mile thick was either

completely or nearly completely ice-free as recently as about 7,000 years ago. That corresponds with a time called the Holocene Thermal Maximum, when temperatures were just a few degrees warmer on average than they are now. Walcott-George says that's within the range of warming we might experience by 2100.

Polar survival specialist and guide Gíslason uses a Shaw portable drill to bore through solid rock on a nunatak on the Greenland ice sheet.
Jeffery DelViscio

Not long after Moravec sensed that the drilling rig was on the verge of core break, the team pulled its first sample of the season up from 165 feet below. Minutes later the core sat inside the capped inner core barrel, ready for inspection.

Walcott-George and Allie Balter-Kennedy of Tufts University stood shoulder to shoulder in a small, blacked-out tent originally designed for spearfishing pike over a frozen lake. The only light was a dim tangerine glow coming from a single LED strip taped to the ceiling. Balter-Kennedy and Walcott-George screwed off the drill head at the end of the barrel, tipped the tube up at an angle and gently shook it to get the material inside to slide out into the tray. This rock could tell them when it last saw the light of day. It also "remembered" how long it had been buried. But that memory was delicate, and even a flash of sunlight could throw it off.

Certain minerals in the rock act like batteries by “charging” when they are buried. Radioactive decay in elements surrounding the grains strips their electrons, causing the grains to luminesce, although the rocks don’t visibly glow. “We can determine essentially the charge rate, and by doing this we can figure out how long these quartz and feldspar grains have been buried,” Walcott-George says. But even seconds of sunshine can reset this signal, so every time a piece of rock is unearthed from below the ice sheet, they return to the blacked-out tent.

There is another source of stored memory in a subglacial stone, and it originates inside the hearts of dying stars. The cataclysmic explosions that mark the death of a star throw cosmic rays across the galaxy. Those rays blast their way to Earth, creating a cascade of elementary particles that buffet the planet’s surface. “When they interact with rocks, they create these nuclear reactions that create isotopes or nuclides that we don’t otherwise find on Earth,” Balter-Kennedy explains. “We know the rate at which those nuclides are produced. If we can measure them, we can figure out how long that rock has been exposed to these cosmic rays—or, in our field, how long that rock has been ice-free.”

It’s called surface exposure dating, and it works by revealing the total amount of rare isotopes in the rock sample. Over time, periods of sun exposure and burial create on/off spikes in the total amount of nuclides in the rock, with exposed being “on” and covered being “off.”

Allie Balter-Kennedy, now at Tufts University, and Walcott-George, soon to be at the University of Kentucky, measure and package a core sample in a blacked-out fishing tent. The samples have to be protected from contaminating sunlight, which would throw off the climate signal the researchers are trying to extract.
Jeffery DelViscio

If researchers take two of these nuclides—say, beryllium-10 and aluminum-26—and measure their relative levels along many feet of a rock core, they get what's called the decay clock. This clock runs down as each isotope decays at a different, predictable rate. When scientists see parts of the rock record where the clock has gained time, they know that the surface saw the sun. When the sample is buried, the clock slowly loses time in a countdown to zero cosmogenic nuclides.

The two methods allow the scientists to interview the bedrock, so to speak. "You ask: When have you been ice-free? For how long? And how many times have you been ice-free in the recent geological past?" Schaefer says. But that day in the tent it appeared that there might be no bedrock to interview. The core they had pulled up wasn't quite right.

"Where's that smooth bed?" Walcott-George asked, referring to the solid bedrock pay dirt they were looking for.

"I feel like it's gravelly ice, and then ..." Balter-Kennedy trailed off.

“Dirty ice,” Walcott-George said, completing the thought.

They decided they’d try again tomorrow.

Approximately 5,500,000,000,000 tons. That is how much water weight the Greenland ice sheet has lost to the ocean since just 2002. Sequentially dumped into Olympic-size natatoriums, it would provide a personal 660,000-gallon lap pool for every person living in Africa and Europe—all 2.2 billion of them.

But how, exactly, future melt will bring more green to Greenland is one of the biggest questions that science has yet to answer. “The scientific community right now does not know how the Greenland ice sheet disintegrates,” Briner says. “We don’t know what the mechanisms are and how long it takes for the ice sheet to get to its teeny-tiny state.”

In discussions of Antarctica, the word “collapse” is now often associated with the loss of ice through ice shelves such as the Thwaites, a floating extension of the Antarctic ice sheet. Nearly 75 percent of Antarctica’s coastal ice is in ice shelves floating in water. But the fate of Greenland is believed to be tied to that of its ice streams, which are more like small tongues that ring the island and are confined by deeply carved fjords.

Dorthe Dahl-Jensen, a Danish ice-core climatologist, first came to the Greenland ice sheet in 1981. Back then, “no one was talking about global warming,” she says. When she told people she was drilling ice cores for climate research, they assumed she was investigating when the next ice age would arrive. In her four decades of working on this ice sheet, Dahl-Jensen has seen changes happen in real time. One day in 2012 she was on the ice—and it rained. “I saw it as a very pure sign of global warming that we actually got rain on the center of the Greenland ice sheet,” she says.

Some of the displayed drill bits for the Winkie Drill system are best for drilling through ice; some are for cutting through bedrock.
Jeffery DelViscio

More recently Dahl-Jensen led research for the East Greenland Ice-Core Project, which in 2023 managed to pull a 1.5-mile-long ice core (and some subglacial mud and stone) from close to where the NEGIS begins. The entire process had taken eight years. “When you look at the balance of the ice sheet and how much it has lost, half of the extra loss is from melt along the coast of Greenland, but the other half is from acceleration of the ice in the streams,” she says. Dahl-Jensen knows that ice streams are a big factor in sea-level rise, but she’s also aware that we don’t yet know how they behave. “We are not capable of modeling them properly into our ice-sheet models,” she explains.

That is why the GreenDrill team wanted to get bedrock underneath the NEGIS from a site much closer to where it meets the coast. Measurements from each of these projects will feed into the mathematical models, which attempt to simulate how the real world works. “We have so many gaps in our physical understanding of how an ice sheet actually responds,” Schaefer says, noting that current models have big error margins.

Ice-sheet models work much like the climate models we use all the time—the ones that predict tomorrow's weather. They use mathematics to simulate the interactions among real atmospheric phenomena: wind, pressure, moisture, thermodynamics, and lots more. They are reasonably trustworthy over hours to days because they are loaded with real data: historical data; measurements from weather satellites and balloons; and observations from land, sea and commercial aircraft.

Improving the ability of ice-sheet models to accurately predict how the sheet will respond to the warming it is experiencing now—and that yet to come—is no different. The models need data-based gut checks to make sure their predictions are informed and constrained by as much reality as we can feed into them.

Schaefer believes reducing the error will make ice-sheet models better tools for adapting to climate change. "If you are a politician and you want to make New York City—or any city that is close to the ocean—sea-level safe, you need precise predictions of what is going to happen," he says. And those predictions will become increasingly vital as the world moves deeper and deeper into its climate-warmed future—a future that those who study Greenland fear will be societally altering.

"Think about the mass migration that will happen if we melt all of the Greenland ice sheet," Bierman says. "That's not tomorrow—that's centuries from now and even millennia from now—but when that happens, that will be the biggest movement of humans ever because they'll lose their farms, they'll lose their cities, they'll lose their homes," he says. "It will be creeping and slow, but it will happen."

The day after the heartbreak in the fishing tent, the team hit solid rock. It was what they had come for, and they found it just in time. A blizzard blew through camp hours later, shutting down drilling for the next two days.

When the work resumed, the team decided to try for a second core. This one would be half as deep as the first, so, the researchers reasoned, maybe they could get even more precious rock from under the ice to interrogate in half the time it took to get the first sample. All work had to be wrapped up within a week to leave them enough time to pack up for extraction. With good-enough weather, the twin-engine ski plane would be landing at the site, and it wasn’t going to wait for anything.

Barbara Olg Hild, the polar bear guard, stands in the GreenDrill camp during a blizzard that lasted for two straight days. During the team's weeks in the field, two such storms would stop work for two to three days in a row.
Jeffery DelViscio

Over the next two days they made good progress. Rather than setting up the drill tent all over again, they decided to chance a mostly unprotected drill hole. A small wind break was all that separated them from the wind and blowing ice. While Moravec, Harmon and Tanner Kuhl, the third and most experienced ice-drilling engineer, started again, the others fanned out onto the nunataks, dark peaks that broke through the ice-bound oblivion like the heads of whales surfacing through the ocean of ice. There Walcott-George, Balter-Kennedy and Arnar Pall Gíslason, the team’s survival guide, used backpack-size rock drills to take a core from the surface of a nunatak. The rock was constantly exposed to sun and cosmic rays, and the luminescence signal and cosmogenic

nuclides pulled from it would provide the baseline against which the under-the-ice-sheet rock cores would be compared. Just as it started to look like they might have this victory-lap sampling in the bag, a second blizzard blasted through the site.

“Let’s get the hell out of here,” yelled Matt Anfinson, the camp mechanic. He emerged from the drill tent into a whiteout. The storm was still picking up. The drill tent, the only refuge aside from the mess and sleeping tents, was bowing ominously in the 50-mile-per-hour winds. It was time for the team to grope its way back to camp with only a line of red flags to guide it through the nearly zero-visibility conditions.

For the past three hours the group had been involved in a kind of mechanical open-heart surgery. The patients were two backpack drills that had stopped working during sampling on the nearby nunatak. The team had brought two to be safe; both had died. The drills lay on the worktable, guts exposed. After fiddling with the ignition coils, Anfinson ripped on the starter pulls. As one drill spun into high gear through smoke and sputter, he looked like an ice-field Dr. Frankenstein, gleefully and maniacally gazing on his reincarnation. It was a rare victory amid a “weather daze,” as Harmon, the driller, called it.

Balter-Kennedy breaks a bedrock core into pieces for packaging and shipment. This core was the last one the team collected before being extracted from the GreenDrill camp.

Living through blizzards like these feels like what you'd expect inside a sensory-deprivation white-noise machine. This latitude sees no darkness in May and June, but without a break in the gale-force winds, the conditions outside are both bright and blinding. Wind-sculpted snowdrifts grow through the field camp like giant, icy fingers. They block the doors of sleeping tents and make walking treacherous; you either trip on a three-foot-tall snow wall that wasn't there hours before or fall off one into three feet of powder.

There was a cruel monotony to the continuous winds. They forced the crew into smaller and smaller circles of living—sleep tent to mess tent to bathroom tent and back. Barbara Olga Hild, the polar bear guard, fought through the long, bright nights to keep the electrified wire fence around the camp from being covered by drifting snow. Walcott-George sat in the mess tent brewing carafe after carafe of strong coffee and engaging in Arctic self-care, using superglue to seal his dry, cracked fingers against drilling fluid. Balter-Kennedy patched punctures and tears in her favorite polar bib and pored over her core-sample logbooks. Moravec and Harmon played cribbage for hours. Everyone skulked outside into the whiteout on rotation to fill an orange five-gallon cooler with snow to be melted on a camp stove for water (it is ironic how much effort it takes to make drinkable water when we are surrounded by ice).

Perversely, it was during the weather's harshest moments that people used to working on the ice opened up about why they seek out the cold and the isolation of polar work. "The reason people go to the Arctic is [that] you can hear the silence," Hild said. Dahl-Jensen, the Danish ice-core scientist, told me that the months of near-complete isolation from the rest of the world have become a prized part of the experience, worth any amount of cold and discomfort. "We live in our camp and do our research, and the time

where you can only focus on one thing is really wonderful," she said. That feeling—of slowing down, of concentration—is something many on the team told me they miss when they're off the ice. "I always dread the end of a field season," Balter-Kennedy said. On the other side is the stark return to normal life, the avalanche of unanswered e-mails, the fact that things are different than when you left them.

When the storm finally cleared after three days, the team practically launched through the tent opening to get back to work. Because of the blizzard, they had just two full days to complete the new drill hole. The first core took a week to get, and that was without any weather delays. Everything had to go right now.

Just one day later the entire team was standing around the drill and taking in the last sample before packing up. The drill had burned through almost 70 feet of ice. The weather was sunny. The day felt unseasonably warm—about 15 degrees Fahrenheit above freezing—and the team easily cranked through the last drilling run. As the last rock core entered the bottom of the barrel, the sounds of the rock band Ween floated out onto the open ice.

The core came up clean. The team closed the hole with a cheer and a small pour of the Danish liqueur Gammel Dansk, or, as it was better known here, "driller's fluid." It wasn't for the crew. "You were a good hole," Harmon said as Moravec poured booze down to the bedrock.

Walcott-George hoisted the final rock core like a prize striped bass. Then, as they had done all season, he and Balter-Kennedy noted its lengths and features and stored it for transport, not yet knowing what story of Greenland's ice-free past, and our flooded future, it might tell.

Jeffery DelViscio is currently chief multimedia editor/executive producer at *Scientific American*. He is former director of multimedia at *STAT,* where he oversaw all visual, audio and interactive journalism. Before that he spent more than eight years at the *New York Times,* where he worked on five different desks across the paper. He holds dual master's degrees in journalism and in Earth and

environmental sciences from Columbia University. He has worked onboard oceanographic research vessels and tracked money and politics in science from Washington, D.C. He was a Knight Science Journalism Fellow at the Massachusetts Institute of Technology in 2018. His work has won numerous awards, including two News and Documentary Emmy Awards.

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https://www.scientificamerican.com/article/greenlands-ice-sheet-collapse-could-be-closer-than-we-think

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Fun Ways to Ditch Fast Fashion for a Sustainable Wardrobe

Trade impulse clothing purchases for botanical dyes, upcycled apparel, creative mending, flexible sizing, and more

By Jessica Hullinger edited by Jen Schwartz & Jen Christiansen

In Chile's Atacama Desert, a mountain of more than 59,000 tons of clothing can now be seen from space. This so-called garment graveyard comprises fast-fashion discards inherited from the U.S., Europe and Asia. In 2024 activists, designers and NGOs organized Atacama Fashion Week—with a fashion show atop the garment graveyard—to draw attention to this growing problem. Mauricio Nahas/Artplan

In New York State's Hudson Valley, Lilly Marsh weaves scarves, shawls, and other apparel out of fibers sourced from the Northeast. The items are beautiful and informed by historical techniques—for her Ph.D., Marsh studied contemporary North American hand knitting—but her interest in producing woven goods goes far beyond the final product. In 2017 Marsh co-founded the Hudson Valley Textile Project (HVTP), a natural-textile supply chain that aims to break free from the global fashion industry.

One big problem the HVTP set out to solve involves wool. After sheep are shorn at farms, the wool is greasy and needs to be

cleaned, or scoured, before it can be worked with. For years the scouring facility closest to New York was in North Carolina, and it had a 1,000-pound minimum for processing—an amount most small farms can't reach on a yearly basis. Using money from grants and private donations, the HVTP opened Clean Fleece, a local scouring facility that washes small batches of wool and other animal fibers. "It's enabled a ton of farmers who want to work on a small or mid-size scale to get that done," Marsh says. "That's made a big difference in our industry." Now farms across the region are selling socks, hats and mittens on a consistent basis—and at prices that are comparable to those of similar products from major brands.

The HVTP now has more than 160 members working up and down the supply chain, including Marsh. The work hasn't been easy, she says, and they've faced a handful of setbacks, such as a recent flood at a favorite dyeing facility. Also, many artisans who want to scale up production are having trouble finding enough employees trained in the craft. "We're trying to restart an industry that left the U.S. 40 years ago or more," Marsh says. "It's hard to find skilled work." But, she adds, the benefits of nurturing a local textile industry are many: more transparent supply chains, support for local economies and regenerative farming practices, less waste, fewer emissions, and a profound sense of community and interconnectedness. "We all know each other in some way," Marsh says of her colleagues. "It's an accountability system because I care about your well-being. I think that's kind of incalculable."

A child wears pants by brand Petit Pli, which makes clothing items that adapt to the wearer through several sizes of growth. Flexible-size clothing also exists for adults, which means people don't have to buy new items when their bodies change.
Marcus Smith

The HVTP is one part of a growing effort to mitigate the harms of the global fashion industry, in which millions of low-paid garment workers around the world endure unsafe working conditions to churn out huge amounts of clothing and textiles year after year. The pull on the planet's natural resources is immense: Annual textile production uses up enough water to fill at least 37 million Olympic-size swimming pools. Cotton agriculture alone uses 2.1 percent of the world's arable land. And because roughly 60 percent of global textiles now contain plastic derived from fossil fuels, it is estimated that more than a third of the microplastics in the oceans today were shed from clothing.

The fashion industry is also responsible for up to 10 percent of global greenhouse gas emissions—more than the aviation and shipping industries combined. If apparel consumption continues to grow at its current rate, by 2050 the industry will be using more

than one quarter of the world's carbon budget. The problem becomes even worse when you consider that most clothes make a quick trip to the landfill, where they'll emit greenhouse gases such as methane.

These numbers reflect a growing appetite for fast fashion, a business model that brings trendy designs to the masses as quickly and cheaply as possible. As clothing consumption rises, the consumer tends to shoulder the blame. But what's enabled things to get this bad is a lack of regulation.

Despite being worth some $1.7 trillion, the global fashion industry has for years been allowed to operate with little transparency or oversight. "There's nothing stopping a brand from churning out an insane number of products," says Kate Hobson-Lloyd, the fashion-ratings manager at Good On You, a website that monitors and rates fashion brands' sustainability. "There's nothing to incentivize brands to *not* operate on a fast-fashion model," she says. "If there's money to be made, they're going to do it."

> Projections indicate that by 2030 the world will be producing 134 million tons of textile waste every year.

Some new regulations are meant to make the industry more accountable. The European Union, for instance, recently started requiring fashion and textile brands to report transparently on their greenhouse gas emissions and supply-chain labor practices; improve their products' durability and recyclability; and take responsibility for collecting and recycling clothing and footwear, essentially encouraging a circular textile economy. The E.U. also moved to restrict microplastics in textiles and introduced a rule requiring that clothing come with a "passport" that gives shoppers a detailed rundown of a product's life cycle, including its origins, manufacturing process, environmental footprint, and safe disposal or recycling instructions.

The passport concept speaks to consumers who are more and more aware of the industry's harms—in one international 2025 survey, 70 percent of consumers said sustainability is a factor when they're shopping for clothes. But making responsible and informed decisions is increasingly complicated. Are clothes made from plant fibers such as cotton and linen always better than polyester and other synthetics derived from petrochemicals? What about recycled materials made from plastics? And how do you know that an innovative material that's better for the environment isn't harming the people who make it?

With some T-shirts, reading the tag is not unlike trying to decipher a food label making a barrage of claims that may not be standardized or enforceable. Nearly 60 percent of brands are behind on achieving even their own self-imposed sustainability goals. Greenwashing—when brands make misleading claims about the impact of their sustainability efforts—is "an absolutely enormous problem" in the fashion industry, Hobson-Lloyd says.

The HVTP isn't waiting for top-down initiatives to change the fashion industry. And it has company. Fibershed, which started in 2011, involves a regional community of farmers, textile producers and artisans who make clothes from regenerative materials sourced and assembled within a 150-mile radius. The initiative, which began in California, has now grown to 79 Fibershed textile economies operating across 18 countries. Movements such as these are making it easier to participate in accessible alternatives to fast fashion—all while bringing some fun back to getting dressed.

The true scale of the modern fashion machine is difficult to gauge. Brands aren't required to disclose how many new garments they produce every year, so most of them simply don't. But our landfills provide clues. In the U.S. alone, at least 17 million tons of textiles are discarded annually, which works out to about 100 pounds of clothes per person. Projections indicate that by 2030 the world will be producing 134 million tons of textile waste every year.

While the E.U. is “regulating the heck [out] of the fashion industry,” says Rachel Van Metre Kibbe, founder and CEO of advisory firm Circular Services Group, things in the U.S. are moving more slowly. In 2024 California introduced the nation’s first extended producer-responsibility law for apparel and textiles, which puts the onus on brands to ensure their products don’t end up in landfills. Similar bills are pending in New York State and Washington State.

Van Metre Kibbe says the success of California’s bill isn’t guaranteed. “We’re about to start collecting the most clothes we’ve ever collected in U.S. history,” she says, emphasizing that there is almost no infrastructure in place for such an endeavor. The waste could simply get transferred to another warehouse in another country, which wouldn’t be a success at all. Although state bills are a start, Van Metre Kibbe says, federal regulation is needed. To get there, we need to frame the regulation of textile waste as an opportunity. “We have to make the business case for why this is the future,” she says. “There are job opportunities and manufacturing opportunities. Ultimately, it should be more cost-effective to reuse materials.”

> “Recycled versions are preferable, but the recycled content of that fiber could be less than 10 percent.” —Kate Hobson-Lloyd, *Good On You*

Donating unwanted clothes rather than throwing them out isn’t an effective solution to the growing waste problem. Charity shops are overwhelmed by the sheer volume of low-quality garments they receive, and many of these items are exported or thrown away. In a study published last year in the journal *Nature Cities*, researchers said charity shops are unintentionally shielding the public from the true volume of overconsumption and postconsumer textile waste. The authors called for investment in new circular business models such as clothing rental and upcycling.

In Los Angeles, the Suay Sew Shop is an innovative model for how this kind of business might work on a larger scale. It operates a circular textile-recycling program, taking in a significant amount of unwanted clothes from brands and the local community. Suay deconstructs these items and then patchworks the materials into funky-chic garments and home goods. Old jeans get turned into jackets, nylon track pants into wrap skirts, flannel shirts into oven mitts. “We can do something with everything,” says Suay co-founder Lindsay Rose Medoff. “We can use the cheap stuff, finding ways to really transform it.” The company says its operations have diverted more than four million pounds of textile waste from landfills since 2017.

At the same time, Medoff says she is committed to prioritizing worker rights, creating a positive and safe working environment, and paying Suay employees well for their skills. Labor, she says, is her biggest cost, and she’s aiming to set up a worker-owned business model.

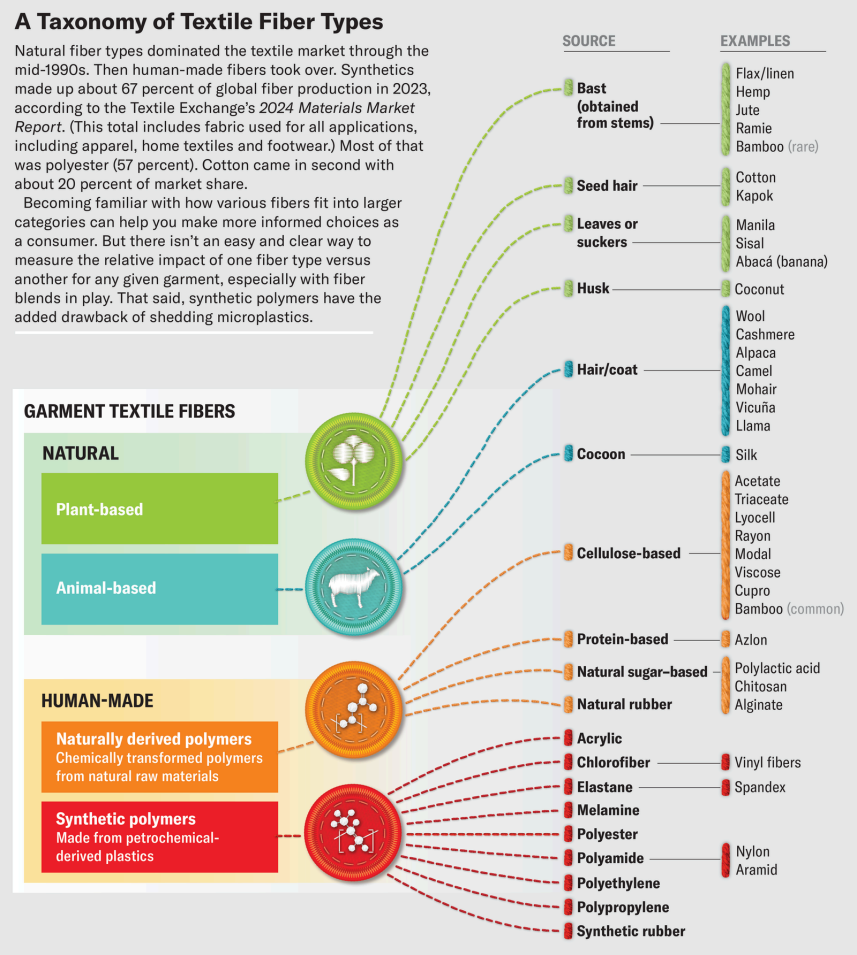
These photographs show parts of the process of turning abacá banana plants into Bananatex fabric, which was created by Swiss bag brand QWSTION. (*From left to right*): Abacá banana plants grow in their natural habitat in the Philippines. Abacá fibers are stripped at a harvesting site. The raw fibers are collected at a warehouse. Compressed abacá fiber bales are shipped to a processing facility, where the fiber is made into yarn and then warped before the weaving process begins. The yarn is woven into Bananatex fabric. Abacá fibers are made into paper before being cut and spun into yarn. Designers review zero-waste pattern designs for their products.

Suay's operations are unconventional because donating to the shop isn't "free." Customers pay $20 to offload 20 pounds of textiles, and they get $20 of in-store credit in return, which they can spend on upcycled clothes, repair services or one of Suay's workshops. The customers' money supports the shop, and in turn the shop supports a behavioral shift toward more sustainability.

Suay isn't a cottage operation. It's a team of about 50 workers who have completed an extensive in-house training program to learn the art of upcycling at scale. They sort, prep, clean, dye and rework textiles from the community and from apparel brands. In the days following the Los Angeles fires in January 2025, the shop received more than 100,000 pounds of donated textiles. Medoff is trying to get funding to expand in the most impactful ways, perhaps by building a hub for training on upcycling. "Suay cannot repair every pair of jeans in the world," she says, "but it really has the skills to teach people how to do that on a larger scale."

Clothes often end up discarded because of tears, missing buttons, frayed hems, stubborn stains and moth holes. Up until the 1960s, mending worn-out clothes was the societal norm. "It was supercommon knowledge," explains Sara Idacavage, a fashion historian and sustainable-fashion educator who is currently getting her Ph.D. at the University of Georgia. With the rise of cheap clothes and fast fashion, much of this repair culture has been lost.

Flora Collingwood-Norris, a knitwear designer based in Scotland, is one person trying to bring it back, but with a twist. Using so-called visible creative mending, she fixes a garment's flaws by patching and darning in contrasting colors and patterns. The objective is not to repair a hole by blending the repair in as much as possible but to give a sweater a custom—and imperfect—new mark.



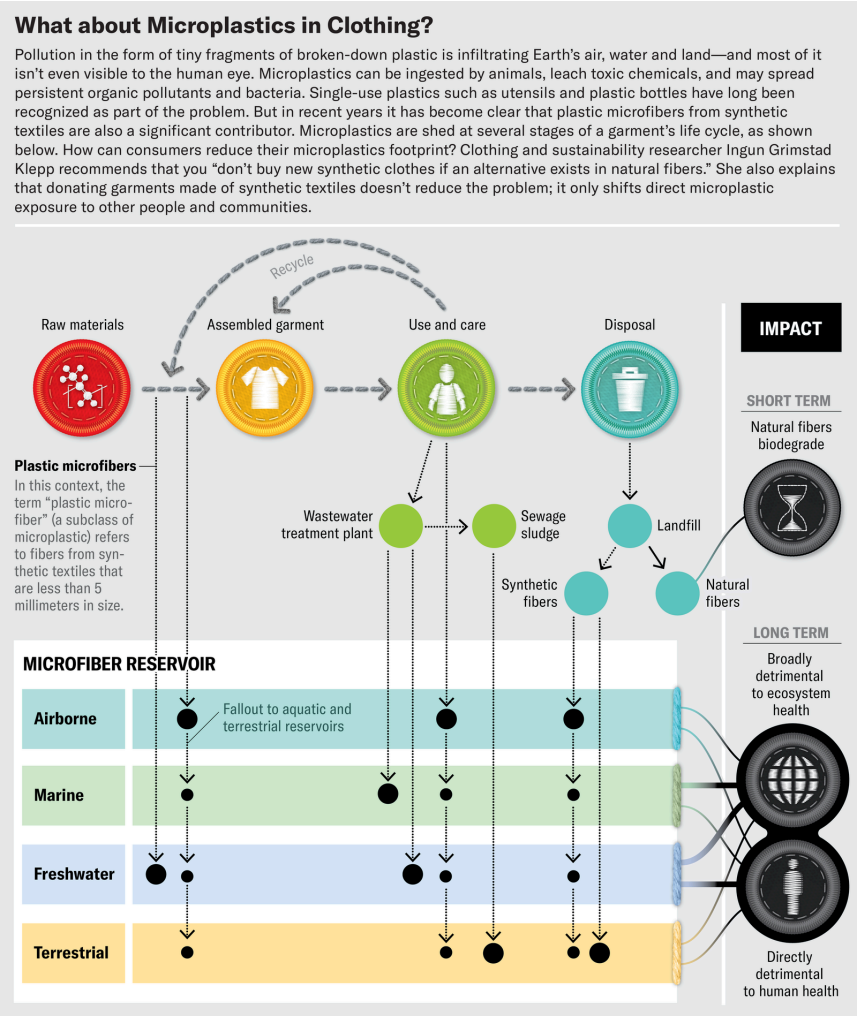
Jen Christiansen; Source: *Plastic in Textiles: Potentials for Circularity and Reduced Environmental and Climate Impacts*, by Saskia Manshoven, Anse Smeets, Mona Arnold and Lars Fogh Mortensen, Published by European Topic Center on Waste and Materials in a Green Economy, 2021; and *Facilitating a Circular Economy for Textiles Workshop Report*, by Kelsea Schumacher and Amanda L. Forster, Published by National Institute of Standards and Technology, May 2022 (*references*)

"Not only do you feel like you have something new in your wardrobe, because you've just changed it, but you get to enjoy the creative process," says Collingwood-Norris, author of *Visible Creative Mending for Knitwear*. At 39 years old, she still has (and continues to wear) most of the sweaters she owned when she was a teenager—but these days they're covered in her bright stitching and delicately embroidered flowers. Her jeans are "more mend than the original jeans," she says.

Studies show that the main reason people don't mend their clothes is that they simply don't know how. Visible mending doesn't have a steep learning curve, Collingwood-Norris says. "You just need a needle, some yarn and a pair of scissors." You can also pick and

choose which technique you like most. If darning is too complicated, try patching instead. “They’re both valid, and they’re both going to fix your hole,” she says.

Collingwood-Norris began teaching online workshops on visible mending in 2019. Since then, her workshops have become the most successful part of her knitwear business. She’s also noticed many more knitwear companies and brands offering mending services and workshops. Womenswear brand TOAST, for instance, offers visible mending as part of a free repair service.



Jen Christiansen; Source: “Microfibres from Apparel and Home Textiles: Prospects for Including Microplastics in Environmental Sustainability Assessment,” by Beverley Henry, Kirsi Laitala and Ingun Grimstad Klepp, in *Science of the Total Environment*, Vol. 652; February 20, 2019 (*primary reference*)

People also discard clothes because of fit. This is especially true for children, who can outgrow seven or eight sizes in the first two

years of their lives. The authors of one small study found that size or poor fit was the number-one reason for throwing out children's clothes, accounting for 47 percent of all discarded items. To address this problem, some new brands are designing clothes that grow with kids.

Clothes from U.K.-based company Petit Pli have intricate pleating that allows the fabric to expand or collapse to make the garment larger or smaller. Founder and CEO Ryan Mario Yasin, a former aerospace engineer, got the idea while designing instruments that can be packed inside nanosatellites and then deployed in orbit. "It involved a lot of research into origami and folding little carbon-fiber panels into a two-millimeter gap," Yasin says.

The three sizes Petit Pli offers in its children's line cover kids for the first nine years of their lives. The prices range from about $75 to $130 per item. "So, yes, it's more expensive initially," Yasin says. "But it's cheaper in the long run."

Adults' bodies aren't static, either. There is now an abundance of so-called flexible fashion that can accommodate fluctuations in weight or body shape. There are one-size-fits-all garments designed to stretch and spring back, as well as a clothing line made specifically to adjust to body changes during pregnancy, postpartum, and beyond. When the brand Universal Standard launched in 2024, its CEO announced it would offer free exchanges if one of its garments lost its fit.

Climate activist and drag artist Pattie Gonia wears a dress made from upcycled tent fabric by designer Bradley Sharpe. Bonded technical fabrics used for tents and water-resistant apparel are often made of materials sourced from petroleum products. Upcycling—or repurposing—materials is an effective way to keep unwanted items or scrap fabric out of landfills.
Samuel Crossley

Sustainable fashion doesn’t have to mean no new purchases. Knowing some basics about different fibers and how they function can help you pick items that will best meet your needs, letting you stock your closet with things you’re more likely to wear, enjoy and take care of for a long time. There are three main types of fibers used in textile production: natural plant fibers such as cotton and linen; natural animal fibers such as wool; and synthetic or human-

made fibers, which include plastic-derived materials, such as polyester and nylon, and viscose, a common material made from wood pulp [see "*A Taxonomy of Textile Fiber Types*" graphic to learn more].

Each material has its merits and purposes as well as its cons. Natural fibers are renewable and, depending on how they're processed, potentially biodegradable. They also require huge amounts of land and water to grow, and these crops are often treated with hazardous fertilizers and pesticides. Their supply chains can be rife with human- and animal-rights violations. When buying clothing made from natural fibers, look for labeling that guarantees it is certified organic, such as the Global Organic Textile Standard.

Synthetic fibers such as polyester, nylon and acrylic are made from plastic derived from petrochemicals. They're ubiquitous in modern fashion and account for roughly 60 percent of global fiber production. These materials are cheap and versatile, but they also contribute hugely to plastic pollution. A single laundry load of polyester clothes will shed somewhere between 640,000 and 1.5 million plastic microfibers per wash. And when these clothes end up in a landfill, they emit greenhouse gases such as methane and release dangerous chemicals into the surrounding environment as they decompose over hundreds of years.

Human-made cellulosic fibers such as viscose rayon, modal, Lyocell and cupro are technically renewable because they're derived from trees (or, more specifically, from cellulose, the molecule that gives trees their structure). The process of extracting the cellulose from wood pulp and converting it into usable fiber filaments relies on harsh chemicals, and the manufacture of these fabrics contributes to deforestation.

> "People are still interested in fashion trends. It's hard not to get swept up in those. We just don't have to do it so

mindlessly.” —Alyssa Beltempo, *sustainable stylist*

Recycled versions of all these fabrics exist, and “from an environmental perspective, recycled versions are preferable,” Hobson-Lloyd says. It is important to remember, however, that recycled materials still require the consumption of energy and water to be converted into something suitable for clothing manufacture. Clothing labels with vague references to recycled materials can be misleading. “The recycled content could actually be less than 10 percent,” Hobson-Lloyd says. Also, brands might say a garment is made from “recycled” material when what they mean is that the item *can* be recycled eventually if the consumer so chooses.

Some big-name brands are investing in R&D to clean up the industry, including through the use of biodegradable polyester alternatives and enzymes that make it possible to infinitely recycle plastic synthetic fibers. Others are developing textiles through advanced manufacturing processes. Bananatex, a natural fabric made by Swiss bag brand QWSTION, is derived from the fibers of the abacá banana plant, which grows in the Philippines and doesn’t require fertilizers or pesticides.

Because the abacá plant thrives in the shade of taller plants, it can’t be grown as a monoculture, which makes it a good candidate for reforestation projects. Unlike most other trees cut down for their cellulose, the abacá plant regenerates: each tree grows suckers—small shoots that develop at the base of the plant and grow again after being cut back. Workers harvest these suckers for their strong fibers and leave the rest of the plant intact. The fibers are dried and woven into a durable fabric that has been incorporated into designs from major brands, including Balenciaga, Stella McCartney and H&M.

This cardigan was mended by Flora Collingwood-Norris, who uses a "visible creative mending" technique to fix holes and tears and extend the life of knit garments. The method allows for flexibility and imperfection, making it more accessible to people who want to mend their own clothes.
Collingwood

But not all solutions involve technological innovation. Hemp, for instance, grows fast, retains water, prevents soil erosion, encourages biodiversity, is an impressive carbon sink and, like the abacá plant, can be grown without pesticides. These traits make hemp a very sustainable alternative to cotton. Hemp products are now much more widely available than they were even a few years ago, and some brands make entire clothing lines from the plant. The global hemp-fiber market is projected to grow from $5.76 billion to $23.57 billion between 2022 and 2030.

The fashion industry continues to be propelled by rapidly shifting and seasonal trends. But growing awareness of the harms of fast fashion has inspired the “shop your closet” movement, which encourages consumers to re-create inspired styles using items they already own instead of buying something new.

This idea had a big moment on social media last year when fashion writer and analyst Mandy Lee started the #75hardstylechallenge, which encourages people to document their efforts to shop their closet for 75 days. Lee wrote that more than 70,000 people joined in. It’s fitting, in a way, that Instagram and TikTok—platforms

awash with the fashion hauls and try-on videos that have helped supercharge the fast-fashion movement—can be harnessed to nudge people toward sustainable habits.

“It’s about a mindset shift,” says Alyssa Beltempo, a slow-fashion content creator and sustainable stylist. “People are still interested in fashion trends. It’s hard not to get swept up in those. We just don’t have to do it so mindlessly.” Beltempo teaches shop-your-closet techniques on her YouTube channel, which has nearly 300,000 subscribers. She starts with what she calls the “elements of style,” the basic, broad categories that underpin every outfit: things like silhouette, proportion, texture and use of color.

Beltempo encourages people to take inspiration from these elements rather than trying to replicate an outfit they’ve seen on someone else. “Do you actually like that sweater, or do you like the vibe it’s giving?” she asks. “Do you like how it’s styled with a wide-leg pant? Then maybe it’s the proportions you like. Maybe it’s the use of color that you like, and it has nothing to do with the sweater that [someone else is] wearing.” By teasing apart what appeals to you about an outfit that flashes across your social feed, you can think about how to re-create something similar with your current wardrobe rather than making a spontaneous purchase. This level of consideration “is joyful and engaging, and it allows the consumer to feel good about themselves,” Beltempo says. Not only is it better for the environment, “it’s better for you,” she adds.

Moth Snow of Touch Threads fashion brand works on the production floor at Green Matters Natural Dye Company in Pennsylvania. Green Matters uses botanical dyes—sourced from plants such as indigo and restaurant scraps such as avocado pits—to color clothing.
Winona Quigley

To that end, Beltempo gives her followers basic tips for avoiding impulse buys, such as always shopping with a list and implementing a 24-hour pause before buying something new. “It just gives you that space to think and serves as a trigger to be like, ‘Wait, do I have anything at home that can do that job already?’” she explains.

Sometimes, though, the items in our closet seem stale. Maybe the colors have faded from years of washing and sun exposure. One way to reinvigorate old clothes is to re-dye them. But not all methods are the same.

The textile industry uses more than 10,000 tons of synthetic dyes every year, many of them laced with toxic heavy metals that get released through factories' untreated wastewater and wreak havoc on soil health and aquatic ecosystems. According to the European Parliament, textile dyeing and finishing are responsible for about 20 percent of pollution of clean water worldwide.

These dyes can be toxic for humans, too. Textile dyes in the largest commercial class, known as azo dyes, can release carcinogenic compounds when they come into contact with the bacteria on human skin. The E.U. and the U.S. both have some restrictions on azo dyes in clothing, but these regulations are patchy.

There is an alternative: botanicals have been used to dye textiles for millennia. To extract a plant's unique coloring, people simmer its roots, seeds, bark or leaves at low heat until the water changes color. To help the dye bind to fabric, manufacturers treat clothes with a nontoxic mineral mordant such as a food-grade aluminum sulfate. When the dyeing process is done, the water can simply go down the drain without risk of harm to the watershed, and the remaining pigments and plant matter can be composted.

Until synthetic dyes were created, this was the way all textiles were imbued with color. Green Matters Natural Dye Company in Lancaster County, Pennsylvania, is trying to bring this technique back to the mainstream. Owner Winona Quigley says the company often uses local plants or even food waste from restaurants in its dye recipes. "We have a shed in our parking lot that has hundreds of thousands of dried avocado pits in it," she says. "We work with local restaurants to collect those." The pits impart a dusky pink color.

Green Matters attracts commercial clients that are looking to turn away from synthetic dyes in their textile and clothing production. It is one of the only dye houses in the U.S. producing solely plant-based dyes on an industrial scale. But much of the company's recent growth has come from people looking to breathe new life into their own garments. To meet this demand, Quigley launched custom dye services for individuals in 2022, including a community "dye lot of the month" club that has quickly become her most popular service. For $35, people can mail in their natural textiles to be dyed in one big batch, with colors rotating monthly. Recent offerings include "eggplant," a dark violet made from the root of the *Rubia tinctorum* plant, commonly known as madder.

Quigley says this side of the business grew 800 percent in 2024. "We've been really excited that there are people who want to have tools to keep their own garments out of the landfill," she says. People also send in their sheets and tablecloths (which can be tie-dyed to offset any stains)—and even their wedding dresses and precious but outdated family heirlooms. "It's more than just a piece of clothing," Quigley says. "It's a piece of family history, and seeing people turn it into something that's a part of their life is really touching."

Sending in a batch of well-loved clothes to be dyed a new color doesn't take any more time or effort than sending back an impulse clothing purchase that doesn't fit. It's less expensive than buying new, and you'll still get the joy of receiving and unwrapping a package. Sustainable fashion doesn't have to be a chore or financially inaccessible or staid—you can have fun while sending a message to the fast-fashion industry. "I think people can feel very empowered to take action to keep their own garments out of the landfill," Quigley says. "These are choices we can make that will have an impact on companies' sales."

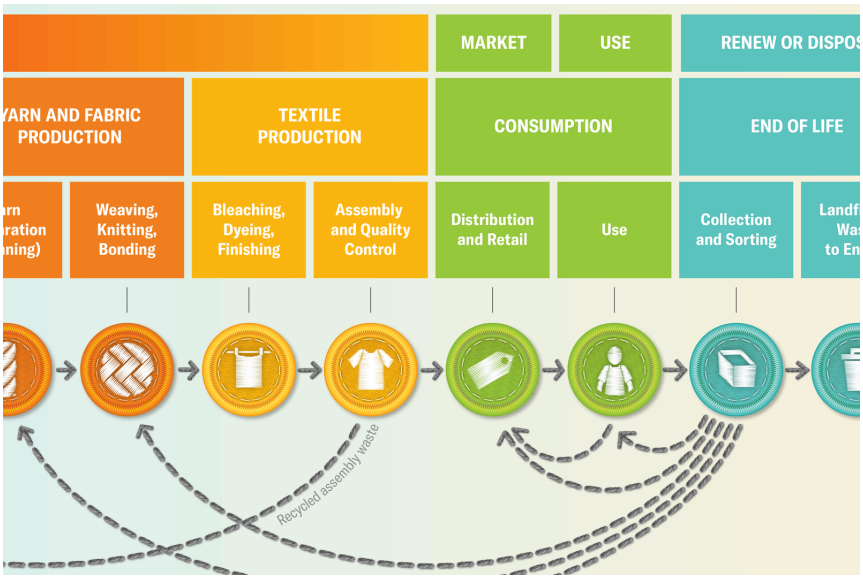
Jessica Hullinger is a freelance journalist based in London and a former editor at *The Week.*

https://www.scientificamerican.com/article/the-fast-fashion-backlash-is-fueling-a-sustainability-revolution

How to Be a Smarter Fashion Consumer in a World of Overstated Sustainability

Outsmart greenwashing with tips for more sustainable clothing

By Laila Petrie, Jen Christiansen & Amanda Hobbs edited by Jen Schwartz & Jen Christiansen

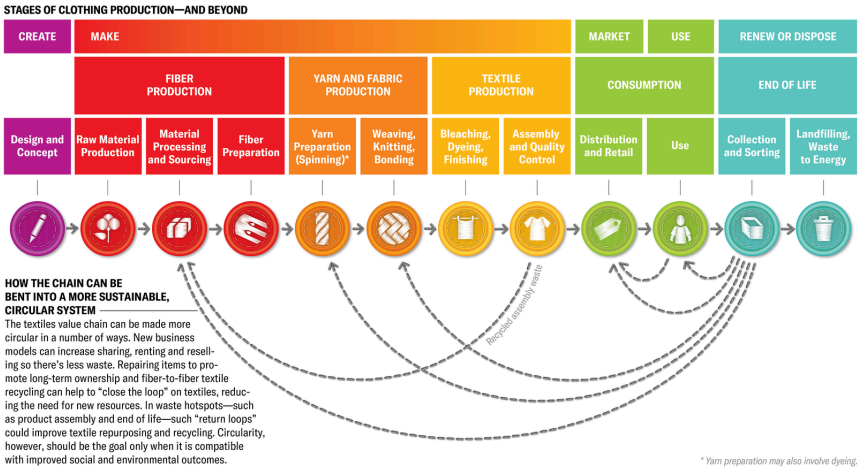


Jen Christiansen

Why is it so hard to cut through the greenwashing and overstated claims of the sustainable-clothing landscape? To start, the development, production and distribution of most garments are complex endeavors involving a global web of interconnected farmers, factories and traders, all supplying parts and processes to a huge number of brands and customers. Along that chain, there are many types of human and environmental impacts to consider. Some are challenging to measure, and some even “trade off” against one another—for instance, recycled materials are good for resource use but are potentially more likely to increase microfiber shedding. Many standards, product innovations, materials and brands claim to have a lower impact—and many more companies share very little information. All of this makes it challenging for a consumer to make decisions while shopping.

This guide will help you understand the stages of clothing inception and production. It will let you better piece together clues for a given garment or company to figure out whether sustainability was a priority at different stages of the life cycle, in terms of both the environment and human rights. You'll learn key terms that are important for evaluating whether claims have evidence behind them. The guide will also point you to other resources that can help you cut through the noise and get clear guidance, including rating and information sites such as Good On You or reports such as the United Nations Environment Program road map.

Above all, the two simplest ways to participate in sustainable fashion are to buy less and to ask questions. Many people in developed countries significantly overconsume apparel. As clothing production has doubled, the number of times each item is worn or used has dropped by approximately 40 percent. Using, repairing or adapting what you already have; borrowing items; buying vintage or secondhand; or leasing from sustainable rental companies can all provide a low-impact alternative to purchasing new products. If you do want to buy new, ask the right questions: look for evidence to support claims, don't be fooled by terms such as "natural," and engage with companies directly to request more information and more sustainable processes and products. These actions alone, if done at scale, would have the power to change the fashion industry.



Jen Christiansen (*design*); Amanda Hobbs (*research support*); Sources: *Circular Fashion: Making the Fashion Industry Sustainable*, by Peggy Blum; *Sustainability and Circularity in the Textile Value Chain: Global Stocktaking*. Published by U.N. Environment Program, 2020 (*primary references*)

WHAT YOU SHOULD KNOW ABOUT CLOTHING PRODUCTION

Here we break down the dominant linear pathway of garments, punctuated with details for each stage that impact sustainability from both a human-rights and an environmental point of view. For the most part, policymakers, corporations and designers are in the position to make the most substantive changes to each step—including by bending production flow to create a circular pathway. That said, consumers can use this knowledge to make informed decisions in support of sustainable practices.

Design and Concept • Material and construction-technique decisions—made by designers and fashion brands—influence the impact of production and the garment's lifespan. As fashion scholar Peggy Blum writes, "Design is key in the shift to a circular fashion model, which requires greater focus on doing things 'right from the start.'"

Raw Material Production • There are three primary fiber-source categories: natural fibers, natural polymers and synthetic polymers. For natural fibers, "production" refers to cultivation or breeding. In the case of polymers, it refers to cellulose or oil extraction.

Material Processing and Sourcing • Raw materials must be processed or extracted before fiber preparation. This involves, for

example, cotton baling and sheep shearing, as well as the transport of the materials. For synthetics, it involves the chemical production of specific polymers from the source ingredients to make, for instance, polyester chips.

Fiber Preparation • Fibers are aligned and elongated. In the case of cotton, a series of specialized machines pick fibers off bales, then clean and straighten them into long and loose untwisted strips. Synthetic polymers are extruded to create fibers.

Yarn Preparation (Spinning) • Spinning is the torsion process by which fibers are twisted into yarn. Short fibers (cotton and wool) are called staple fibers. Long fibers (silk and many synthetics) are called filaments; they generally require less processing at this stage. Different spinning methods yield different characteristics.

Weaving, Knitting, Bonding • Yarn is then manipulated into fabric. Woven fabrics are made of perpendicular and stable interlocking yarns. Knitted fabrics are made of stretchable, interlocking loops. Bonded fabrics are technical textiles in which fibers and/or fabrics are bound by adhesives, heat or pressure.

Bleaching, Dyeing, Finishing • Textiles are washed and prepared for dye using water and chemical baths followed by heating or steaming. (Some of these treatments may also be used during yarn production.) Next the fabric may be printed or dyed, then fixed with dye stabilizers, flame retardants, antimicrobials, and other treatments.

Assembly and Quality Control • Assembly includes fabric cutting, sewing, trimming and ironing of the finished garment. Finishes, such as bleaching or sandblasting for faded denim, may also be applied.

Distribution and Retail • This stage includes logistics, transportation from assembly location to retail storage, packaging and marketing, store operating impacts, and/or direct shipping from warehouses to consumers. (Transportation from retail stores to consumers—such as direct shipping—is not reflected in the data below.)

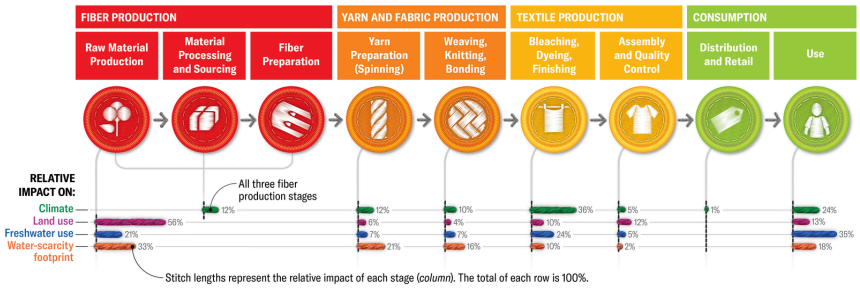
Use • Use includes consumer wear and care. It covers maintenance —cleaning, drying, ironing and storing—as well as repair. The garment may cycle over into being used again by another consumer via a direct secondhand donation or via thrift and consignment shops, or it may be used by multiple customers in a rental-based model.

Collection and Sorting • Per a 2020 U.N. report, at most 1% of textiles is recycled back into clothing. Another 12% is used in products such as cleaning cloths, insulation material and mattress stuffing. There is a significant global trade of used garments for recycling, often ending up in locations without processing capacity.

Landfilling, Waste to Energy • In the dominant linear garment pathway, most garments end up in a landfill or an incinerator plant after one or more uses. In a circular pathway, the textile would avoid this stage by being used for much longer or by more customers, upcycled into a new garment, or broken back down to the fiber level and spun anew.

ENVIRONMENTAL IMPACT

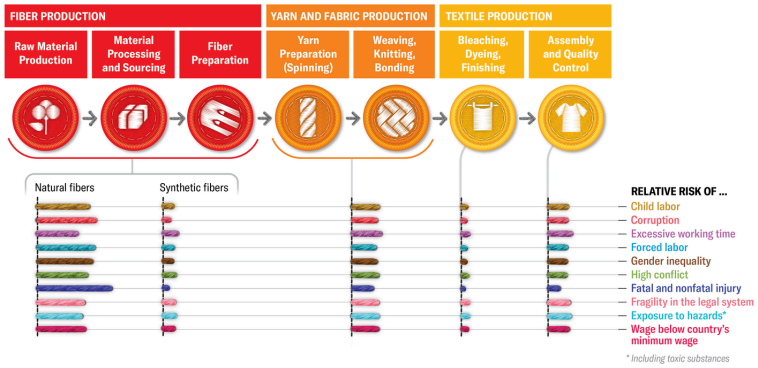
Breaking down environmental impacts by stage allows for targeted reduction efforts. The values shown here, as published by the U.N. Environment Program, were calculated using a global baseline year of 2016. At that time, apparel was estimated to comprise 30% natural fibers and 70% human-made fibers. (Some categories, including water use, vary widely depending on fiber type and region.) Energy-intensive stages emerge as hotspots. Dyeing and finishing require large quantities of water and electricity for heating, as do washing and drying by individuals at the use stage. Variation resulting from regional laundry habits suggests that this is a pain point that consumers can influence directly.



Jen Christiansen (*design*); Amanda Hobbs (*research support*); Source: *Circular Fashion: Sustainability and Circularity in the Textile Value Chain: Global Stocktaking.* Published by U.N. Environment Program, 2020 (*data*)

HUMAN IMPACT

Garment manufacturing is a significant source of jobs for people around the world—particularly for women in low-income countries. It's also an industry rife with poor working conditions. The relative risk values shown here, published by the U.N. in 2020, were calculated for a hypothetical low-cost garment made from a cotton and polyester blend. Fiber production emerged as the stage that carries the highest levels of social risk. Further, "the high social risks of fiber production are overwhelmingly due to natural fiber production ... [The values] are even more striking bearing in mind that these results are for a low-cost garment made up of 70% synthetic fibers and only 30% natural fibers."



Jen Christiansen (*design*); Amanda Hobbs (*research support*); Source: *Circular Fashion: Sustainability and Circularity in the Textile Value Chain: Global Stocktaking.* Published by U.N. Environment Program, 2020 (*data*)

TIPS FOR CONSUMERS

Simply buying less stuff is the most impactful way to make more sustainable fashion choices and push back against the relentless consumerism perpetuated by the fast-fashion industry. But that doesn't mean never adding something new to your closet. Whether you are looking for a warm coat after moving to a cold climate, restocking your sock drawer, or sourcing an outfit from a vintage store for a special occasion, ask yourself whether the item truly fits you, functions in your wardrobe and will last. Evaluate the quality and seek information about production processes and sustainability policies. Brands are sensitive to customer demand, so use your power to advocate for change.

Design and Concept • Look for specifics on the clothing brand's website about its sustainable-design ethos, including details about how it designs for garment longevity, durability and recyclability and for how it reduces waste and production im-pacts. Bonus points for brands that design for circular business models or directly provide repair, returns or recycling.

Fiber Production • In many cases, organic or recycled materials have a smaller environmental impact than conventionally grown plant materials and newly created synthetics. But recycled products can have high social and labor risks. Get familiar with the coverage of different standards such as Better Cotton, Organic or Responsible Wool Standard. ITC and Textile Exchange both have rating systems for different schemes and branded materials. Often there isn't one ideal solution. If you focus on social issues, then choose Fairtrade; if you value veganism, then synthetic leather substitutes may be your priority even if they have large climate or

chemical impacts. Try to find the “best” available version of the fiber category. Rather than moving away from cotton altogether, for instance, choose highly sustainable or recycled cotton in place of conventional. Is there any evidence to support raw material claims, such as a Life Cycle Assessment? Terms like “green” and “natural” do not have a specific meaning. Try to substantiate words like “recycled” by searching for the actual percentage of recycled material.

Yarn Preparation (Spinning) • Spinning is one of many energy-intensive activities with the supply chain. Look for brands with a Scope 3 Science-Based climate target. If a company has an identified spinner list, it is also an indication it has put significant resources into its traceability and data-collection systems.

Weaving, Knitting, Bonding • Bonded fabrics are less sustainable than woven or knitted ones but can be useful for specific technical purposes, such as water-proofing. They often contain PFAS, and as of 2025, clothing with PFAS is banned from sale in New York State and California. Waxed cotton canvas and boiled wool also provide water resistance.

Bleaching, Dyeing, Finishing • Certifications such as GOTS or Oeko-Tex provide controls on the chemicals used in dyeing and finishing. Look for brands implementing water-management plans and applying chemical and wastewater controls such as those from

ZDHC, or creating funding programs to help manufacturers and producers invest in renewable energy.

Assembly and Quality Control • Faded or treated jeans have particularly high worker-health impacts and should be avoided. Look for labor plans aligned with programs such as ILO, Sedex or OECD. If this information is missing, ask the company questions on its social media—this puts pressure on companies for action and transparency.

Distribution and Retail • If you are buying products new, don't create excessive transport impacts by purchasing and returning significant volumes of garments. Consider more circular options such as buying secondhand or vintage clothing or renting clothing for specific uses (look for sustainable solutions to the cleaning and transport of rented options).

Use • To increase a garment's lifespan, follow the care instructions provided and repair damaged areas. Wash clothes less frequently and at lower temperatures or air-dry—which can reduce environmental impact. Avoid dry-cleaning. Microfiber filter products might also help reduce the impact of shedding from laundry.

End of Life • Textiles in good condition should be sold, swapped or donated to optimize their use. For an unwearable item, can you repurpose it at home as a rag or drop cloth? If not, check whether you can recycle it at the store where you bought it (such as H&M or Patagonia). Or use a direct recycling solution such as Retold or a local collection facility. Aim for ones that speak to how they sort and recycle fabrics and avoid those that are not transparent about where waste goes. You don't want your clothes to become a burden on countries that receive high volumes of waste.

Laila Petrie is a sustainability expert with 20 years of experience creating global programs and reports for brands, international NGOs and global bodies such as the United Nations. She is currently director general of the charity Future Earth Lab.

Jen Christiansen is author of the book *Building Science Graphics: An Illustrated Guide to Communicating Science through Diagrams and Visualizations* (CRC Press) and senior graphics editor at *Scientific American*, where she art directs and produces illustrated explanatory diagrams and data visualizations. In 1996 she began her publishing career in New York City at *Scientific American*. Subsequently she moved to Washington, D.C., to join the staff of *National Geographic* (first as an assistant art director–researcher hybrid and then as a designer), spent four years as a freelance science communicator and returned to *Scientific American* in 2007. Christiansen presents and writes on topics ranging from reconciling her love for art and science to her quest to learn more about the pulsar chart on the cover of Joy Division's album *Unknown Pleasures*. She holds a graduate certificate in science communication from the University of California, Santa Cruz, and a B.A. in geology and studio art from Smith College. Follow Christiansen on Bluesky @jenchristiansen.com

Amanda Hobbs is a freelance researcher, writer and visual content editor specializing in storytelling via art and information graphics. Her work can be viewed at www.athcreative.com

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https://www.scientificamerican.com/article/a-beginners-guide-to-ethical-and-sustainable-fashion

Could Mysterious Black Hole Burps Rewrite Physics?

After black holes devour stars, sometimes the feast comes back up

By Yvette Cendes edited by Clara Moskowitz

Mark Ross

Black holes are invisible, yet they are among the brightest things in the universe. If a star wanders too close to a black hole, it gets torn apart in a fireworks show called a tidal disruption event. As the star approaches, it gets twisted and pulled, and about half of it ends up flung outward. The other half forms a Frisbee-shaped accretion disk around the black hole itself. This newly formed disk is not stable: material sloshes around and smashes into itself, creating a light show detectable in radio wavelengths.

These are rare occurrences—scientists estimate that the giant black hole at the center of our Milky Way galaxy gobbles a star about every million years or so. But when it happens, it releases a tremendous amount of light and energy visible millions or even billions of light-years away.

Until recently, astronomers had thought that after the initial feast, the swallowed star was never to be seen again. Observations in the past five years, however, suggest otherwise. In a surprising turn unpredicted by theory, it appears that black holes can suffer from indigestion, spewing out material years after the initial stars were shredded. In fact, scientists are now finding that up to half of black holes that devour stars start shining again in radio light years after they had gone quiet—the equivalent of a cosmic burp. We know this material isn't coming back from beyond the event horizon—that's impossible. It's most likely sloshing about in an accretion disk outside that boundary. But explaining how these black hole burps can occur so late is challenging. What's going on? Solving the mystery of these regurgitations may reveal new secrets about the physics of the most extreme environments in the universe.

Most galaxies around the size of the Milky Way or larger have a supermassive black hole skulking in their center. Each of these black holes can be millions or even billions of times more massive than our sun, and their event horizons—the points of no return—can extend past the radius of Pluto's orbit around the sun. Despite this gargantuan size, however, a black hole doesn't suck in material like a vacuum cleaner any more than our sun sucks in the planets. If our sun were instantly replaced by a black hole, for example, Earth would continue on the same orbit as always. Instead what makes a black hole so unique is its density. Within the event horizon distance, its gravitational pull is so strong nothing can escape.

And for supermassive black holes, their mass alone means they have an extremely strong gravitational pull. This is the case for our own Milky Way's black hole, called Sagittarius A* (or Sgr A* for short). It's located about 27,000 light-years from Earth and is about four million times as massive as the sun. Astronomers have carefully tracked several dozen individual stars for decades that are in stable orbits around Sgr A*. But astronomers believe there are thousands of objects orbiting Sgr A* that we can't see—many of

them the leftover remains of dead stars, such as neutron stars or white dwarfs, that are too dim to detect. If one of those unknown objects passes near a star, it may disrupt its orbit, sending it on a collision path toward Sgr A*.

> It appears that black holes can suffer from indigestion, spewing out material years after the initial stars were shredded.

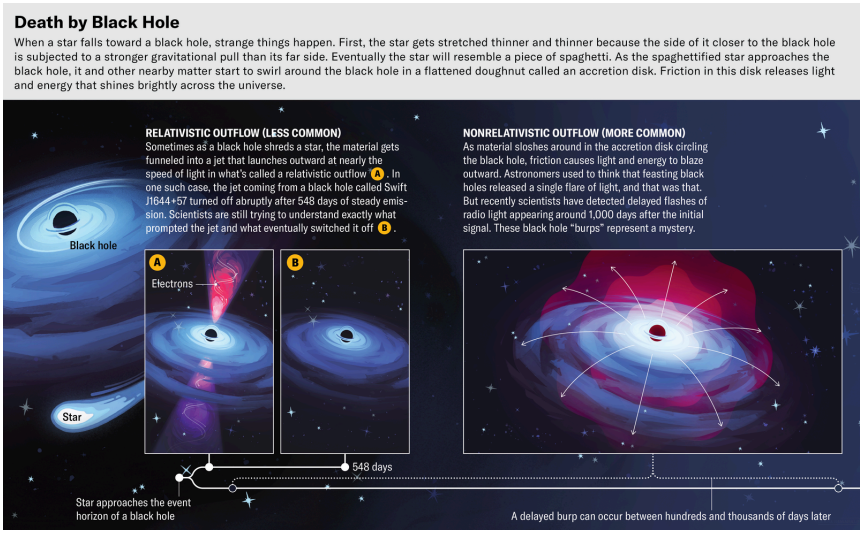
Well before it reaches the event horizon, the doomed star will start to experience tidal forces. Gravity gets stronger the closer you get to a massive object, so the side of the star closer to the black hole will feel stronger gravitational forces than its far side does. The star will begin to stretch, and eventually, at a boundary called the tidal radius, the difference in pull between the two sides of the star will be greater than the gravitational force holding the star together. The star will unravel along its direction of motion in a process called spaghettification—first changing from a sphere into an oval and then becoming a long string of material that resembles a thin strand of pasta. As the star's density decreases, its internal fusion stops, and a star that might have burned for billions of years unravels in just a few hours. Half the material is immediately flung outward, never to return, and the rest forms a new accretion disk sloshing around the black hole. When this happens, the rapid change of mass into an accretion disk creates a very bright flare, usually at optical wavelengths.

The first tidal disruption event candidates were discovered in the 1990s, and astronomers have now seen about 100 of them. The unbinding of a star gives off a flare visible from millions of light-years away, similar at first glance to an exploding star. There are a few key differences, however: First, a tidal disruption event occurs in the center of a galaxy, where supermassive black holes lurk, whereas supernovae can occur anywhere. Second, the light from a black hole flare will reveal a spectrum unlike that of a dying star. Astronomers can spot the light signature of an abundance of

hydrogen because the star will likely have copious leftover fuel that never got a chance to be used, implying the star didn’t meet a natural death.

We discover about a dozen new tidal disruption events a year. These eruptions occur around black holes that otherwise aren’t eating much. That makes them different from black holes we call active galactic nuclei, which are engaged in many-years-long eating fests, sucking in large amounts of gas over long timescales and continuously emitting light as they do so. Those feeding frenzies are intensely chaotic and play out at a haphazard pace. In comparison, tidal disruption events are relatively controlled events that allow us to watch what happens when a small bit of very dense material is injected into the black hole all at once.

When someone spots a new one, radio astronomers like me swing our telescopes to look for emission from the mass and energy flowing outward from the newly formed accretion disk, looking for any radio emission present where there was none before, called the outflow. Radio waves come from electrons spiraling in magnetic fields created in those outflows, giving us a physical picture impossible to get at other wavelengths. We can detect the speed of the escaping material, the energy of the blast, the strength of the magnetic fields, and even the density of gas and dust the outflow is plowing through. Furthermore, once the outflows leave the newly formed accretion disk, they can travel several light-years in distance before they fade. Observing these outflows gives astronomers a unique way to probe the environment around a previously dormant supermassive black hole on a detailed level not possible with other methods.



Olena Shmahalo

About 99 percent of all the mass released in a tidal disruption event is called nonrelativistic—it moves along at 10 percent the speed of light or less. The remaining 1 percent, however, is very different. In these cases, material from a shredded star gets funneled into a jet launched at nearly the speed of light. This is so fast that the laws of relativity must be considered when we study it, and thus we call it a "relativistic" outflow. The first known relativistic tidal disruption event, called Swift J1644+57, was detected in 2011 when NASA's Neil Gehrels Swift Observatory spotted a strange burst of radiation from the center of a galaxy 3.8 billion light-years away. After a year and a half of steady emission, the jet in Swift J1644+57 turned off abruptly, presumably when the material from the star that was feeding the jet had been mostly consumed, and the accretion rate—the amount of mass being eaten by the black hole in a given time—declined below some critical value. Before this discovery, no one expected these black hole feeding events to be capable of launching relativistic jets, let alone one that turned on and off on such a short timescale. Exactly how and why they're created is not fully understood.

Astronomers also assumed that the light pattern from all tidal disruption events matched that one—a flare for a few months followed by nothing. After they go dark, we usually stop looking. After all, radio telescope time is a precious resource. Why waste

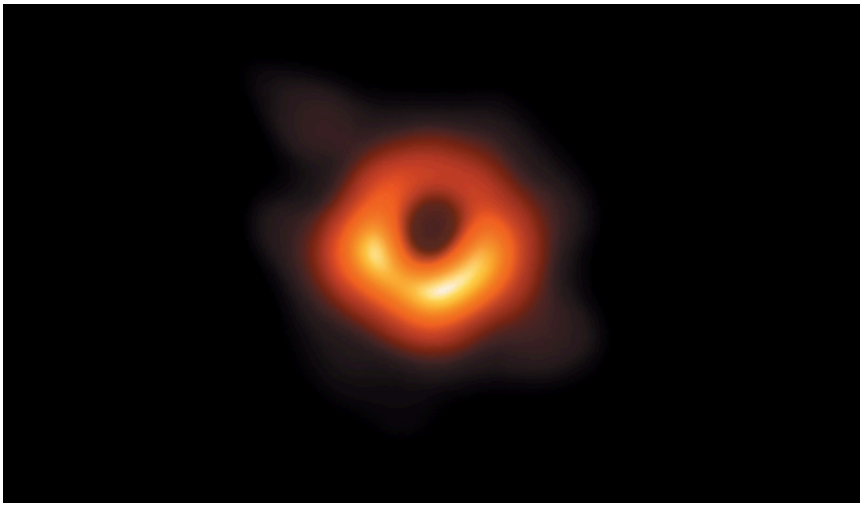
valuable time looking at an explosion years after it occurred? It was a reasonable assumption to make, but it turns out it was the wrong one. It did, however, set me up to make the discovery of a lifetime.

I first decided to be an astronomer when I was 13 years old and read a book about space. I have always loved stories, and the story of the universe is the biggest and grandest one we have. I decided to be a radio astronomer in high school, thanks to Carl Sagan's 1985 novel *Contact*, in which the heroine, Ellie Arroway, uses the Very Large Array (VLA) in New Mexico to discover an extraterrestrial message. Once I started working in the field, I never stopped, because radio astronomy feels like magic: it lets us tease out the faintest signals by linking together antennas the size of buildings, which sing a story impossible to hear otherwise. My career as a radio astronomer has been filled with adventures, but none has matched the discovery of AT2018hyz, my first burping black hole.

It all began on a bright autumn day in 2021 in Cambridge, Mass. I was a postdoctoral researcher at the Center for Astrophysics | Harvard & Smithsonian, working on data from the VLA that no one else had time to look at. A few months before, another team had detected a tidal disruption event in radio light called ASASSN-15oi, more than 100 days after it was first seen in optical light, despite no radio detection at earlier times. Most people assumed the flare was the result of some unusual circumstance intrinsic to this object or its environment, but I thought it wouldn't hurt to do a survey with the VLA and see whether any other black holes displayed repeated flares.

The VLA collects radio light from 27 antennas, and then these data must be combined to create a radio picture. If we see a source of radio light, it appears as a cluster of pixels in a sea of black. If there's nothing out there, we see only a noise pattern. On this fateful day, I opened an image of a tidal disruption event called AT2018hyz that had been discovered in optical light in 2018. As I

looked at the screen, I paused in confusion for a moment before going to manually confirm that the coordinates were correct. Where I'd expected noise, which is all anyone had seen in radio light from this region of space before, there was an unmistakably bright source—this despite being some 665 million light-years from Earth. It had, very definitely and without any fuss, turned "on."



In 2019 the Event Horizon Telescope captured the first image of a black hole, revealing a dark "shadow" within an accretion disk of glowing gas.
EHT Collaboration

I reached out to my collaborators, who were all as excited as I was, and I found a radio survey image that just happened to be taken of the same patch of sky only nine months earlier. There was nothing but noise, implying the radio emission from AT2018hyz had risen rapidly in just a few months. No one had ever seen anything like it before in astronomical history.

Around the time that the first observations were coming in, I went home and told my husband about the discovery. "The problem is AT2018hyz doesn't really roll off the tongue," I told him, "and it's pretty obvious we'll be talking about this for a while. Would you like to name it?" My husband paused, taking the correct tone of gravitas and sober dignity one should have when your wife offers you naming rights to a black hole. "Jetty McJetface," he said firmly. It's not official, but from then on AT2018hyz was called "Jetty" at our house.

In some sense, the most remarkable thing about Jetty was that it turned out it wasn't alone. By the time I had analyzed the data from the full observation campaign, I had several new radio detections of years-old tidal disruption events, all of which had been initially discovered, then turned off, and were now shining again. It seemed that black holes, after consuming stars, suffer a fit of indigestion after a few years and "burp." This was surprising for several reasons. Lighting up again after a few years is an unusual timescale for such a thing to happen on. You don't return to the site of a bomb explosion years after it occurred expecting to see new debris released. And we don't think the black hole simply started snacking on a new star—if that were the case, we'd also see optical light, but we don't.

Ultimately, my team and I surveyed about two dozen black holes, all of which were first detected and confirmed in optical light. From these discoveries, we knew exactly when the initial brightening event had occurred. All of them had been surveyed in radio light in the intervening years and were dark. Of these, we discovered 10 burping black holes that were alight again in radio waves. Whatever is happening, it's common and opens our eyes to a new phenomenon that we can use to test the physics of black holes.

> We live in a universe filled with cosmic destruction on grand scales and at distances often hard to comprehend.

We still have many open questions, but here's what we know so far. First, the assumption that tidal disruption events release light and energy primarily in the first few months is wrong. Although we always observe optical light at the initial disruption, our data suggest that radio emission is most common at least 1,000 days after that. Some black holes even seem to release a *second* flood of radio waves—one relatively promptly and another hundreds of days after the first one has faded. There appears to be no significant correlation between when the black hole starts to shine in radio

light and when it emits in other wavelengths—the radio emission isn't accompanied by an optical flare indicating a second star has been disrupted or by x-ray light indicating a significant change in how much mass the black hole was accreting.

Finally, the radio data collected so far tell us that these delayed burps look like relatively normal nonrelativistic tidal disruption event outflows—just seen much later than we'd expect. The density of gas we measure in their environments is also similar to that in our own Milky Way. In other words, there's nothing special about the black holes' surroundings.

Now, of course, the million-dollar question is *why* black holes burp. It appears as if they gobble up mass, pause, and then start spitting a bit out. To be clear, we are not seeing material escaping from beyond the event horizon of the black hole: this would be physically impossible, and we have absolutely no indication that this is what's happening. Instead we think something is going on in the accretion disk or beyond. Perhaps, astrophysicists have suggested, the accretion disk forms much later than we'd previously assumed, or possibly the black holes are creating unusual density fluctuations in their environments. The flares could be caused by interacting dust clouds, or maybe a cocoon of material around the black hole delays the flow of radio emission until later. It is currently unclear which theory, or theories, is correct.

The exception to all of this, though, is Jetty (or AT2018hyz). Although other black hole burps show some similarities to one another, Jetty literally outshines them all. Its brightness has continued to rise since I first discovered it, and it's now about 40 times brighter than it was at that detection. We still aren't sure what's driving it, but there are two possibilities. The first is that Jetty "burped" about two years after eating a star, releasing an outflow traveling at roughly one-third the speed of light. That would be the first "mildly relativistic" outflow we know of,

somewhere in the middle of the nonrelativistic and the nearly light speed.

The second option is potentially more incredible. Perhaps when the original tidal disruption event happened in October 2018, a relativistic jet of material was launched at an almost 90-degree angle to Earth. This jet would be one of the highest-energy ones we've seen. To start, its direction would make it invisible to us, but over time the jet would widen and enter our line of sight. This could be what we are seeing now, years later. Just *how* energetic and *how* bright it will get is impossible to know until we see it happen.

To distinguish between the two possibilities, my collaborators and I are studying Jetty with another method, called Very Long Baseline Interferometry (VLBI). With VLBI, we are linking together radio telescopes spread across North America and Europe to create a virtual radio telescope that's effectively the size of the distance between Germany and Hawaii. We believe this combined scope will have enough resolution to see the material flying out of the black hole directly, despite our being hundreds of millions of light-years away. The first observations are in, but analysis of data over such large distances is tricky—we hope to have the answer soon.

We also hope to grow our collection of known tidal disruption events to monitor for burps. The Vera C. Rubin Observatory, turning on this year, is an 8.4-meter-diameter telescope housed in Chile that will survey the entire night sky every night. Once fully operational, Rubin is expected to find millions of new objects, ranging from supernovae to asteroids, and should uncover around 1,000 new snacking black holes a year. Additionally, the Nancy Grace Roman Space Telescope will launch in 2027. This scope should produce images of similar sharpness to the Hubble Space Telescope but with a field of view 100 times wider. We expect it to find hundreds more tidal disruption events a year. For scientists

who were used to discovering a comparative trickle of new objects, this fire hose of new data should be exciting and challenging.

We live in a universe filled with cosmic destruction on grand scales and at distances often hard to comprehend. But black holes will continue to feast—and burp—and my colleagues and I will be watching.

Yvette Cendes is a professor in the department of physics and astronomy at the University of Oregon. Follow her on Bluesky @whereisyvette.bsky.social

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https://www.scientificamerican.com/article/why-some-black-holes-keep-burping-light-after-eating-a-star

The Truth about Testosterone

To boost mood and manliness, men are spending lots of money on the hormone testosterone—yet they may see trouble instead of benefits

By Stephanie Pappas edited by Josh Fischman

Xvision/Getty Images (*man*); Jonathan Knowles/Getty Images (*pills*)

Rob, 42, is a fitness guy. He loves working out, spends his spare time in the jujitsu gym and eats a high-protein diet heavy on avocado oil. He cares about his health and wants to optimize it, and a lot of the social media influencers he follows are the same.

So a few years back, when Rob started seeing ads for testosterone replacement therapy—TRT—pop up in his feeds, he was intrigued. (Names of patients in this story have been changed to protect their privacy.) Rob was already a man in good shape. But testosterone sounded like a great way to get an extra edge.

“I bought into what I was listening to on social media, which is, ‘You’re going to feel better, you’re going to get stronger, and you’re going to look better,’” he says.

Rob went to a local, privately owned clinic. There he got a blood test, which revealed that his testosterone was well within normal range. “I certainly didn’t need TRT,” he says.

The clinic prescribed it anyway.

Rahim, 48, tells a similar story. He walked into a men’s health clinic a decade ago looking for an energy and fitness boost. He got an injection that very day. On subsequent visits the clinic pushed his dose higher and higher, but he perceived little benefit. “I just felt like I was taken advantage of,” he says now. “I felt like somebody was using my body to make money.”

Testosterone therapy—prescription supplements in the form of pills, patches, injections or implantable pellets—has probably never been more publicized or popular. Podcaster Joe Rogan is on it. On Reddit and on TikTok, on highway billboards and in TV commercials, you’ll see testimonials in praise of TRT promising mood boosts, better sex, extra energy and quite possibly an abdominal six-pack. The global market has been estimated at $1.9 billion.

For the right men, usually those with seriously low levels of the hormone, TRT can improve mood, energy levels and sex drive. It can increase muscle, decrease fat and lower levels of biomarkers for heart disease. Rigorous studies have dispelled once common medical concerns that the supplements increase the chance of prostate cancer; they don’t. And many responsible clinics that prescribe TRT inform their clients of the potential risks and benefits and monitor them closely.

But many men getting supplements may not have low testosterone to begin with, and for them, boosting levels of the hormone even higher could cause harm. There is a lot of medical disagreement about what constitutes “low,” driven by several studies with different populations and different cutoffs. Because of this

uncertainty, some clinics will legally prescribe TRT for men whose hormone levels are, according to many measures, just fine. “It will not make you live longer. It will not make you otherwise healthier,” says Channa Jayasena, who is a reproductive endocrinologist at Imperial College London.

And TRT carries risks. Supplemental testosterone can increase the chances of infertility and shrink testicles. It can lead to an abnormal blood condition called erythrocytosis. It is also associated with heightened rates of acne and painful swelling of male breast tissue. So urologists and endocrinologists who study the hormone caution men thinking about TRT to proceed very carefully.

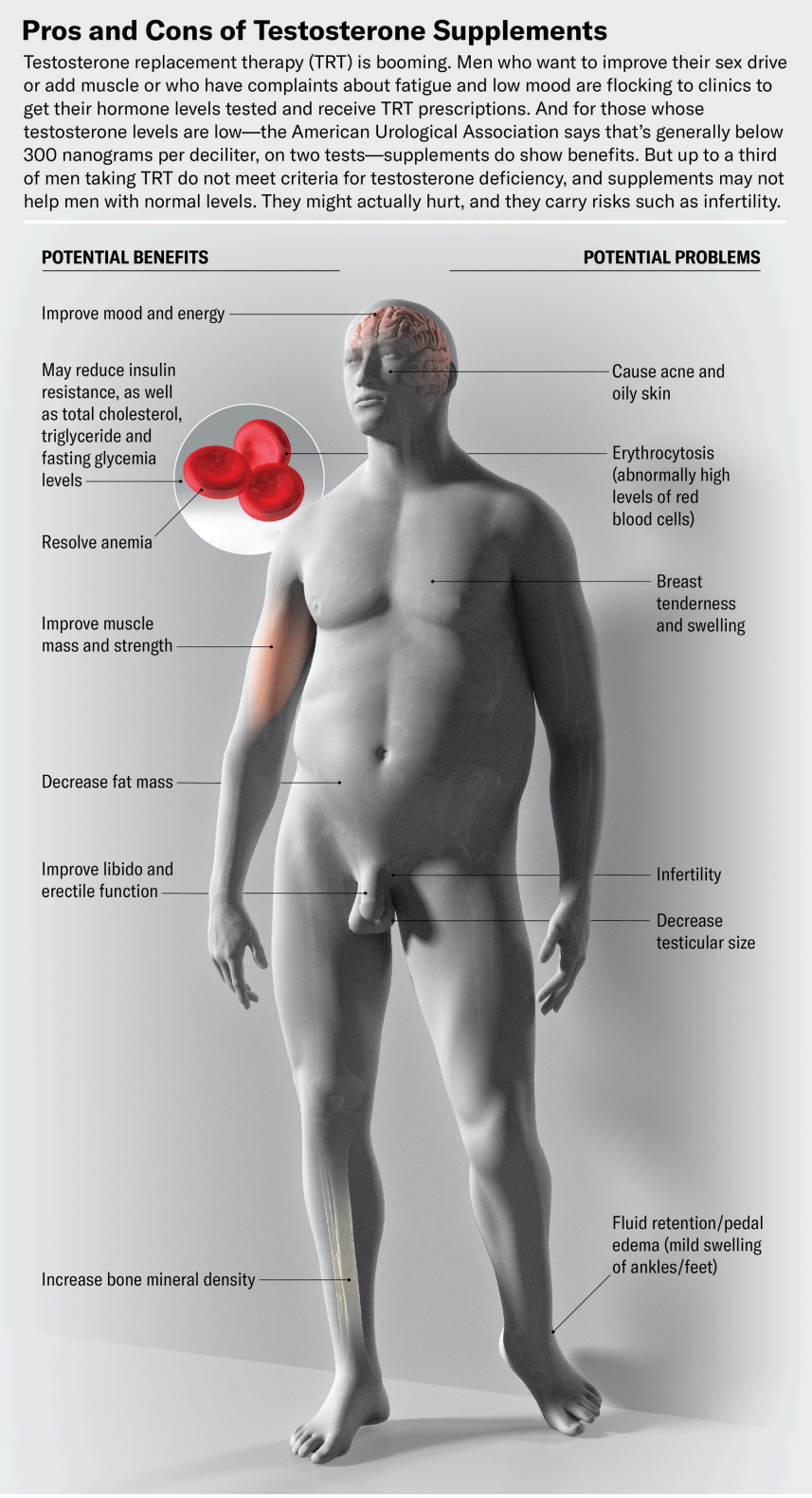
Thanks to its inexorable cultural ties to masculinity, testosterone is perhaps more prone than other “wellness” treatments to emotional appeal. The TRT ads that show up on social media promise a lot but rarely mention side effects or proper testing. “The majority of the testosterone information on TikTok and Instagram is horrible, horrendous,” says Justin Dubin, a urologist at Memorial Healthcare System in southern Florida. “It’s not accurate.”

The normal range for testosterone level is broad, spanning from around 300 to 1,000 nanograms per deciliter of blood (ng/dl). After about age 40, a person’s amount of circulating testosterone starts to decline by approximately 1 percent a year, and with the U.S. population getting older, it’s no surprise that interest in TRT is rising. There is also some evidence that average levels of testosterone are dropping in young men. Diseases that have become more common, such as obesity and diabetes, affect hormone production and likely explain some of that decline.

But interest in boosting testosterone goes way back—back to before anyone knew what testosterone was. In 1849 German scientist Arnold Adolph Berthold observed that castrated roosters showed little interest in fighting over females. When rooster testes

were transplanted into these peaceniks, they suddenly developed an interest in sex and barnyard brawling.

Doctors soon sought to harness the testes' miraculous masculinizing power. In 1889, 72-year-old Mauritian neurologist Charles-Édouard Brown-Séquard injected himself with a slurry of crushed-up dog and guinea pig testicles, seeking rejuvenation. He reported that after a few injections he could sprint down stairs like a young man and stand at his laboratory table for hours.



Violet Frances; Source: Abraham Morgentaler (*scientist reviewer*)

Russian-born physician Serge Voronoff tried transplanting testicles from monkeys into people and gushed about his results in his 1925 book, *Rejuvenation by Grafting*. He wrote of one 74-year-old patient that after surgery, "his superfluous fat had disappeared, his

muscles had become firm, he held himself erect and conveyed the impression of a man in perfect health ... The grafting had transformed a senile, impotent, pitiful old being into a vigorous man, in full possession of all his faculties."

Today doctors say any positive effects from these treatments were pure placebo. In 2002 Australian researchers tried making Brown-Séquard's testicle extracts and found that the amount of testosterone in the preparations was a quarter of what would be needed to produce a biological response. And in the days when Voronoff worked—before modern tissue-preservation advances or any understanding of antirejection drugs—testicle transplants (especially cross-species transplants) would have been incredibly unlikely to survive.

A synthetic form of testosterone was developed in 1935, making a drug form of TRT possible. But its advent did not lead to a prescribing boom right away. (It did catch the notice of bodybuilding communities, who began asking for it.) In part, the medical reluctance was because of a small 1941 study showing that adding testosterone made prostate cancer grow faster and that the tumors shrank when levels of the hormone were low. The connection made doctors extremely wary of treating men with testosterone—even men with undeniable hypogonadism, meaning their testes could not make sufficient amounts of the hormone. "There was a near-complete prohibition," says Abraham Morgentaler, a urologist and testosterone researcher at Harvard Medical School.

In the 1980s Morgentaler, who had investigated the effect of testosterone on the reproductive behavior of lizards as a student, was a young urologist specializing in male infertility, treating patients with low testosterone, erectile dysfunction and a lack of libido. They were desperate. Morgentaler thought back on his lizards, which had failed to woo females when deprived of testosterone. Cautiously, he began to dose a few of his patients with

the hormone. Not only did they report improved sex lives, he says, but “they described to me how they felt better outside of their sexual symptoms—things like ‘I’ve never had so much patience for my small children,’ ‘I wake up in the morning, I swing my legs over my bed, I’m optimistic about my day.’”

As Morgentaler continued his hormone-treatment research, he failed to see any increase in prostate cancer growth in patients. Over time the evidence that testosterone does not necessarily supercharge prostate tumors has piled up. By the early 2000s fears of prostate cancer with testosterone treatment were easing, if not altogether disappearing.

As a result, TRT began to rise in popularity, and its use increased more than threefold between 2001 and 2011, according to research published in 2013. Still there was hesitation. The U.S. Food and Drug Administration issued a warning in 2014 that TRT might raise the risk of heart attacks and strokes. Testosterone influences muscle growth and activity; muscle fibers are dotted with many androgen receptors. The heart, of course, is a muscle. In men who take anabolic steroids for bodybuilding—natural testosterone is a form of this type of hormone—heart problems are a known consequence.

To tackle these two safety issues, a consortium of researchers put together the TRAVERSE trial, the largest-ever randomized, controlled trial on TRT for men with low testosterone. They screened more than 5,000 men, aged 45 through 80 years, to ensure participants had low levels of prostate-specific antigen (or PSA, a marker of prostate cancer) at the onset of the study, and they followed the men for an average of three years. In 2023 the researchers reported the results. There was no increase in prostate cancer with testosterone treatment. Nor was there an increase in strokes, heart attacks or cardiovascular deaths.

That’s the good news for men interested in TRT: for those with low testosterone and normal PSA levels who get boosted into the

average range for testosterone, the risk of cancer or heart problems is low. But TRT remains controversial, largely because there is no consensus on how to define “low testosterone.” The American Urological Association guidelines suggest that as a rule of thumb, “low” means a total testosterone level under 300 ng/dl, as measured twice on different mornings (because testosterone levels fluctuate). But an international group, the Endocrine Society, has a “normal” range—between 264 and 916 ng/dl—that partly overlaps with that category. The European Academy of Andrology guidelines put the “lower limit of normality” between 231 and 350 ng/dl. One reason for these disparities is that testosterone levels can swing by 100 ng/dl or more in a single day, so symptoms (fatigue, for instance) can correlate with very different numbers.

The TRAVERSE trial used a cutoff of 300 ng/dl for “low.” When men who had lower levels received supplements, there were clear benefits for mood and energy. In 2024 researchers reported a 50 percent increase in sexual activity among men with low testosterone from TRAVERSE who were treated with hormone supplements. That translated to an increase of almost one additional sexual “event” per day—a category that included partnered sex, masturbation, daydreams, flirting and spontaneous erections. A comparison group that got a placebo had only a 25 percent increase.

Less clear are the effects of TRT on the fuzzier symptoms sometimes ascribed to low testosterone, such as fatigue, brain fog, depression and irritability. Joe, 38, says he was in a pretty low place when he learned, in his early 30s, that his level was only 95 ng/dl. He started TRT that keeps him above 600, and he says it works. “It just helps me feel incredibly normal,” he says. The TRAVERSE trial found no benefit of TRT over a placebo for addressing low-grade depressive symptoms. But it did find improvements in both mood and energy in men with significant depression, according to another 2024 study. There was no benefit for cognition or sleep.

> Doctors say that every month they treat multiple men who haven't been warned that their testosterone regimen will crater their sperm count.

Men in the borderline-low range, with levels around 300 ng/dl, haven't been studied systematically, says Frederick Wu, an emeritus professor of medicine and endocrinology at England's University of Manchester who led the European Male Aging Study (EMAS), a very large study of aging men. And for men with normal-range testosterone, the results of TRT might not be as dramatic as they are for men with uncontested low levels. Symptoms such as low energy are particularly difficult to tie to testosterone. Any of the minor insults of midlife can cause fatigue and irritability: young kids who don't sleep, a sedentary computer job, stress, a poor diet. One of the first things urologists or endocrinologists do when a patient comes in with these symptoms is check for sleep apnea, which can cause brain fog and fatigue while also reducing testosterone. "Testosterone is a very robust indicator of general health status," Wu says. "If you find low T in a patient, then it is imperative to investigate their general health status rather than having a knee-jerk reaction of starting testosterone treatment."

There are also almost certainly symptom differences in the way individual men respond to particular hormone levels. "It's possible that a man with a total testosterone of 350 ng/dl might be deficient in certain ways," says Joshua Halpern, chief scientific officer at fertility clinic Posterity Health and an adjunct professor of urology at Northwestern University Feinberg School of Medicine. "Different tissues and organ systems in the body require different levels of testosterone to function optimally."

Herein lies another area of disagreement. Some doctors argue for trying testosterone only after other health interventions because changes in exercise and diet can boost testosterone and improve general health. Others, such as Morgentaler, argue that TRT can be

offered first to men with low levels because supplements could give a man with low energy the boost he needs to start working out and eating better. This argument may now be complicated by the arrival of GLP-1 drugs, such as Ozempic, which make losing weight a lot easier. Should a man with obesity and low testosterone be offered TRT or Ozempic? It's a question that hasn't been studied.

A final uncertainty is what type of testosterone measurement to use. Most studies have looked at total testosterone, a measure that captures all of the hormone circulating in the blood. But a lot of that testosterone is bound to other proteins, such as albumin and sex-hormone-binding globulin (SHBG). The hormone sticks tightly to SHBG, and in that state it can't be used by body tissues. "Free" testosterone, which isn't bound, can. Ultimately, the amount of free T might be a lot more important than total testosterone when it comes to how men feel. "Symptoms follow free T," Morgentaler says. In a 2018 study using EMAS data, researchers found that in obese men who developed hypogonadism, only those whose free testosterone dropped alongside their total testosterone actually experienced symptoms. Still, medical societies have no specific free-T cutoffs for treatment, so a doctor's judgment plays a large role in determining how to use the numbers.

None of these medical debates is likely to come up, however, when people walk into one of the many men's health clinics. Like Rob or Rahim, they'll probably be offered a prescription. In 2022 Dubin, Halpern and some of their colleagues published a study in *JAMA Internal Medicine* for which they went undercover, sending Dubin's own testosterone measurements to seven men's health clinics. Dubin's level happened to be 675 ng/dl, above what most urologists aim for when treating low-T men. In addition, he told the clinics that he hoped to have children in the future. This statement should have stopped them cold. Testosterone is part of the feedback loop that regulates sperm production; if levels of the hormone stay high in the bloodstream, the testes stop making their own

testosterone and sperm. “There was really no situation in which I was a good candidate for TRT,” Dubin says.

Six of the seven clinics offered him TRT anyway. This outcome isn’t unusual. “Looking back, it was so ridiculous,” Rahim recalls of his own same-day testosterone initiation. Although professional guidelines universally agree that men should be tested at least twice before starting TRT, a single test seems common for online and private clinics. Rahim’s numbers were in the high 300s, he recalls, but he was soon put on a dose of testosterone so high that it caused side effects, for which the clinic offered to prescribe more medications. “It was in their best interests to inject me with more T because it was better for their revenue, even though it wasn’t necessarily better for my health,” he says.

Other men report similar experiences. John, 42, was in his mid-30s when he sought out TRT, motivated to keep up in the military special-operations job he had at the time. He was prescribed implantable testosterone pellets, which made his total testosterone level shoot up to more than 1,800 ng/dl. He then dealt with a mandibular disorder from clenching his jaw, as well as benign prostate enlargement that required a cascading series of prescriptions.

Morgentaler says that these cases are cautionary tales that men should take seriously. Avoid clinics that offer TRT without first taking a baseline test, he says, or those without a clear follow-up plan for monitoring bloodwork. One 2015 study found that less than half of men on TRT in a large metropolitan health center ever got a follow-up blood test. And that could be a problem because one common side effect of TRT is erythrocytosis, which results in the overproduction of red blood cells.

An ethical clinic should also be honest about TRT’s effect on fertility. Dubin and Halpern say that every month they treat multiple men who haven’t been warned that their testosterone

regimen will crater their sperm count. Online influencers often shrug off fertility side effects as short-term, but doctors say they can persist. It can take up to two years after cessation of TRT for men to recover a regular sperm count, according to a 2006 study in the *Lancet*. As any couple going through infertility struggles can attest, two years is a long time.

Two medications that doctors prescribe to hasten sperm-count recovery, human chorionic gonadotropin and clomiphene citrate, often aren't covered by insurance and can have their own side effects. Sperm quality may not be as high in men who have recovered post-TRT compared with men who never took testosterone replacement, Halpern says.

Finally, although the TRAVERSE trial suggests that men trying TRT aren't putting themselves at undue risk of prostate cancer or heart problems, there was a small but unexplained rise in bone fractures in men on the treatment. In addition, there are no studies looking at the impacts of TRT over several decades—and a man starting TRT in his 30s may well be committing to 40 or 50 years of treatment if he doesn't want to go through the hormonal crash of quitting.

One concern from studies of heavy users of anabolic steroids is that natural testosterone production might not fully recover after long-term use, says Harrison Pope, a Harvard Medical School psychiatrist who has studied anabolic steroid use. A 2023 study in the *Journal of Clinical Endocrinology and Metabolism* looked at men who had used anabolic steroids illicitly. These people reported a lesser quality of life two years after quitting compared with men who had never used them. In the body, these steroid drugs have effects that are similar to testosterone supplements, so the study results raise worries about TRT.

"If you had interviewed me 20 years ago, I would have assured you that if you'd been taking testosterone for a long time, if you stop,

the system will rebound and you will go back to normal," Pope says. "In some cases, I would have been dead wrong."

For some men it will be worth the risk. Rob, John and Rahim are all on lower doses of testosterone now and being treated by practitioners they trust. They all see benefits in mood, muscle building and energy. But all three feel some ambivalence about the experience. It's a hesitation about TRT shared by a lot of medical professionals. "There are still many unknowns when it comes to testosterone deficiency," Halpern says, "including even the basics."

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https://www.scientificamerican.com/article/why-testosterone-therapy-could-harm-some-men-though-it-could-help-others

What If We Could Treat Psychopathy in Childhood?

New strategies help to reduce callous and unemotional traits in children, guiding them toward productive lives

By Maia Szalavitz edited by Madhusree Mukerjee

Galen Dara

Lillyth Quillan knew almost immediately that something was wrong with her baby. At around eight months old with eight sharp new teeth, he began deliberately biting her breast as she fed him, then looking her in the eyes and laughing. Even though she cried out and pulled him away for significant stretches of time, whenever she returned to nursing, he'd bite again—and then snicker. Within days she had to switch to bottle feeding.

Quillan's son, Alex (his name has been changed for privacy), was almost expelled from preschool because he repeatedly hurt other children. In middle school he began stealing and selling his parents' electronics. He would pretend to hug his mom, then headbutt her instead. "I remember hitting my mom as a kid," Alex says. "I know I shouldn't have enjoyed it, but at the time, I did." He adds, "If

you’re looking for a reason, I wish I had it.” By high school he was using a gun to commit armed robberies.

Quillan, who comes from an upper-middle-class family of northern California artists, was 22 years old and essentially a single mother when she started raising Alex. By the time he was five, she’d married her now husband, who adopted Alex. The couple tried all types of discipline short of corporal punishment. They saw counselors, psychologists and psychiatrists; wasted thousands of dollars on brain scans; got diagnoses of attention deficit hyperactivity disorder and Asperger’s syndrome; and tried medications, therapies and special education. Nothing worked.

Finally, when Alex was 14, Quillan told her own therapist that she thought her son was a sociopath. The therapist said such terms weren’t used to describe children—but she diagnosed him with conduct disorder, which can be a precursor to psychopathy in adults.

Conduct disorder is characterized by defiance of rules, aggression toward people or animals, and ongoing cruelty such as bullying. It affects between 2 and 5 percent of children between the ages of 5 and 12 and up to 9 percent of teenagers. The type that Alex turned out to have comes with so-called callous-unemotional (CU) traits and is seen in up to 2 percent of children. CU traits—a lack of empathy and generally low emotional response—can be caused or exacerbated by child abuse or neglect, but genetic predispositions alone can also spur their development. When they appear as early as they did in Alex’s case, they are overwhelmingly driven by genetics and more likely to develop into adult psychopathy. (At least one relative on each side of Alex’s biological family seems to have some of these traits.)

Psychopathy sits at the uncomfortable intersection of mental illness and morality, with symptoms such as cruel behavior and remorselessness that inherently raise questions about the line

between medicine and criminal law. Consequently, research in the area is underfunded and relatively sparse—despite the fact that the costs of failing to address the condition, which drives many of the most heinous violent or financial crimes, are billions of dollars annually. Parents like Quillan, who founded the first Facebook support group for people with children like Alex, are caught in the crossfire.

Treating adult psychopathy is extremely difficult, but there is hope for children with CU traits. Long-term studies have found that around half of them do not progress to psychopathy and instead go on to lead relatively normal lives, typically because of nurturing caregivers or other protective factors in their environment. At 25, Alex has been steadily employed for four years, and he has a good relationship with his parents. “He feels terrible for what he did,” Quillan says, noting that he has repeatedly apologized to her.

Because the positive influences that can help children grow out of CU traits are not always present, experts agree that it is best to start treating kids well before harmful tendencies become ingrained. “Early intervention is something we really ought to be investing in,” says Essi Viding, a professor of developmental psychopathology at University College London.

> Television serials may dwell on the sadistic criminal, but research suggests executives and politicians also have high rates of psychopathic traits.

Many thorny issues complicate such treatment, however. One is that children with CU traits don’t respond to punishment, which is often what parents, teachers and society at large rely on to deter harmful behaviors. Successfully treating these children—reducing their callousness and unemotionality or at least redirecting their attention toward constructive endeavors—requires creative methodologies that are informed by the emerging neuroscience of psychopathy.

First classified by psychiatrist Hervey Cleckley in 1941, psychopathy has long confounded physicians, police and the public. The condition is full of contradictions. People with psychopathy can carry out cold, calculated crimes and cons that require significant planning, but they may also engage in wildly impulsive aggressive behavior. They can understand the perspectives of other people well enough to manipulate their emotions but lack the intuitive emotional empathy that would help them care about causing harm. Most disturbing, unlike people with classic psychiatric illnesses such as schizophrenia, people with CU traits appear socially typical and may even be charismatic. Television serials tend to dwell on the sadistic criminal, but some research suggests executives and politicians have high rates of psychopathic traits as well.

Like other personality disorders, psychopathy exists on a spectrum from mild to severe. The severe form is believed to affect around 1 percent of the general population and is far more common in men than in women. According to a study published in 2021, among people imprisoned in the U.S., up to one quarter of men and up to 17 percent of women meet the criteria for psychopathy. The condition is typically diagnosed based on a measure developed by psychologist Robert D. Hare in the 1970s and since modified to improve precision. Because psychopathy is marked by dishonesty, Hare's checklist is scored not only according to an individual's responses on a questionnaire but also with input from clinicians, family and others who have knowledge of relevant behavior.

One widely accepted view, the triarchic model, first proposed in 2009 by psychologist Christopher Patrick of Florida State University and his colleagues, divides psychopathic traits into three domains: boldness, meanness and disinhibition. To meet the criteria for psychopathy, people must have some of each. Disinhibition—saying or doing whatever you feel without considering consequences—and poor impulse control are common in other psychiatric conditions (such as bipolar disorder), but the

combination of fearlessness, callousness and remorselessness is unique to psychopathy.

Curiously, psychopathy is not included in the *Diagnostic and Statistical Manual of Mental Disorders*, the most recent edition of which is the *DSM-5*. Disagreements about the nature of psychopathy, as well as concerns that too many people would receive a highly stigmatizing label, prevented its inclusion in the *DSM-IV* more than 30 years ago.

The *DSM-5* does, however, include antisocial personality disorder (ASPD). Nearly all people with psychopathy will qualify for ASPD diagnoses as well, but the converse is not necessarily true: ASPD is a much broader category. People with ASPD might mug grandmothers to get drugs, for example—but many of them will feel guilty afterward, and they may stop their harmful behavior if they gain better impulse control. In contrast, people with psychopathy might not care about or might even enjoy knocking helpless people down. Adding to the confusion is sociopathy, an antisocial behavior disorder that was once believed to be caused by social factors such as child abuse. The term is often used interchangeably with “psychopathy” but has no widely accepted definition.

The *DSM-5* also includes childhood conduct disorder, the diagnosis that Alex finally received. It is a prerequisite for an ASPD diagnosis and a predictor of adult psychopathy. If school-age Alex were diagnosed today, he would almost certainly qualify for the newly added *DSM-5* specifier “with limited prosocial emotions,” which captures the coldness and remorselessness that characterize adult psychopathy.

Callous and unemotional traits are associated with alterations in the brain that impair the individual’s ability to experience sensations and emotions—especially negative ones—in themselves and in others. To begin with, people with these characteristics have a

reduced ability to feel pain. Quillan describes an incident in which Alex fell and needed to have the resulting wounds on his head stapled. At the emergency room, their doctor panicked after realizing she had forgotten to use any local anesthetic before she began stapling, but Alex said it didn't hurt and told her to continue.

In 2012 Jean Decety and his colleagues at the University of Chicago first showed that teens with CU traits have higher thresholds for their own pain and abnormal brain responses to images of other people in pain. The study, which was conducted in Taiwan, compared the responses of 13 young offenders with CU traits with those of 15 incarcerated youths who did not have these traits and 15 typical control participants of the same age. In one part of the experiment, participants placed their hands in a device that applied gradually increasing pressure and reported when it started to hurt. Compared with both control groups, it took significantly longer for the CU youths to report pain.

Galen Dara

The researchers also measured brain-wave responses using electroencephalography (EEG) as these teens viewed pictures of others in painful situations. Those with high levels of CU traits

perceived others as having less pain than the other participants estimated. Correspondingly, the EEG measurements from this group showed less responsiveness in brain areas involved in perceiving pain. Similar results have been reported in other research on CU youths and adults with psychopathy. For example, a 2025 study found reduced levels of sensitivity to their own pain in people with more severe psychopathic traits—which correlated with their lower levels of empathy for others' pain.

Alex says that when he was a child, he sometimes saw hitting his mother as being "playful." But, he adds, "if she said 'ow,' I didn't think it was an actual 'ow.' You know, like, if you flick my hand, I'm going to say 'ow,' but obviously it doesn't hurt." He literally did not perceive her pain.

By itself, however, reduced pain perception doesn't imply psychopathy. People born with genetic conditions that cause complete pain insensitivity have varying empathy levels, just as people in general do. Although they respond less empathically to pictures of people's limbs in painful situations, such as having a car door slammed on their hand, their response to facial expressions of pain is normal. Their empathy level, not their condition, predicts their concern for someone who might be hurt.

But people with CU traits also have difficulty recognizing facial expressions of distress. Researchers who have studied such people's brains have found changes in the insula, which helps with intuitive perception of the emotional state of oneself and others, as well as reduced volume in the orbitofrontal cortex, which is involved in understanding one's own and others' perspectives. These changes imply difficulties in both experiencing intuitive empathy and feeling concern for others' viewpoints.

> Those with callous and unemotional traits easily make friends and—at least initially—seem charming.

Before Alex was properly diagnosed, he was mislabeled as autistic and placed in autism-focused special education. In fourth grade, his class was given daily worksheets aimed at helping the students identify emotions in facial expressions, an ability that is sometimes impaired in people with autism. “My son had a 100 percent failure rate on negative emotions” such as fear, Quillan says.

A 2012 review of research, published by Amy Dawel of the Australian National University and her colleagues, shows that CU traits can also be associated with deficits in recognizing positive emotions such as happiness. Still, the link is strongest for fear and sadness. This disability seems likely to increase harmful behavior simply because if you don’t know when you are hurting or terrifying people, you are less able to avoid it.

Attention and focus are also aberrant in people with psychopathy. Once CU children or psychopaths zero in on something they want to obtain or achieve, they tend to have an extremely restricted view of the world—so much so that they lose awareness of the potential for harm to themselves or others. “It’s like this ultrafocused attention on reaching a goal,” says neuropsychologist Inti Brazil of Radboud University in the Netherlands. Viding, the developmental psychopathologist at University College London, for example, recalls working with a child who ritually killed ducks. She describes it as a kind of habit for the child, resembling the type of obsessive interest and rigidly patterned behavior seen in some autistic children.

Autism is also linked with difficulties with empathy. But research now indicates that autism and psychopathy are, in many ways, opposites. For one thing, when autistic children struggle with empathy, the problem is most frequently that they are overwhelmed by other people’s distress, not unconcerned about it. “I think the reason people used to think those on the autism spectrum can’t empathize is that they often would do things that would look cold and callous,” Viding says, describing how an autistic child might

abandon someone who is crying. This choice can come across as “unfeeling,” she says, but “you walk away if you feel distressed by the cries and don’t have the social skills to engage.”

Another contrast: Autistic people often care deeply and yearn for connection, but they have trouble making and keeping friends. Those with CU traits, however, easily make friends and—at least initially—seem charming. They tend, however, to see relationships as ways to exert power or get other things they want, not as reciprocal connections. Another opposing characteristic is that autistic kids tend to prefer to follow rules and are often obsessed with justice and repelled by hypocrisy, whereas CU children deliberately violate laws and conventions. “We have shown with genetically informed twin-study research that the genetic risk is almost entirely separate,” Viding says.

Another contradistinction between these conditions is that autistic people tend to be very anxious, whereas those with CU traits often appear unflappable. Studies have found alterations in emotion-related brain regions such the amygdala—which processes strong emotions, including fear—in people with psychopathy. A 2015 study by Leah M. Lozier, then at Georgetown University, and her co-workers found that the less a CU child’s amygdala responded to fearful faces, the more likely that child was to act aggressively without provocation. For his part, Alex still tends to find danger exciting rather than frightening. As a child, he loved risky activities such as BMX riding and skateboarding, and now he rides a motorcycle. “I was always an adrenaline seeker,” he says.

Psychopathic traits do have some upsides. They seem to confer resilience to stress and an ability to act calmly under duress. CU children tend to have a low resting heart rate, which is also associated with stress resilience. A higher resting heart rate correlates with anxiety and stress sensitivity. Research published in 2021 by David Farrington of the University of Cambridge and his colleagues showed that children whose hearts beat faster than

average at age eight were at lower risk of developing adult psychopathy, despite having adverse childhood experiences such as harsh discipline and an incarcerated or depressed parent.

Nick Thomson, an associate professor of psychiatry at Virginia Commonwealth University, notes one potential explanation for why studies of CU children and fear show varied results. Typically when people are frightened, the (inaptly named) sympathetic nervous system goes into overdrive, causing anxiety, raising heart rate and blood pressure, and reducing focus on anything other than responding immediately. Only after the danger has passed does the countervailing parasympathetic system, which is calming and better suited to long-term planning, kick in.

In CU children, however, these systems are activated simultaneously in scary situations. “Kids with callous-unemotional traits do respond to fear, but they’re responding in a way that could be perceived as fearless,” Thomson says. “They’re engaging both branches of the autonomic nervous system, so they’re getting the benefits of both. They’re staying calm and relaxed from the parasympathetic, but they’re alert and attentive from the sympathetic. It’s probably one of the most ideal kinds of responses”—and it may allow people to succeed in occupations such as firefighting or policing that require poise under extreme stress.

Perhaps the most confounding characteristic of people with callous-unemotional traits is that punishment does not deter them from doing harm. This attribute has been remarked on since Cleckley first described psychopathy. Criminals diagnosed with psychopathy often commit repeated offenses after being released from prison, for instance. People with CU traits may be unable to learn from punishment, partly because they have little fear; additionally, they may have deviations from the norm in their striatum, a part of the brain that helps people predict and encode reward and punishment. Treating children who have CU traits

therefore requires methods that are tailored to their specific characteristics—which require an accurate diagnosis.

Unfortunately, clinicians often avoid diagnosing conduct disorder because of labeling fears, a phenomenon that Quillan encountered several times. Such fears are understandable: labeling children with stigmatizing conditions can harm them if that label makes the adults around them more punitive and less supportive of their ambitions. But parents like Quillan, as well as some experts, argue that in cases like Alex's, the lack of an accurate label does even more damage, leaving families to struggle without help—or with inappropriate therapies and the criminal prosecution system. "I'm pro-label because we need to know what we're dealing with," Quillan says.

"The parents who come to me are never asking, 'How do I help my kid with this stigmatizing label?'" agrees Abigail Marsh, a professor of psychology at Georgetown. "What people actually want is help. So I think the correct diagnosis is the only route to get the correct treatment."

Another issue is that group treatments in residential facilities, where many CU youths wind up by their teens, can be counterproductive. These centers tend to aggregate kids with disparate psychiatric disorders and trauma histories. Teens in general are strongly influenced by their peers. When you place adolescents with CU traits together, it can normalize antisocial behavior rather than deterring it, a process described by the late psychologist Tom Dishion of the University of Oregon as "deviancy training."

After multiple arrests and stints in juvenile hall, at age 16 Alex was sent by a judge to a California residential treatment facility. The program itself didn't offer much; Alex was still on a waiting list to see a psychiatrist when he left after nearly two years. There was no

therapy beyond a basic points system that rewarded good behavior and punished violations and was apparently easy to game.

> It is extraordinarily difficult to lovingly parent a child who doesn't care about harming you or even enjoys it.

The lack of programming beyond high school classes left plenty of room for deviancy training. One of Alex's classmates, for instance, had grievously wounded his mother by planting a bomb designed to produce maximum shrapnel in the family's oven. He offered to teach Alex how to make a similar one—but, fortunately, Alex wasn't interested in the technical details.

One experience did seem to have a positive impact, however. While waiting to use the phone, Alex overheard another teen—whom he described as a hardened gang member—speaking with his mother. From what he could hear, Alex deduced that not only had the mom forgotten her child's birthday, but she didn't even know his age. The young man, who was one of the toughest kids in the center, broke down in tears.

When it was his turn to use the phone, Alex called his mother and began genuinely apologizing to her for the first time. He'd thought his parents were being deliberately hateful and mean to him. Their relationship had become one of constant conflict. Because the legal system has recognized that tough sentencing for young people is often counterproductive, Alex had frequently been able to evade those kinds of consequences. But his parents consistently—and, it seemed to him, relentlessly—disciplined him. He began to realize that they did it because they cared.

"My son actually called me, and he was like, 'Mom, I am so sorry,'" Quillan says. He told her that he knew she'd never forget his age or his birthday and that he felt bad for misinterpreting her attempts at discipline as a lack of love. "I think it was seeing

someone who had it worse," Alex says. "Seeing the polar opposite of what I went through put it into perspective."

Counterintuitively, the fact that Alex's condition is "primary," or thought to be largely genetic in origin, probably means it was easier for him to recover than it would have been otherwise. It might seem like "secondary" CU traits, which develop in response to childhood maltreatment or personally traumatic events, should be more readily altered, but in fact kids with primary callous-unemotional traits seem to be more pliable. For CU children, at least, nurture trumps nature.

"We've developed a treatment for kids with callous and unemotional traits, with the idea of preventing psychopathy," says Eva Kimonis, a professor of psychology at the University of New South Wales in Australia, who conducted the first study that compared treatment outcomes for people with primary versus secondary CU traits. "Both groups improved," she says, "but this primary group maintained its gains, whereas the secondary group deteriorated."

The study included 45 families with children between three and seven years old who had serious CU traits and conduct disorder. The researchers used a technique called parent-child interaction therapy, which they adapted to address callous behavior. In 21 weekly hour-long sessions, which the families participated in one at a time, each parent and child interacted in a special playroom with a therapist observing from behind a one-way mirror. The parent, usually the mother, was fitted with a headset so the therapist could direct their play.

The first goal was to break patterns like the one that had developed between Alex and Quillan by his teen years, in which he had come to believe that she hated him. Because CU children don't change their behavior when punished, effective treatments aim to restore warm, rewarding relationships. Experts emphasize that consistent

consequences must be imposed when harmful behavior occurs to avoid unfairness to others. Still, the focus in treatment is on rewarding good actions, which—unlike punishment—does drive change for these children.

Early sessions focus on helping the parent and child reengage warmly and letting the child lead imaginative play with toys. Research has shown that CU children with warm parents who set appropriate limits are more likely to outgrow these traits. But it is extraordinarily difficult to lovingly parent a child who doesn't care about harming you or even enjoys it. The therapy aims to bolster parents' skills and avoid a cycle of swinging between harsh discipline and avoidance. Trained therapists help parents learn to praise even small improvements and to be emotionally expressive and demonstrative.

In later sessions the emphasis is more on discipline, which can include consistent time-outs when needed. But the therapists teach the parents to use rewards as much as possible and help them tailor the types of rewards provided to appeal to the individual child's interests. Guided by the therapists, parents teach their children to recognize distress in faces and voices. Parents are also encouraged to provide special rewards and be especially attentive to compassionate and loving acts by their children. When the child is angry or aggressive, parents and therapists identify the triggers and teach more constructive coping responses.

"We try to figure out what these kids are motivated by," Kimonis says. "How can we reward them for the good behaviors that we want them to be doing, like listening to their parents and behaving in gentle and nonaggressive ways?"

Improvements achieved through the therapy were striking: 58 percent of the children with primary traits whose families completed treatment (the majority of those who started it) no longer met clinical criteria for CU traits three months after the

study ended. “They came in perhaps listening to the parent 20 percent of the time, and now they’re going to 80 percent of the time,” Kimonis says, noting that the reduction in destructive behavior improves the parent-child relationship. That, in turn, makes it warmer and helps end one cycle that worsens CU traits.

Another promising approach, being developed by Thomson, uses a virtual-reality environment to train emotion recognition and regulation in a gamelike, fun experience. The researchers tailor treatment to individuals so that the programming is challenging enough to maintain interest but not so challenging as to be frustrating. “They’re immersed in the story,” Thomson says. “They don’t have the distractions of their phones and everything else. They’re inside it, and it’s very reward-focused.” The storylines involve social experiences such as parties, along with games that help to improve relevant skills.

Thomson says 98 percent of the CU children age 10 to 17 who have tried it liked it—which is critical because many of them resist talk therapies. In pilot research, it improved recognition of all emotions but particularly sadness and fear, for which CU kids have the greatest deficits. The authors of a forthcoming paper found that these changes were accompanied by reductions in aggressive behavior and rule violations—as well as in the severity of CU traits themselves. If backed by further data, this approach could be particularly useful because it does not aggregate these children in groups, it is less resource-intensive than other family interventions such as parent-child interaction therapy, and it could be used pretty much anywhere.

When Alex left the residential treatment center at age 18, he had more insight into his behavior but, unsurprisingly, did not turn around overnight. Both mother and son say that what made the real difference was the fact that he found a mentor in a boss who hired him to work at his auto-related business. The man was highly

respected in his community and church—and Alex saw that he could be like him only if he, too, behaved honorably.

“I think it just was ‘right people, right time,’” Alex says of the experience, describing the joy he felt when he was praised for good, hard work. “It was feeling that it was actually genuine and not just a compliment because they’re trying to get something from you,” he says. And this understanding meant that when he did get something wrong, “I would own up to it instantly because I cared about them, too, so I wouldn’t want to lie to them.”

Being more mature probably helped on its own—research shows that the prefrontal cortex, which checks impulsive behavior, typically does not finish developing until the person is in their early to mid-20s. This delay may be why all types of criminal and antisocial behavior show peaks in the late adolescent and early adult years.

Alex still has the intensity of focus that led him to be careless when pursuing misguided goals in the past. He knows he has to make sure he continues to guide it in the right direction. But, sometimes to his annoyance, these days he feels more. As a child, he’d often laugh at films that terrified his peers. Now, he says, “the stupidest movie will make me cry. It’s quite irritating, I’ll be honest.” Overall his intentions have changed for the better, and he’d like to use his calmness under pressure to serve in the military or law enforcement. “I think it was just me pointing my arrow at something else,” he says.

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https://www.scientificamerican.com/article/is-it-possible-to-treat-psychopathy-before-it-starts

Denmark’s Radical Archaeology Experiment Is Paying Off in Gold and Knowledge

The Danish government deputized private detectorists to unearth artifacts buried in farm fields. Their finds are revealing the country’s past in extraordinary detail

By Elizabeth Anne Brown edited by Kate Wong

Kristen Nedergaard Dreiøe (*left*) and Marie Aagaard Larsen (*right*) swing their metal detectors over a field where grain is typically grown in southern Denmark.
Alastair Philip Wiper

Ole Ginnerup Schytz, an engineer in Denmark’s sleepy Vindelev agricultural area, had used a metal detector only a handful of times when he found a bent clump of metal in a friend’s barley field. He figured it was the lid from a container of tinned fish and tossed it in his junk bag with the other bits of farm trash that had set his metal detector beeping: rusty nails, screws, scrap iron. A few paces away he dug up another shiny circle. Someone had clearly enjoyed a lot of tinned fish here—into the sack it went. But when Ginnerup found a *third* metal round, he stopped to take a closer look. Wiping the mud from its surface, he suddenly found himself face-to-face

with a Roman emperor. At that point he had to admit “they weren’t food cans,” Ginnerup recalls with a chuckle.

After a brief intermission for an online Teams meeting for work that December day in 2020, Ginnerup dug up 14 glittering gold disks—some as big as saucers—that archaeologists say were buried about 1,500 years ago, during a time of chaos after ash clouds from a distant volcanic eruption created a miniature ice age. Four medallions feature Roman emperors, and several bear intricate geometric patterns. But the real showstopper is an amulet called a bracteate with two stylized designs: a man in profile, his long hair pulled back in a braid, and a horse in full gallop. An expert in ancient runes says she was awestruck when she finally made out the inscription on top: “He is Odin’s man.”

These embossed runes are the oldest known written mention of Odin, the Norse god of war and ruler of Valhalla. Ginnerup’s bracteate, which archaeologists describe as the most significant Danish find in centuries, extended the worship of Odin back 150 years—and it’s all because Ginnerup received a metal detector as a birthday present from his father-in-law.

Many other European countries have prohibited or heavily restricted hobbyist metal detecting, but Denmark has embraced it, creating a system for members of the public to hand over finds to government archaeologists. The result has been an embarrassment of riches, with more than 20,000 items turned in annually in recent years. The curators assigned to identify and catalog the artifacts can’t dream of keeping up, but the fruits of their collective labor are clear: whereas neighboring countries have only vague sketches of the past, metal detectorists have filled in the ancient map of Denmark with temple complexes, trade routes and settlements that would have otherwise been lost to history.

“Private detectorists have rocketed Denmark ahead of its neighbors in archaeological research,” says Torben Trier Christiansen, curator

of archaeology at Denmark’s North Jutland Museums. “There’s nothing ‘amateur’ about them.”

Denmark has been inhabited since the end of the last ice age, when nomadic hunter-gatherers from southern Europe arrived following the migration of reindeer and retreating glaciers as early as 12,500 years ago. The ancestors of modern ethnic Danes showed up some 5,000 years ago, journeying from the steppes of what is now Ukraine and southwestern Russia. Their descendants lived in small farming communities across Scandinavia for thousands of years, building megaliths and barrows for their honored dead and making human sacrifices in bogs to appease their gods.

In the early centuries of the common era, these farming communities coalesced into a series of Germanic tribes—the Cimbri, the Teutons, the Jutes, the Angles and the Danes—who became skilled seafarers, explorers and metalworkers. Because precious metals—including silver, gold and the components of bronze—do not occur naturally in what is now Denmark, its denizens had to barter for or steal these metals from abroad. They traded extensively with the Roman Empire, which never reached as far north as Scandinavia.

Detectorist Ole Ginnerup Schytz found this gold amulet, or bracteate, bearing the inscription "He is Odin's man." The find extends the worship of Odin back 150 years. (The swastika design next to the man's head predates the adoption of this symbol by the Nazis.)

By the ninth century, in the Age of the Vikings, Norsemen traded mainly in slivers of silver by weight, but they also had access to dirhams from the Islamic caliphates, solidi from the Roman Empire, and gold from the shores of Ireland, all of which have been found by their metal-detecting descendants. Denmark has been a unified kingdom since at least the 10th century, making it the oldest surviving monarchy in Europe.

Metal detectors hit the Danish consumer market in the late 1970s. “Before that, metal detectors were really just military equipment” used to find unexploded ordnance from World War II, Trier explains. Through the 1980s, metal detectors were so uncommon that most European countries didn’t have laws to govern who could look for relics and where. But that all changed after some high-profile thefts demonstrated how much damage a bad actor with a detector could do. The Swedish island of Gotland became something of a battleground between professional archaeologists and looters—both locals and “tourists” from abroad—who used metal detectors to find and plunder Viking Age sites, making off with many silver relics. The episodes soured Sweden on private detectorists for decades, Trier says. And beyond outright theft, many archaeologists believed they were destroying important archaeological context in a selfish desire to hold history in their hands.

As Sweden drafted legislation to heavily restrict private metal detecting, one man decided Denmark already had a relevant law on the books—from 1241. Olaf Olsen, the director of the Danish National Museum in the 1980s, championed the idea that detection finds could fall under a medieval law that declared all precious metals without a clear owner the property of the crown.

Olsen’s interpretation of the *Danefæ* (“Danish treasure trove”) law led to one of the most permissive approaches to metal detecting in

Europe. Today anyone can metal detect in Denmark without a permit as long as they have the landowner's permission and agree to turn over any potentially historic finds to the government. It's a classically Danish system built on social responsibility—in a country where people regularly leave babies to nap outside in their strollers, it's no wonder the government trusts the public with treasure.

It wasn't until about 10 years ago, though, that interest in metal detecting really surged, thanks to television shows and social media. In 2013 about 5,600 items were turned in for evaluation as potential *Danefæ*. By 2021 that number had skyrocketed to more than 30,000. That's a lot of nonarchaeologists digging holes. But in Trier's opinion, Danish archaeologists benefit from all these boots on the ground.

About 60 percent of Denmark's landmass is dedicated to farmland, and much of that is tilled every year. Modern plows can reach more than half a meter into the soil, bringing a fresh slate of long-buried objects close enough to the surface for a metal detector to spot them. "But once an artifact is at the surface of a field, it's going to be facing frost and sun and rain and the climate," Trier explains. Then it's a race against time before the object is destroyed.

A solid gold ring set with a garnet was found by a detectorist near the hamlet of Emmerlev in Denmark. A detail of the setting ties the ring to the Merovingian dynasty of central Europe, suggesting that a noble Merovingian woman might have married into the ruling Nordic elites near Emmerlev.
National Museum of Denmark

Whatever is in Denmark's forests can safely wait another 200 years for professional archaeologists to get around to it, Trier says. But the detectorists walking plowed fields are the front lines of archaeological rescue operations.

A prime example is a discovery known as the Vaarst complex. A private detectorist surveying a farm in northern Jutland found a concentration of jewelry—gold rings, dress pins and cloak clasps—so substantial that Trier mounted a rescue dig to stabilize whatever archaeological context had managed to escape the plow. Over the next two years Trier and a team of professional archaeologists

uncovered a vast burial complex with hundreds of graves, many including human remains, their heads all oriented west toward the North Sea. Farming and erosion had eaten away at the topsoil for so long that only a few centimeters of depth covered many of the graves. “One or two more seasons of plowing and they would have been gone,” Trier says.

Just a kilometer away from the Vaarst complex is a modern town called Gudum. Historians had puzzled over the origin of the town’s name, which translates to “home of the gods.” Now, thanks to the detectorists’ find, researchers believe it might have been the site of a major religious center.

> It’s a big ask to expect the finder of a pristine ancient treasure to turn it over to a government bureaucracy. Detectorists find ways to keep their favorite artifacts close to their hearts.

Detectorists hand over their artifacts to Denmark’s 28 local archaeology museums—an astonishing number for a country one-third the size of New York State. It’s up to local archaeologists such as Trier to designate sites of interest before they’re destroyed by farming or construction and to identify and record the finds before they’re passed on to the central *Danefæ* department at the National Museum. Trier says he has about 300 detectorists who regularly turn in finds to him. “They can often tell even from a teeny sound the detector makes what kind of an object and how deep it is,” he notes.

Some private detectorists have résumés that rival those of professional archaeologists. On an uncharacteristically sunny day in March, husband-and-wife duo Kristen Nedergaard Dreiøe and Marie Aagaard Larsen picked me up at a train station in southern Denmark, in an area north of the border with Germany. “You know, people used to call this place the ‘rotten banana’ of Denmark,” Aagaard told me. But not anymore. The detectorist power couple’s

finds have revealed that the area where Aagaard grew up was an important hub of wealth and power 1,000 years ago.

In 2016 Aagaard, Dreiøe and their friend the late Poul Nørgaard Pedersen discovered nearly 1.5 kilograms of Viking Age gold artifacts near the modern town of Fæsted, including armbands that archaeologists have interpreted as oath bands: twisted rings that would have been given by a chieftain or lord to his lieutenants to wear as a sign of their fealty. It's the largest hoard of Viking gold ever discovered in Denmark.

But Aagaard and Dreiøe haven't let the gold go to their heads in the decade since. Quite the opposite: they show an unusual willingness to investigate every signal on their detector, even for iron. Iron is a perennial pest for detectorists. It elicits a loud, petulant scream from the detector and is almost always farm trash. Once detectorists become experienced enough to recognize this sound, most won't lift a shovel for it.

Aagaard and Dreiøe's dogged digging, however, led them to discover a cache of more than 200 iron weapons—spears, lances, daggers and swords—in 2018. Subsequent excavations by the local archaeologist, Lars Grundvad, uncovered a series of temples used by what he calls a "cult of destruction" starting around C.E. 0. They found evidence of at least 15 incarnations of the temple, each a few meters apart from the rest, spanning an estimated 550 years, Grundvad said. Many of the weapons seem to have been placed in support poles—whether as sacrificial offerings in the inauguration of a new temple or as a way of symbolically "killing" the old one remains unclear. Fifteen temples "felt very Indiana Jones," Aagaard says. Looking back, Aagaard and Dreiøe laugh when they remember they considered taking up hunting or sailing as their joint hobby instead.

Troels Taylor, a detectorist based in Zealand, Denmark, has tattoos of some of his favorite discoveries.
Alastair Philip Wiper

The dig site I visited with Aagard, Dreiøe and Grundvad in March is in a field where grain is typically grown, just a stone's throw from a highway. On the horizon we could make out a suburban neighborhood, windmills—and a dolmen, a burial mound with large stones perched atop it, probably about 5,000 years old. The dolmen was already ancient by the time of the Vikings, Grundvad mused.

The museum had rented a lime-green excavator for the occasion. A young tradesperson operating the digger painstakingly scraped layers of just a few centimeters of soil at a time from the surface of

the ground over an area about the size of two basketball courts. Four metal detectorists, including Aagaard and Dreiøe, had taken the day off from work to participate. Supervised by a pair of local archaeologists, they followed behind the excavator as it crept through the plow layer toward what we hoped would be an undisturbed archaeological context.

Just 20 minutes in, Dreiøe let out a triumphant whoop. The archaeologists and detectorists all gathered to see a Roman silver coin called a denarius cradled in his palm. “Today is like my birthday, New Year’s and Christmas in one,” Aagaard said.

As the day wore on, about 10 more coins in bronze and silver, carefully labeled in individual baggies, accumulated in Grundvad’s bucket of finds. But the archaeologist was more interested in a small, curved piece of bronze that Aagaard found: a fragment of a goblet or a pot the coins might have been buried in. The hope is that deep under the plow layer, there might be evidence of a settlement.

Grundvad treats Dreiøe and Aagaard—who are, by trade, a sales manager and a psychologist, respectively—as colleagues. “At first we wondered if they’d roll their eyes at us because archaeology is their job and our weekend hobby,” Aagaard says. “But not Lars. He’s one of the youngest and hippest local archaeologists.”

Recently Taylor found what he believes to be a Viking Age silver decoration that would have been mounted on a sword scabbard.
Alastair Philip Wiper

Nearly every weekend during the detecting season, Aagaard and Dreiøe take their “time machines” out in the field. They send snapshots of their discoveries to Grundvad for immediate identification. “Not to sound arrogant about it, but we’ve gotten used to them bringing in extremely nice finds,” Grundvad said. In many ways, he credits Dreiøe, Aagaard and Nørgaard with putting his little museum on the map. It’s a very different mentality than his colleagues in Sweden have, according to Grundvad. “The Swedish authorities think that metal detectorists will destroy finds, take them out of their context. We think the finds are being saved.”

The oldest wing of the National Museum, in downtown Copenhagen, is home to Denmark's treasure bureaucrats. It's up to the curators of the *Danefæ* department to identify the thousands of objects streaming in from the fields every year and decide which are worthy of joining the museum's research collection—and which will earn their finders a monetary reward.

Even though detectorists can now upload photographs and GPS coordinates of their finds to a dedicated app, the curators' identification process remains much as it was 40 years ago. The best resources are thick reference books, their margins filled with hand-drawn diagrams and annotations from curators stretching back to the 1940s. With the breadth of objects that come across their desks, from flint-knapped stone tools and Bronze Age weapons to Viking jewelry, curators need an encyclopedic knowledge of Danish prehistory just to have a chance of knowing which book to reach for.

Kirstine Pommergaard knows what style of brooch was popular in C.E. 300. She can tell whether a coin is a Roman solidus or a dirham of the ancient Islamic caliphates at a glance. "You have to love items and the stories they can tell to be able to do what we do," she says.

Pommergaard is a curator of prehistoric archaeology and one of just three archaeologists in the country dedicated to identifying *Danefæ* full-time. As of 2025, there's a daunting backlog of more than 50,000 objects in a secret "secure facility" awaiting evaluation. "[Each one is an] important piece of the puzzle, even if it's not made of gold or if we have 1,000 of them already," she says. But what Pommergaard cherishes most are the items whose very existence reveals unforeseen connections.

Taylor also recovered a small hoard of “hacksilver,” fragments of bullion and coins that were used in Viking trade.
Alastair Philip Wiper

All the curators were dazzled when a detectorist turned in a solid gold ring set with a blood-red garnet. But Pommergaard, a self-professed craftsmanship nerd, became fixated on something many might have overlooked in the quest to figure out the origin of the ornament: the underside of the ring’s setting. Four delicate curlicues that the goldsmith used to attach the shank to the head were a smoking gun for Pommergaard. This jewelry-making technique was exclusive to Frankish craftsmen living under the Merovingian dynasty, a royal dynasty that used marriage diplomacy to consolidate power across central Europe after the fall of the Roman Empire. Thumb rings with a similar construction

have been found in the graves of high-status Merovingian women on the level of empresses and queens, Pommergaard says.

Could the ring have been a spoil of war? The stone says otherwise. Although the Merovingian queens wore signet rings, red stones were a symbol of power among the Nordics. “There must have been someone in Emmerlev who was important enough to marry one of their daughters off to,” Pommergaard says, referring to the hamlet nearest to where the ring was found. Before the discovery of the ring, Emmerlev was known only as the site of a cattle trade that operated in the 1500s.

Pommergaard had dreamed of working with ancient items since she was seven years old, when she found half of a stone ax with her grandfather on the Danish island of Fyn. But what she probably didn’t foresee—and what seems to be her least favorite part of the job—is being asked to put a price on the priceless.

It falls to the *Danefæ* team to determine the finder’s reward for each item chosen for the museum’s collection. Most of the payouts are quite modest and far below what the objects might fetch on the black market—250 or 350 kroner (around $40 or $50) would be a typical finder’s fee for a coin from the 12th or 13th century. But the blockbuster treasures can command eye-watering sums. Aagaard, Dreiøe and Nørgaard received just over a million kroner for the oath ring treasure, the equivalent of about $150,000. Ginnerup—the discoverer of the golden bracteate with Odin’s name—declined to share how much he received for his hoard. “The National Museum emphasizes not to talk about the money,” he says.

After detectorists found a cache of Roman coins in a farm field in Vejen, Denmark, local archaeologists organized a formal excavation, hoping to find more artifacts.
Alastair Philip Wiper

Pommergaard says she isn’t allowed to discuss how they decide the payouts, only that they consider an artifact’s historical value and condition and the care the finder took in collecting it. Altogether, Danish detectorists received the equivalent of $1.3 million in 2023, up from just $130,000 in 2012. Technically the sky’s the limit—the law doesn’t stipulate a cap on *Danefæ* payouts. But the same can’t be said of the budget for archaeologists to process the finds.

Currently the average wait for an artifact to be processed by the *Danefæ* team is “at least 2.5 years” once the object reaches their doors, according to Pommergaard, but that duration doesn’t include the time the objects spend being evaluated at local museums, which don’t receive dedicated funding for *Danefæ*. As local museums struggle to process the finds their detectorists turn in, they risk missing the opportunity to identify sites such as the Vaarst complex before they’re lost to construction or the plow, Trier says.

The long processing time also means some prolific detectorists have tens of thousands of kroner in rewards tied up in the system, sometimes for up to a decade. But archaeologists and hobbyists agree that detectorists aren’t in it for the money. “Hour for hour,

we'd be better off picking up cans off the side of the road and turning them in for the recycling fee," says Troels Taylor, a longtime detectorist based in Zealand. Nevertheless, "we are grateful for our system where we get a little reward for the huge work and effort we do," Taylor adds. Detectorists do want to know their finds are being examined and used for research, however. If not, they'd be happy to display them in their homes.

It's a big ask to expect the finder of a pristine ancient treasure to turn it over to a government bureaucracy. Detectorists find ways to keep their favorite artifacts close to their hearts. Taylor, like many detectorists, has several tattooed on his body, including one image from a strap end he found of two stylized beasts that twist on his forearm. Other detectorists, such as the finder of the royal Emmerlev ring, hire metalsmiths and jewelers to make re-creations of their discoveries.

The *Danefæ* program provides a tremendous return on investment from the perspective of the Danish government, Trier says. Private detectorists spend thousands of hours in the fields, and taxpayers pay them only when something extraordinary is uncovered. But simmering frustration with wait times risks upending the program. "Our system is working really well, but it's only working because the detectorists feel heard—they feel that they are contributing and that we're actually taking them seriously," Trier says. If processing times get any longer, however, he worries the program will stretch the detectorists' goodwill. "The trust system only works as long as we archaeologists supply our part of the deal."

But many detectorists say that even if wait times ballooned, they doubt they'd ever be able to give up their hobby. "As long as I can walk and dig holes," Ginnerup says, "I will continue with my metal detector."

Editor's Note (6/20/25): This article was edited after posting to correct the spellings of Kristen Nedergaard Dreiøe's and Marie

Aagaard Larsen's names in the first image caption.

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https://www.scientificamerican.com/article/denmark-let-amateurs-dig-for-treasure-and-it-paid-off

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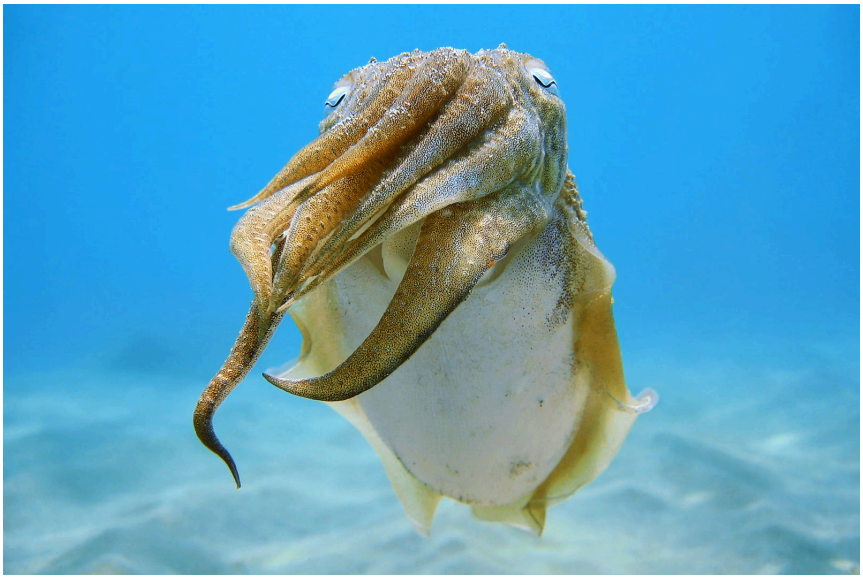
Animals

- **Cuttlefish May Communicate with Discolike Arm Gestures**
  Scientists identified four arm wave signals cuttlefish use: “up,” “side,” “roll” and “crown”

Cuttlefish May Communicate with Discolike Arm Gestures

Scientists identified four arm wave signals cuttlefish use: “up,” “side,” “roll” and “crown”

By Chris Simms edited by Sarah Lewin Frasier



Researchers observed the common cuttlefish (*Sepia officinalis*) routinely wave its arms in four flashy gestures.
Damocean/Getty Images

Cuttlefish wave their expressive tentacles in four distinctive dancelike motions, a new study finds—possibly to communicate visually and by vibration.

These marine invertebrates, which have eight sucker-lined “arms” and two additional tentacles near their mouth, have been known to alter their body’s color pattern to blend in with the background or create zebralike stripes to attract a mate. Some have been known to raise their arms to intimidate predators, and others to extend a particular arm to signal a mating desire.

But cognitive neuroscientist Sophie Cohen-Bodénès and computational modeler Peter Neri, both then at the École Normale Supérieure in Paris, noticed cuttlefish doing something that hadn't been described before: making specific, repeated and relatively complex arm gestures at one another.

Studying two species, common cuttlefish (*Sepia officinalis*) and dwarf cuttlefish (*Sepia bandensis*), the two researchers have identified four arm-waving signs, which they call "up," "side," "roll" and "crown." The scientists recently posted their observations on the preprint server bioRxiv.

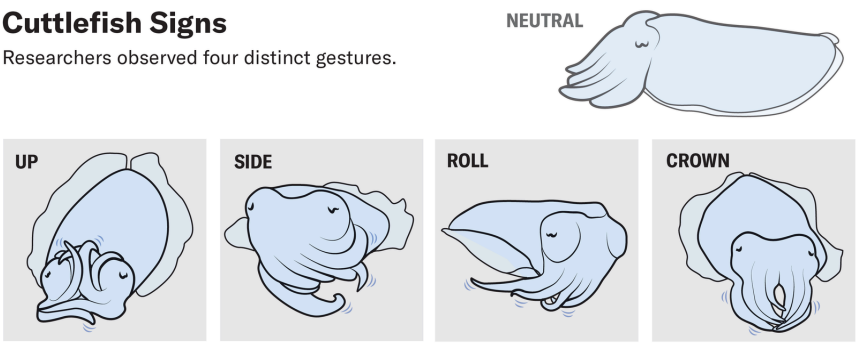
The four cuttlefish gestures: "up," "side," "roll" and "crown."
Cohen, Sophie (2025), "Cuttlefish interact with multimodal arm wave sign displays", Mendeley Data, V4, doi: 10.17632/f3sp55762b.4, CC BY 4.0

The "up" sign involves a cuttlefish extending one pair of arms upward as if swim dancing to the Bee Gees song "Stayin' Alive" while twisting its other arms together in the middle. For the "side" sign, the animal brings all its arms to one side of its body or the other. A cuttlefish makes the "roll" sign by folding all its arms underneath its head as if it is about to do a front flip (which makes its eyes bulge out). And the "crown" sign is rather like when a person puts the fingertips of both of their hands together to form a pyramid shape.

Cohen-Bodénès and Neri recorded cuttlefish signing in various contexts and played the videos back to different cuttlefish. "We

found that when they see [others] signing, the cuttlefish sign back," Cohen-Bodénès says. "We don't think it's a mimicking signal because when they sign back, they sometimes display different types of signs." This behavior suggests a possible communication process, Neri adds.

The researchers also used a hydrophone—a device used to record sounds underwater—to capture the vibrations each sign created. They then played those vibrations back to cuttlefish that couldn't see the signs but could feel the changing pressure in the surrounding water—and the cuttlefish still responded with their own signs. This finding is the first piece of evidence that cuttlefish might communicate with one another by emitting specific vibrational signals, Cohen-Bodénès says. Cuttlefish may detect these signals with saclike sense organs called statocysts or with an array of sensory cells running along their skin, similar to the lateral line system used by fish.



Amanda Montañez; Source: "Cuttlefish Interact with Multimodal 'Arm Wave Sign' Displays," by Sophie Cohen-Bodénès and Peter Neri in BioRxiv. Published online May 5, 2025 (*reference*)

The researchers "have found some fascinating behaviors," says Willa Lane, a marine biologist and psychologist at the University of Cambridge, who says she has seen the crown behavior in cuttlefish in her laboratory. She finds it particularly compelling that the arm movements were observed in two species.

Because the species Cohen-Bodénès and Neri studied don't overlap in their geographic ranges and cuttlefish are quite solitary, Lane wonders whether the signals might be used to confuse prey during

hunting or to scare off predators—or even as part of interactive hunting with other species, a behavior that has been observed in octopuses.

“It’s interesting that they communicate visually and maybe acoustically,” says Sam Reiter, a neuroethologist at the Okinawa Institute of Science and Technology in Japan. He and Neri agree that before this behavior can technically be called a “sign language,” researchers must show the signals’ distinct meanings in particular contexts.

Still, the signals do add to the evidence of how smart cuttlefish are. “In terms of intelligence, they are, in my view, very much comparable to octopuses,” Cohen-Bodénès says.

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https://www.scientificamerican.com/article/cuttlefish-may-communicate-with-discolike-arm-gestures

Archaeology

- **Mummies from Ancient Egypt Smell Surprisingly Nice, Scientists Say**
  Mummies’ aromas may provide insight into historical social classes and periods, according to a team of trained mummy sniffers

What Sniffing Mummies Taught Scientists about an Ancient Society

Mummies' aromas may provide insight into historical social classes and periods, according to a team of trained mummy sniffers

By Gayoung Lee edited by Andrea Thompson & Sarah Lewin Frasier

Yasemin Ozdemir/Getty Images

If you were asked to describe the scent emanating from an ancient Egyptian mummy like you'd discuss a high-end perfume or the bouquet of a fine wine, you might mention fragrance notes of old linen, pine resin and citrus oils—with just a whiff of pest repellent.

These vivid comparisons stem from a new laboratory analysis of nine mummies from various social classes and historical periods, published in the *Journal of the American Chemical Society*. Researchers from Slovenia, England, Poland and Egypt collaborated with the Egyptian Museum in Cairo to identify more than 70 unique compounds from air samples taken around each mummy. The samples were chemically analyzed and also presented to specially trained human "sniffers," who were asked to describe

them with sensory adjectives. The team’s findings demonstrate how the study of smell can help to enrich our understanding of cultural artifacts such as mummies in a noninvasive way that includes local scientists.

The scientists vetted each candidate mummy to obtain a wide range of smells, says study co-author Abdelrazek Elnaggar of the University of Ljubljana in Slovenia. To collect smell samples, they placed small tubes around each mummy (being careful not to touch the fragile remains) to siphon off emitted gas molecules. The team used gas chromatography and mass spectrometry to identify the chemical compounds in the samples.

A group of scientists trained people to people sniff a selection of the mummified bodies at the Egyptian Museum in Cairo to characterize the smell of these ancient artifacts.
Emma Paolin

Elnaggar and his colleagues trained a group of people, mostly museum employees, to identify particular materials used in mummification that could be associated with specific smells and to separate out smells that might be caused by museum infrastructure or conservation treatments rather than the mummies themselves. The mummies’ scent profiles were complex, but they were most often described as “sweet,” “woody” and “spicy.” The researchers hope to use the method on a larger set of mummies to better

understand the varied mummification practices employed in ancient Egypt. “Different historical methods represent different materials used in mummification and also different quality of materials,” Elnaggar explains.

The earliest Egyptian mummies, dating back to roughly 5000 B.C.E.,formed when the remains of deceased individuals were buried in hot, dry sand and mummified naturally. People began using techniques for artificial mummification around 2700 B.C.E., and these practices were the most sophisticated in the New Kingdom period, which started around 1500 B.C.E. During that time, bodies received thorough treatment with a variety of oils and resins—potential sources of the “sweet” and “woody” scents detected in the study.

Some fragrance differences may also come from variations in mummification practices for people of different social classes. Across time, “individuals of high social status would be mummified with better-smelling or more intense—smelling natural extracts,” says study co-author Matija Strlič, an analytical chemist at the University of Ljubljana. For instance, Elnaggar adds, the bodies of pharaohs and other elites were treated with fresh natural salts and with resins derived from expensive herbs, whereas salts and other materials were reused multiple times for the bodies of people from poorer classes. In the study, the best-preserved mummy was in a coffin with a gilded mask; even though it was one of the oldest, it had a wide variety of odor compounds, many of which were found in higher concentrations than in the other mummies.

Emma Paolin, a Ph.D. researcher at the University of Ljubljana in Slovenia, smells the olfactory port of a gas chromatography/mass spectrometry instrument. The analyst describes the smell in terms of quality, intensity and hedonic tone.
Andrej Kriz/Faculty of Chemistry and Chemical Technology/University of Ljubljana

Using local conservators was a key part of this study, Elnaggar says, because they have a stake as caretakers of Egyptian cultural heritage and are exposed to the smell of artifacts in their work. This makes them well prepared to describe mummy scents for both researchers and casual museum visitors.

“Smell is very closely linked to the amygdala and hippocampus—areas in our brain that are responsible for processing memory and emotions,” says Barbara Huber, an archaeochemist at the Max Planck Institute of Geoanthropology in Jena, Germany, who was not involved in the new study but curated a 2023 exhibit on mummy scents in Denmark. Museums commonly display objects behind glass, Huber says, blocking access to smells that can be crucial to our understanding of historical narratives—especially for “an incredibly aromatic experience” such as mummification. According to Strlič, “In order to truly experience cultural heritage, we need to involve all our senses—because smells and sounds of heritage are inherent” in getting a full experience of the past.

Can we expect to grab a bottle of mummy perfume from the museum shop soon? The researchers say this idea might not be off the table. “Everyone would like to smell like ancient Egyptians: sweet, woody and spicy,” Elnaggar says. “What we’d like to do now is share our experience with museum visitors so they can enjoy it in an exhibition—and even take it home!”

A version of this article entitled "Sniff a Mummy" was adapted for inclusion in the July/August 2025 issue of Scientific American. *This text reflects that version, with the addition of some material that was abridged for print.*

Gayoung Lee is a science journalist and former news intern and Games ace at *Scientific American*. A philosopher turned journalist, originally from South Korea, Lee is interested finding unexpected connections between life and different science, particularly in theoretical physics and mathematics. You can read more about her here: https://gayoung-lee.carrd.co

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https://www.scientificamerican.com/article/mummies-from-ancient-egypt-smell-surprisingly-nice-scientists-say

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Artificial Intelligence

- **Replacing Federal Workers with Chatbots Would Be a Dystopian Nightmare**
  The Trump administration sees an AI-driven federal workforce as more efficient. Instead, with chatbots unable to carry out critical tasks, it would be a diabolical mess

Replacing Federal Workers with Chatbots Would Be a Dystopian Nightmare

The Trump administration sees an AI-driven federal workforce as more efficient. Instead, with chatbots unable to carry out critical tasks, it would be a diabolical mess

By Asmelash Teka Hadgu & Timnit Gebru

Moor Studio/Getty Images

Imagine calling the Social Security Administration and asking, “Where is my July payment?” only to have a chatbot respond, “Canceling all future payments.” Your check has just fallen victim to “hallucination,” a phenomenon in which an automatic speech-recognition system outputs text that bears little or no relation to the input.

Hallucination is one of the many issues that plague so-called generative artificial-intelligence systems such as OpenAI’s ChatGPT, xAI’s Grok, Anthropic’s Claude and Meta’s Llama. These pitfalls result from design flaws in the architecture of these systems that make them problematic. Yet these are the same types

of generative AI tools that the Trump administration and its Department of Government Efficiency (DOGE) want to use to, in one official's words, replace "the human workforce with machines."

This proposition is terrifying. There is no "one weird trick" that removes experts and creates miracle machines capable of doing everything humans can do but better. The prospect of replacing federal workers who handle critical tasks—ones that could result in life-and-death scenarios for hundreds of millions of people—with automated systems that can't even perform basic speech-to-text transcription without making up large swaths of text is catastrophic. If these automated systems can't even reliably parrot back the exact information that is given to them, then their outputs will be riddled with errors, leading to inappropriate or even dangerous actions. Automated systems cannot be trusted to make decisions the way federal workers—actual people—can.

Historically, hallucination hasn't been a major issue in speech recognition. Earlier systems might make transcription errors in specific phrases or misspell words, but they didn't output large chunks of fluent and grammatically correct text that weren't uttered in the corresponding audio input. Analysts have shown, however, that recent speech-recognition systems such as OpenAI's Whisper can produce entirely fabricated transcriptions. Whisper is a model that has been integrated into some versions of ChatGPT, OpenAI's famous chatbot.

Researchers at four universities analyzed snippets of audio transcribed by Whisper and found completely fabricated sentences. In some cases, the transcripts showed the AI had invented the races of the people being spoken about, and in others it even attributed murder to them. One recording of someone saying, "He, the boy, was going to, I'm not sure exactly, take the umbrella," was transcribed with additions, including "He took a big piece of a cross, a teeny, small piece.... I'm sure he didn't have a terror knife

so he killed a number of people." In another example, "two other girls and one lady" was given as "two other girls and one lady, um, which were Black."

> We cannot afford to replace the critical tasks of federal workers with models that completely make stuff up.

In the age of unbridled AI hype, with entrepreneur Elon Musk claiming to have built a "maximally truth-seeking AI," how did we come to have less reliable speech-recognition systems than we had before? The answer is that although researchers are working to improve such systems by using their contextual knowledge to create models uniquely appropriate for specific tasks, companies such as OpenAI and xAI claim to be building something akin to "one model for everything" that can perform many tasks, including, according to OpenAI, "tackling complex problems in science, coding, math, and similar fields." These companies use model architectures they believe can work for many different tasks and train their models on vast amounts of noisy, uncurated data instead of using system architectures, training methods and evaluation datasets that best fit the specific task at hand. A tool that supposedly does everything won't be able to do anything well.

The current dominant method of building tools like ChatGPT or Grok, which are advertised as systems along the lines of "one model for everything," uses some variation of large language models (LLMs), which are trained to predict the most likely sequences of words. Whisper simultaneously maps the input speech to text and predicts what immediately comes next, producing a "token" as output. A token is a basic unit of text such as a word, number, punctuation mark or word segment that is used to analyze textual data. The two disparate jobs the system has to do—speech transcription and next-token prediction—in conjunction with the large, messy datasets used to train it make it more likely that hallucinations will happen.

Like many of OpenAI's projects, Whisper's development was influenced by a particular outlook, summarized by the company's former chief scientist: "if you have a big dataset and you train a very big neural network," it will work better. Arguably, Whisper doesn't work better. Because its decoder is tasked with both transcription and token prediction without having been trained with precise alignment between audio and text, the model may prioritize the generation of fluent text over accurate transcription of the input. And unlike misspellings or other minor mistakes, coherent text doesn't give the reader clues that the transcriptions might be inaccurate, potentially leading users to rely on the AI's output in high-stakes scenarios without finding its failures—until it's too late.

OpenAI researchers have claimed that Whisper approaches human "accuracy and robustness," a statement that is demonstrably false. Most humans don't transcribe speech by making up large swaths of text that never existed in the speech they heard. In the past, people working on automatic speech recognition trained their systems with carefully curated data consisting of speech-text pairs in which the text accurately represented the speech. In contrast, OpenAI's attempt to use a "general" model architecture rather than one tailored for speech transcription—sidestepping the time and resources it takes to curate data and adequately compensate data workers and creators—results in a dangerously unreliable speech-recognition system.

If the current one-model-for-everything paradigm has failed at the kind of English-language speech transcription most English speakers can perform perfectly without further education, how will we fare if DOGE succeeds in replacing expert federal workers with generative AI systems? Unlike the generative AI systems that federal workers have been told to use to perform tasks ranging from creating talking points to writing code, automatic speech-recognition tools are constrained to the much better-defined setting of transcribing speech.

We cannot afford to replace the critical tasks of federal workers with models that completely make stuff up. There is no substitute for their expertise when handling sensitive information and working on life-critical sectors ranging from health care to immigration. We need to promptly challenge, including in courts if appropriate, DOGE's push to replace "the human workforce with machines" before this action brings immense harm to Americans.

This is an opinion and analysis article, and the views expressed by the author or authors are not necessarily those of Scientific American.

Asmelash Teka Hadgu is co-founder and chief technology officer of Lesan AI and a fellow at the Distributed AI Research Institute (DAIR). He focuses on building advanced speech-recognition and machine-translation systems for underrepresented languages.

Timnit Gebru is the founder and executive director of the Distributed AI Research Institute (DAIR) and author of the forthcoming book *The View from Somewhere* (One Signal Publishers), a memoir and manifesto arguing for a prosocial technological future rather that one that serves only industry and government.

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https://www.scientificamerican.com/article/replacing-federal-workers-with-chatbots-would-be-a-dystopian-nightmare

Arts

- **Poem: ‘Prayer to Fireflies’**
  Science in meter and verse

Poem: ‘Prayer to Fireflies’

Science in meter and verse

By Genevieve Pfeiffer edited by Dava Sobel & Clara Moskowitz

Masha Foya

And then: your first light.
Eerie star between metallic, blackened trees.
Your lantern-hum alive like any limb. Any reaching arm
any two hands made cup for stark, elusive beam.
Almost yellow, yet another world’s powdered green.
The snag of something bright but soft within the branches.

Steady moon-waver, otherworldly ash: firefly.
Your glow, a concentrated fog mixed to paint.
Where does the star wander tiny tinkerer
in search of a mate? Luminous engineer,
your body a brilliance unlike anything human.
Better than our best bulbs, and we’ve calculated for centuries.

How different, our energy. How friendly,
the warm-windowed house. Our slow fatality,

a murmured whirl of motors. The way we extinguish you
and barely notice.

Measured insect, with a voice of light between branches—
You are my Lucifer and Venus.
My god of earth, the small fire kindling within.
I'll follow your low wink
into the woods

past trees, past the hour my house darkens.

Genevieve Pfeiffer is a Ph.D. student in the Environmental Sciences, Studies and Policy program at the University of Oregon, studying emergent technologies' role in understanding nonhuman communications. She has a master's in experimental humanities from New York University and an M.F.A. in poetry from Sarah Lawrence College.

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https://www.scientificamerican.com/article/poem-prayer-to-fireflies

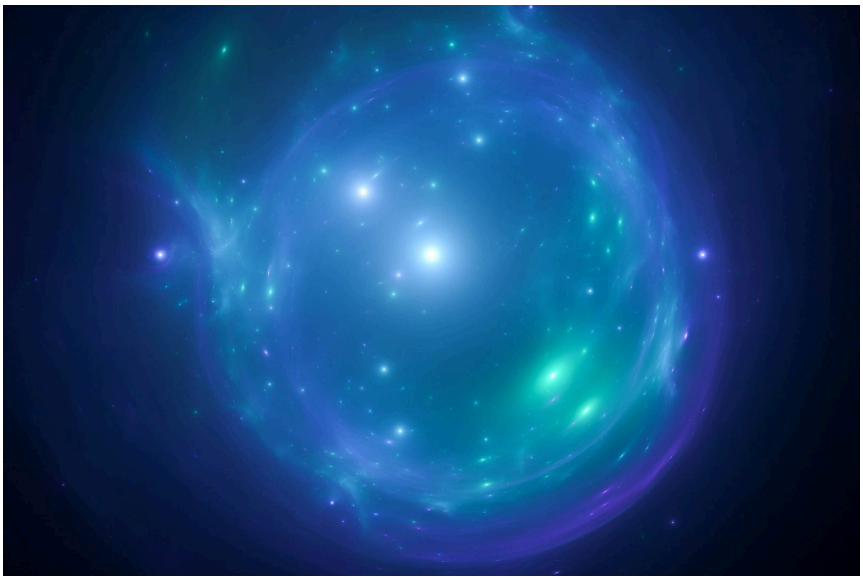
Astronomy

- **What Are ORCs? Astronomers Still Don’t Know**
  ORCs—odd radio circles—are one of the weirdest recent discoveries in the heavens above

Strange Circles in the Sky Are Still Baffling Astronomers

ORCs—odd radio circles—are one of the weirdest recent discoveries in the heavens above

By Phil Plait edited by Lee Billings



Baac3nes/Getty Images

It’s rare these days for astronomers to find a new class of object in the heavens. After all, we’ve been searching the skies for centuries, so all the easy stuff has already been found.

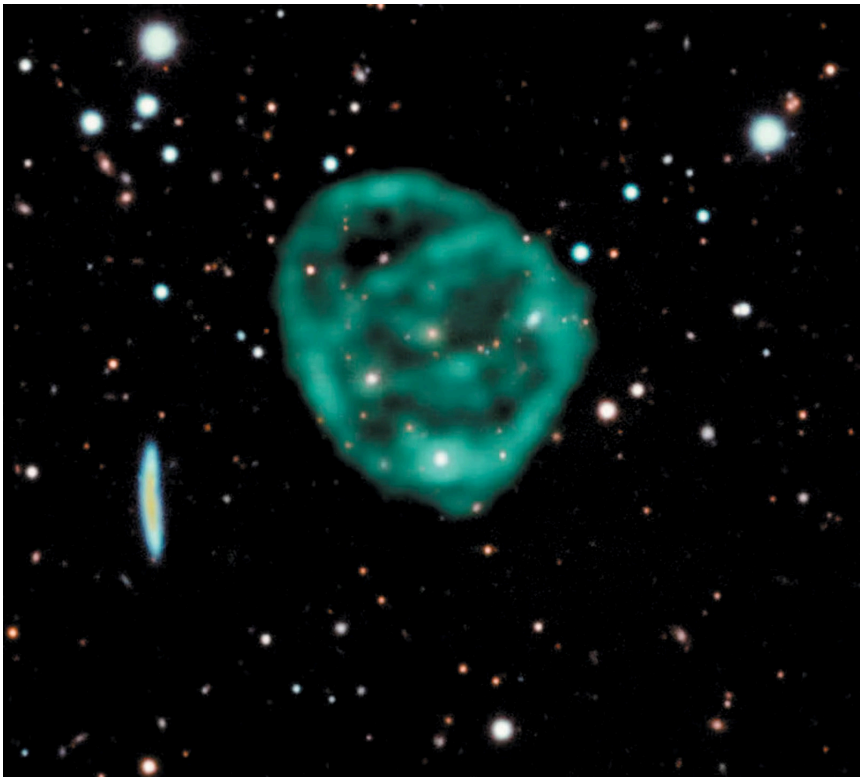
Adding new capabilities to our searches does tend to result in new discoveries, however. Looking in different wavelengths of the electromagnetic spectrum, for example, is a good way to uncover novel things because different objects emit light in different ways.

Objects in newly discovered classes also tend to be faint because, again, bright objects will have been spotted already. This fact is why identifying something completely new is unusual. It’s also why such findings can be baffling—by definition, we’ve never seen anything like them before.

In 2019 astronomers stumbled on just such a thing when they found multiple examples of a previously unknown kind of structure. The objects turned up in a pilot survey using the at-the-time newly completed radio telescope called the Australian Square Kilometer Array Pathfinder telescope (ASKAP), a collection of 36 radio dishes, each 12 meters wide, located in Western Australia.

The newfound celestial objects were relatively big and circular—a common shape for astronomical bodies. When something out there looks circular, it's very likely that we're actually seeing a spherical shell, like a soap bubble. Near the middle of the bubble our line of sight goes through only a small amount of material, but near the edges that path intersects more of it. If the material glows, then it will look like a circle from any viewing direction. Dying stars that are blowing off winds of gas tend to make these kinds of structures, and many examples are known.

These new objects in the ASKAP survey, however, didn't correspond to any previously known structure, didn't have an obvious source and, outside of radio emission, were invisible in wavelengths of light. Lacking any obvious mechanism for their creation, astronomers dubbed them ORCs: odd radio circles. Honestly, I give them credit for coming up with such a brief, descriptive moniker (and for presumably being fans of J.R.R. Tolkien). The discovery paper, printed in *Publications of the Astronomical Society of Australia*, lists four such ORCs.



From “MeerKAT Uncovers the Physics of an Odd Radio Circle,” by Ray P. Norris et al., in *Monthly Notices of the Royal Astronomical Society*, Vol. 513, No. 1; June 2022. Published March 24, 2022 (CC BY 4.0)

The very first ORC seen, called ORC 1 (of course), provided a clue to its origin. Searching images from other telescopes, the astronomers found an object emitting visible and infrared light right at the ORC’s center. Later observations indicated it’s an elliptical galaxy about five billion light-years from Earth. If it’s the source of ORC 1, this first-of-its-kind odd celestial circle is a staggering two million light-years across—more than 15 times wider than our Milky Way galaxy—making it vast indeed. It’s also possible, however, that this galaxy instead is just coincidentally located near the apparent center of ORC 1 in the sky.

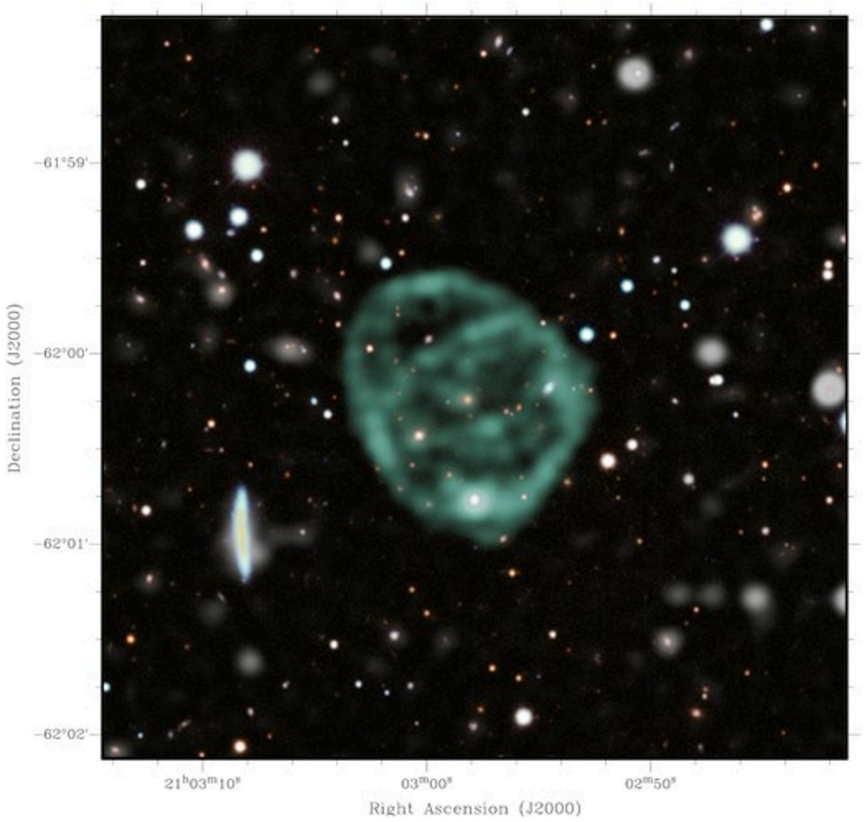
Worse, the other ORCs described in the discovery paper are even weirder. ORCs 2 and 3 are roughly the same size in the sky and happen to be so close together that they’re nearly touching, which strongly implies they’re related to each other in some way. But whereas ORC 2 is ring-shaped and bright, ORC 3 is faint and an evenly filled circle more like a disk. If they’re related, then why are they so different? There are several galaxies apparently close to

them, but again these objects occupy a lot of real estate in the sky, so the odds of coincidentally finding galaxies in proximity to them are good.

Astronomers have found more ORCs in the years since those initial discoveries, and some of them also appear to have a galaxy in their center, which does seem to strengthen the correlation. If those galaxies really are in that position, then those ORCs are also in the million-light-year range in size.

If this connection is real, what physical mechanism is creating the ORCs? Ideas abound. One possible driver is a supermassive black hole. As far as we can tell, every big galaxy has one of these monsters at its heart. As matter falls in, it piles up around the point of no return in a huge disk. Strong magnetic fields that spin like a tornado near the center can launch incredibly powerful beams of matter and energy that scream away from the black hole at high speed. A 2024 study published in the *Astrophysical Journal* shows that these beams can inflate the gas that exists between galaxies, creating structures very much like the ORC observations.

Not all ORCs are created equal, though. In correspondence published last year in the journal *Astronomy and Astrophysics*, astronomers reported they had found diffuse x-ray emission at the location of an ORC they dubbed Cloverleaf, and its spectrum indicated that the high-energy light comes from hot gas typically found in low-mass galaxy groups that are somewhat heftier than our own Local Group (of which the Milky Way and Andromeda galaxies are the biggest members). This would put the ORC about 600 million light-years from Earth.



The MeerKAT image of ORC 1, superimposed on optical data from the Dark Energy Survey. "MeerKAT uncovers the physics of an odd radio circle," Ray P Norris et al., *Monthly Notices of the Royal Astronomical Society*, Vol. 513, Issue 1, June 2022, Pages 1300–1316, Published March 24, 2022 (CC BY 4.0)

The structure of the Cloverleaf emission is somewhat irregular, displaying a patchiness that is usually associated with the collision and merging of two galaxy groups. Such a catastrophic event can dump a lot of energy into the gas around the galaxies, again creating an expanding wind that can take on a roughly spherical shape. An ORC is born.

If this interpretation of the Cloverleaf is correct, it indicates there's more than one way to make an ORC. These weird objects may in fact reflect a wide range of physical structures and distinctly differing origins. Another object, first reported in a 2022 paper, bears a resemblance to the original ORCs but lacks a central galaxy or galaxy cluster and appears as a ring in ASKAP images. Its location, though, is suspicious: it's just three degrees from the edge of the Large Magellanic Cloud, or LMC, a satellite galaxy of the Milky Way. An association with the LMC would mean this ORC is only 160,000 light-years from us, which would make it only about

150 light-years in diameter. That would imply an entirely different formation history, making this ORC a likely supernova remnant, the expanding debris from a star that exploded long ago. What's odd is that it's outside the LMC, where stars are sparse. Sometimes stars do get ejected from galaxies, though; they can get catapulted away if they pass close to a massive black hole, for example, or if their companion star in a binary system they were once part of exploded, flinging them away at high speed.

It looks like the ORC category can encompass several different kinds of objects. That's not too surprising; as we have discovered time and again in astronomy, phenomena that all look similar can have radically different causes. Some supernovae are from high-mass stars that exploded when their cores collapsed at the ends of their lives, whereas others are from already dead white dwarfs that accumulated enough matter on their surface to cause a catastrophic star-wide thermonuclear explosion. Gamma-ray bursts can be caused by extremely massive stars exploding or by two tiny but superdense neutron stars colliding. The list of coincidental similarities in a class of objects goes on and on.

Remember, the term "ORC" is descriptive, not explanatory. Some ORCs may be from galaxy-group collisions, others from exploding stars and still others from supermassive black hole belches. Although astronomers have studied ORCs for several years now, these objects are still part of a brand-new class, meaning we're likely to have more theoretical explanations for them than we do actual examples to study in the sky. More observations should help astronomers classify them, and, as always, the hope is to categorize them, explain them and learn how they work.

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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https://www.scientificamerican.com/article/what-are-orcs-astronomers-still-dont-know

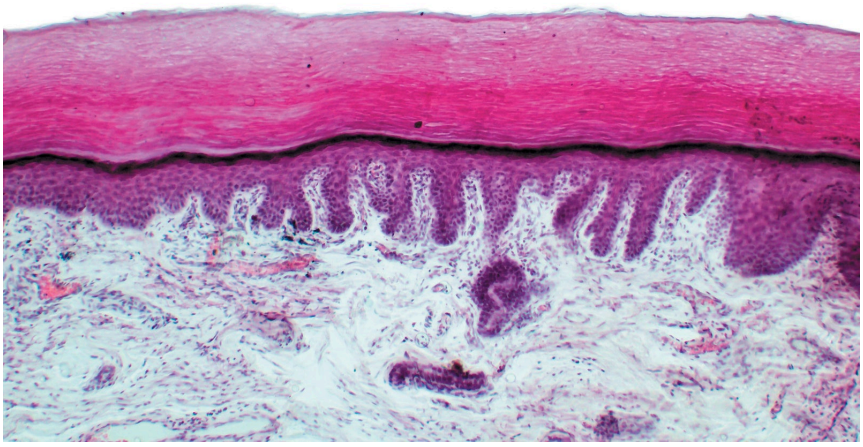
Cells

- **Injured Skin Cells Fire like Neurons to ‘Scream’ for Help**
  Our skin’s epithelial cells send electrical signals like neurons to cry out for help

Skin Cells ‘Scream’ for Help When Injured

Our skin’s epithelial cells send electrical signals like neurons to cry out for help

By Allison Parshall edited by Sarah Lewin Frasier



Epithelial cells from finger skin stained pink.
Yaroslav Stepaniuk/Alamy Stock Photo

Neurons talk to one another using electricity. If you could hear these impulses, they might sound like constant, rapid-fire chatter all over the nervous system. Heart muscle cells do something similar, issuing electrical “heave-ho” signals that make the organ beat.

Skin and other epithelial cells, however, were thought to be silent; they form barrier tissues that protect the body’s interior from the outside world, and they weren’t assumed to need this kind of communication. So researchers were amazed to discover recently that, when wounded, these cells emit a slow electric pulse in a way that resembles neuron firing.

“The epithelial cells are making a signal kind of like a scream: ‘We got injured, we need repair, you need to come over here,’” says Sun-Min Yu, an engineer at the University of Massachusetts Amherst and lead author of the study, published in the *Proceedings*

of the National Academy of Sciences USA. The signal may summon other cells to help rebuild the damaged spots.

Epithelial cells form the skin's outer layer and line the gut, blood vessels, airways—basically "every single organ in your body that connects to the outside world," says Ellen Foxman, who wasn't involved in the new findings but studies epithelial cells at the Yale School of Medicine. When injured, these cells were known to coordinate healing by passing chemical signals to their neighbors. But Yu says she "thought maybe there should be a faster signaling pathway." She cultured epithelial skin cells from humans and kidney cells from dogs in dishes fitted with an array of electrodes. When she used a laser to wound the cells, she detected some electrical "noise" coming from locations near the lesions.

"It was a very evident, active signal" that strongly resembled a neuron's self-generated electrical spikes, Yu says. These bursts were faster than chemical messengers but much slower than neurons' signals; they lasted seconds instead of milliseconds and rippled across at least a dozen other epithelial cells. It is unclear how the epithelial cells produced the signals, but the researchers found that these cells could fire only in the presence of calcium ions. Neuron signaling is also known to rely on ions, including calcium, sodium and potassium; the ions' electrical charge provides the signature voltage spike.

The new observations "show that maybe there's longer-range communication" among epithelial cells to coordinate healing, Foxman says. Understanding exactly how these cells respond to damage could reveal why the process sometimes goes wrong. "When you get a cut, sometimes it heals perfectly," she says, but other times the process leaves a scar—and scars on an internal organ's epithelium can sometimes lead to chronic health conditions. "That's what I'm excited about," Foxman adds. "Whenever you find a new pathway, you could study and potentially use [it] to develop a new treatment."

It’s still not certain what role this signaling plays in living organisms or what other cells do when they receive a signal, says Sarah Najjar, who studies gut epithelial cells at New York University. “What is downstream of this electrical activity?” she wonders. Does it influence neurons? Yu next plans to study whether these two types of cells interact. “I want to know how the high-pitched signals [of neurons] are translated” for epithelial cells tuned to lower-pitch signals, and vice versa, she says. “It’s a study coming from our curiosity.”

Allison Parshall is an associate editor at *Scientific American* covering mind and brain and she writes the weekly online Science Quizzes. As a multimedia journalist, she contributes to *Scientific American*'s podcast *Science Quickly*. Parshall's work has also appeared in *Quanta Magazine* and Inverse. She graduated from New York University's Arthur L. Carter Journalism Institute with a master's degree in science, health and environmental reporting. She has a bachelor's degree in psychology from Georgetown University.

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https://www.scientificamerican.com/article/injured-skin-cells-fire-like-neurons-to-scream-for-help

Climate Change

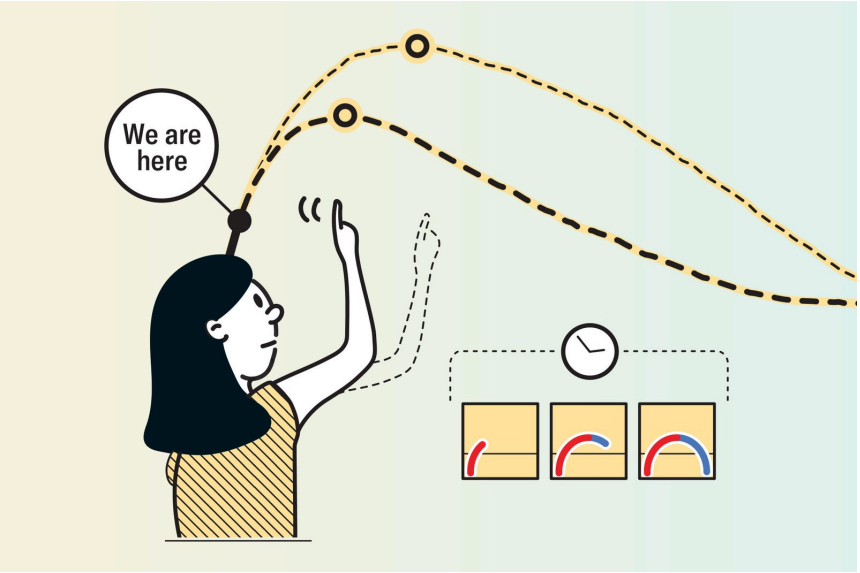
- **Why the Climate Warming Goal of 1.5 Degrees C Isn’t a Lost Cause—Even If We Overshoot It**

  Earth will likely warm by more than 1.5 degrees Celsius, but we can’t give up on trying to get temperatures back down

Why Climate Goals Aren’t a Lost Cause—Even If We Overshoot Them

Earth will likely warm by more than 1.5 degrees Celsius, but we can’t give up on trying to get temperatures back down

By Andy Reisinger & Angela Morelli and Tom Gabriel Johansen/InfoDesignLab edited by Jen Christiansen & Clara Moskowitz



Angela Morelli and Tom Gabriel Johansen/InfoDesignLab

Global warming is set to exceed 1.5 degrees Celsius soon, meaning the world will most likely fail to meet the 2015 Paris Agreement goal of striving to cap the average temperature increase at 1.5 degrees C. Even if Earth warms more than that, though, this key aim isn’t a lost cause. Scientists say we could bring the global temperature back down again if we redouble our efforts. The concept of overshoot—to miss our mark but then return below it—offers both a warning and a path forward.

The warning is stark: even if we reduce warming to 1.5 degrees C sometime before century’s end, some losses will be irreversible. Ecosystems will be transformed, species will vanish and vulnerable communities will bear lasting scars. Nevertheless, ensuring that the

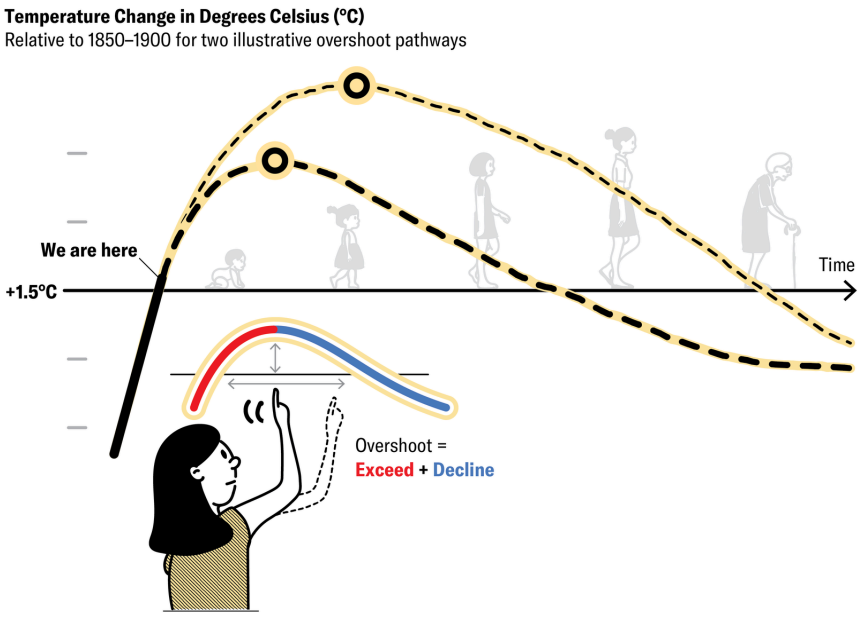
overshoot of 1.5 degrees C is only temporary would curtail the damage and offer some chance of recovery.

Studies indicate that if we limit peak warming to well below two degrees C, there will still be some hope of bringing the temperature down in the future by removing far more carbon from the atmosphere than we emit, an approach called net-negative emissions. Simply achieving net-zero emissions—a major goal of many industrial countries—is no longer sufficient to limit warming to 1.5 degrees C.

Admitting that we will exceed this threshold doesn't justify delaying action; it demands acceleration. Every tenth of a degree of warming beyond 1.5 degrees C will cause more damage to Earth and people and make it more difficult for us to return to that level while adapting to a changing climate. It's a challenging prospect, but at this point it may be our least bad option for limiting long-term climate harm.

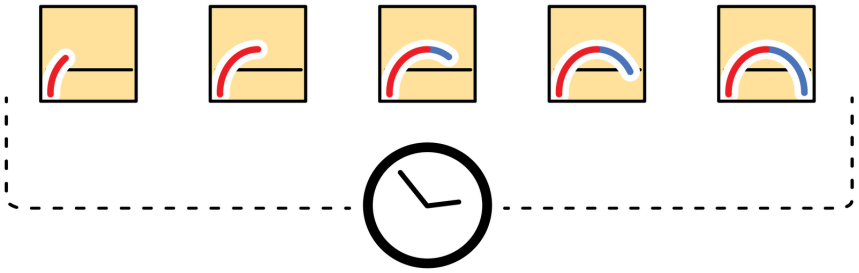
LIMITING BY HOW MUCH WE EXCEED 1.5°C REMAINS CRITICAL

Exceeding 1.5°C of global warming will result in **greater impacts** on humans and ecosystems.



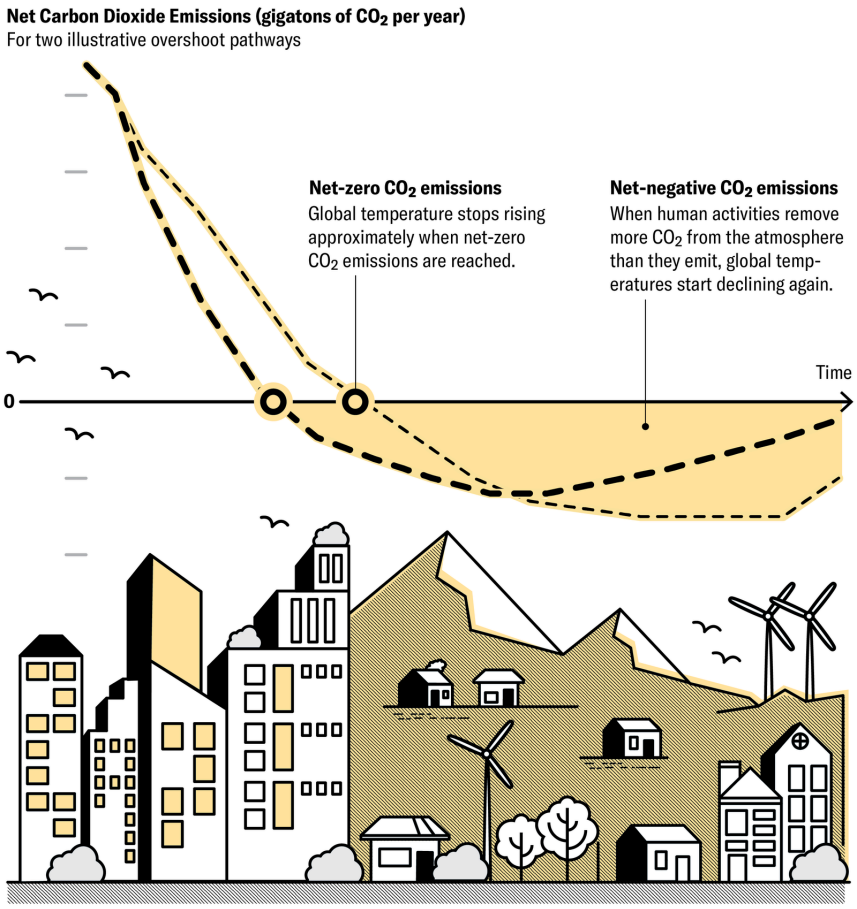
EVEN THOUGH WE WILL EXCEED 1.5°C, WE COULD BRING TEMPERATURE BACK DOWN AGAIN IF THE OVERSHOOT IS NOT TOO HIGH

Overshoot is a trajectory in which global temperature first exceeds a given threshold and later returns below it. The less overshoot we experience, the better.



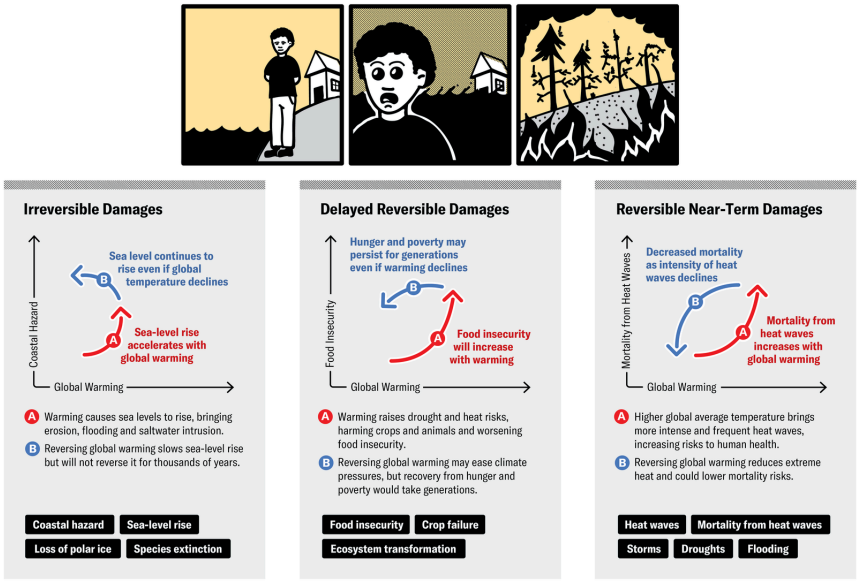
OVERSHOOT CAN BE CHARACTERIZED BY HOW MUCH AND FOR HOW LONG 1.5°C IS EXCEEDED

By how much and for how long depends on the trajectory of net-negative CO_2 emissions, as well as emissions from other greenhouse gases.



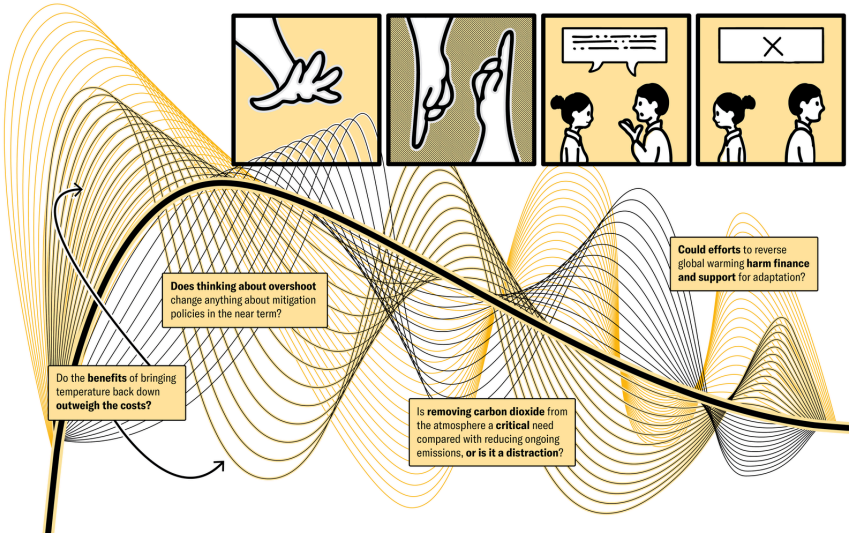
A WORLD THAT RETURNS TO GLOBAL WARMING OF 1.5°C WILL BE A SIGNIFICANTLY ALTERED AND MORE DAMAGED WORLD

Some **climate-related damage** to humans and ecosystems will be **irreversible**, and some could be partially reversed with **significant delay.**



BRINGING GLOBAL WARMING BACK DOWN IN AN OVERSHOOT PATHWAY WOULD BE A COMPLEX PROCESS

The shape of that pathway will be informed by overarching conversations that reveal key **tensions and forces** at play—including answers to the questions below.



Angela Morelli and Tom Gabriel Johansen/InfoDesignLab; Source: "Overshoot: A Conceptual Review of Exceeding and Returning to Global Warming of 1.5 °C," by Andy Reisinger, Jan S. Fuglestvedt, Anna Pirani et al., in *Annual Review of Environment and Resources*, Vol. 50; April 14, 2025 (*reference*)

Andy Reisinger is an honorary associate professor at the Institute for Climate, Energy and Disaster Solutions at the Australian National University.

Angela Morelli and Tom Gabriel Johansen are information designers and co-founders of InfoDesignLab. They co-design with scientists and decision-makers to turn complex data into unique visualizations, meaningful narratives, compelling messages and decision-making tools.

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https://www.scientificamerican.com/article/why-the-climate-warming-goal-of-1-5-degrees-c-isnt-a-lost-cause-even-if-we

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Culture

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  Inside this double issue of SciAm, you'll find black holes that burp up their stellar meals, metal detectorists that hit pay dirt, hope for psychopathy, the truth about testosterone and a consumer guide to sustainable clothes shopping
- **Contributors to Scientific American's July/August 2025 Issue**
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Seeking Sustainable Fashion and Cracking a Greenland Mystery

Inside this double issue of SciAm, you'll find black holes that burp up their stellar meals, metal detectorists that hit pay dirt, hope for psychopathy, the truth about testosterone and a consumer guide to sustainable clothes shopping

By Jeanna Bryner

Scientific American, July/August 2025

Sometimes I joke with my husband that we don't need therapists and other specialists because the solution to every woe of daily life boils down to mindfulness and being thoughtful in our actions. That same concept applies to sustainable fashion. In her striking feature, journalist Jessica Hullinger reveals just how many environmental issues plague the global fashion industry, with so-called fast fashion being an egregious source of greenhouse gas emissions, as well as harmful chemicals that leach from cheap, quickly discarded garments in landfills.

Fortunately, businesses and nonprofits are sprouting up to make garments more sustainable and to extend their lives through repairs and marketing that helps people “shop their closets.” For consumers, the answer could be mindfulness. Senior graphics editor Jen Christiansen worked with researchers to create a color-coded consumer guide. It breaks down the different parts of a garment’s life cycle and the fibers used in clothing production so you can make more informed choices.

For our cover feature, chief multimedia editor Jeffery DelViscio spent a month in the harsh, desolate and otherworldly icescape of Greenland, where researchers were trying to answer a seemingly simple question with global repercussions: Is the Greenland ice sheet more vulnerable to climate change than anyone knew? To find the answer, engineers and scientists drilled underneath a flowing ice tongue called the Northeast Greenland Ice Stream (NEGIS). If the entire Greenland ice sheet melted, a good portion of the resulting flood would drain through the NEGIS into the ocean, potentially raising global sea levels by 24 feet. By drilling through the bottom of the ice and grabbing a core of the bedrock below, the team could glimpse the place before it was covered in ice. Knowing what temperature supported such an ice-free past would tell us what conditions would be needed to do the same today. One of the researchers who has been studying the bedrock for years is worried: “I have, for the first time ever in my career, datasets that take my sleep away at night,” he told DelViscio.

The awe and wonder of Greenland could be matched only by the darkness and mystery of black holes. Radio astronomer Yvette Cendes looks at the dining experiences of some of the biggest black holes at the centers of galaxies. For all their apparent tidiness, black holes are sloppy snackers. When they chow down on a star, the crumbs go flying. All that mess forms an accretion disk around the black hole that sends out radio light. Now physicists are discovering that many black holes suffer from indigestion and burp

out some of their meal long after eating. This finding could explain some bizarre behavior seen near black holes.

Kids consistently baffle parents with their own flavor of bizarre behavior, some of which can be harmful. Children who are repeatedly aggressive and behave in callous and unemotional ways are at risk of developing psychopathy as adults. Although that seems scary, science writer Maia Szalavitz points out some hopeful interventions in her feature. One thing is certain: kids with these traits don't respond to punishment. But new treatments designed specifically for these children can help them grow into thriving adults.

Adulthood can also be tough to navigate. For men of a certain age, testosterone replacement therapy has been touted as a way to boost muscle mass, energy and sex drive. Science journalist Stephanie Pappas gives readers a look at men's experiences with prescribed testosterone supplements, how they fared and the science underlying any benefits and risks.

Anyone with a metal detector can find treasure if they know where to look. Perhaps nowhere is that truer than in Denmark. Science reporter Elizabeth Anne Brown writes that the Scandinavian country has embraced such hobbyists, who follow established rules and turn over more than 20,000 finds a year to government archaeologists. Find out about some of the fascinating discoveries made by these enthusiasts, who are anything but "amateur."

Jeanna Bryner is managing 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.

https://www.scientificamerican.com/article/seeking-sustainable-fashion-and-cracking-a-greenland-mystery

Contributors to *Scientific American*’s July/August 2025 Issue

Writers, artists, photographers and researchers share the stories behind the stories

By Allison Parshall edited by Jen Schwartz

Jeffery DelViscio

Jeffery DelViscio
Greenland’s Frozen Secret

In the spring of 2024 Jeffery DelViscio (*seen freezing above*), who is *Scientific American*’s chief multimedia editor, spent a month on a scientific expedition on the Greenland ice sheet. The sun never set, the wind never stopped, and it was often –20 degrees Fahrenheit even inside his tent. “After the first night, I was like, ‘I think I’ve made a huge mistake. This is the most uncomfortable I think I’ve ever been in my life,’” he says. “The weirdest part is how quickly you can acclimatize to it.” His body adjusted to the new normal after only a few days.

On the ice stream, survival was a group exercise for DelViscio, the researchers, and their survival specialists (including a polar bear guard). DelViscio witnessed the extraction of a special bedrock core, hoisted up from below the ice, which he documents in our cover story and his accompanying photographs in this issue. DelViscio, who has a master's degree in earth science, once collected and studied similar cores from the seafloor.

"There's memory everywhere," DelViscio says. Cores like these reveal our planet's climate history, and the rock below Greenland's ice will help scientists learn when the island was last ice-free. "What this piece of rock remembers has incredibly large implications for how we live as a human species going forward," he says.

Elizabeth Anne Brown
Pay Dirt

Every sunny winter weekend in Denmark, "gold is coming out of the ground," says Elizabeth Anne Brown, a journalist based in Copenhagen. For years Brown lurked in a Facebook group where Denmark's metal detectorists post photographs of intricate, hand-carved Viking treasures they've unearthed. "It's infuriating when you're at home on the couch and don't know any Danish farmers you can ask if you can go metal detect on their property," she says of her own predicament. Instead she began tagging along as a reporter. For her feature in this issue, Brown covered this incredible community of treasure hunters in Denmark—and the archaeologists who partner with them to document the country's past. Wielding a metal detector requires a lot of physical and mental skill, she says; many detectorists can tell just from the beeps what type of metal object lies under the ground.

"I think some people are really just born with an innate desire to search and reach out for connection with the past," Brown says. She considers herself one of them. "I grew up looking for pottery

fragments and old bottles in a stream behind my grandparents' farm" in Alabama, she says. As a journalist, she's always searching for strange, odd creatures to report on—or, as she describes it, she's "on the 'lil fella' beat." For a second story in this issue, in the Advances section, Brown wrote about velvet worms, which are powerful, murderous and wonderful, she says: "Move over axolotls, move over tardigrades: velvet worms are the next big thing."

Maia Szalavitz
Can Psychopathy Be Cured?

Journalist Maia Szalavitz often writes about addiction. It's a heavily stigmatized condition, and she has experienced it firsthand: in her 20s she had addictions to cocaine and heroin. "Trying to figure out what the heck happened and how I went from straight-A student who got into Columbia to shooting up 40 times a day was a big part of how I ended up doing science writing," she says. "I wanted to understand, How do we become who we are?"

For her feature article in this issue, Szalavitz explored what is perhaps the most stigmatizing label in mental health: psychopathy, particularly the callous and unemotional traits in children that can develop into adult psychopathy. "If you're genetically prone to it, it's as much not your fault as if you were genetically prone to addiction or bipolar disorder," she says. But what does that mean when psychopathy often involves remorseless harm done to others?

"I'm always interested in the way our systems of morality intersect with medicine," Szalavitz says. About half of children with these traits don't progress to psychopathy in adulthood, and many of them "learn to do cognitively what other people naturally do emotionally," she says. "I'm always interested in seeing how people deal with the hand that they end up being dealt."

Amanda Hobbs
Fashion Forward

If you want to know the answer to a multifaceted question, put Amanda Hobbs on the case. “I’ve researched almost any topic you can think of,” she says, including lithium batteries, ancient Rome, fungal infections, space and epigenetics. Hobbs is a freelancer whose work often shapes the graphics in *Scientific American*. For this issue, she researched sustainable fashion for graphics by senior graphics editor Jen Christiansen, as part of the feature article by Jessica Hullinger. Today’s fashion industry is a complicated landscape (more so than she’d initially thought), and it’s challenging to identify viable options. “Is it really sustainable? Or is it just paying lip service?” Hobbs asks. She hopes the graphics will help people “get past the greenwashing.”

In college Hobbs was torn between biology and history. “Biology is literally dissecting something to see all the different parts. I’m much more into that figuratively. So I became a history major.” This knowledge helps her research bygone worlds to inform artistic re-creations of scenes from the past, such as Incan mummy rituals or Emperor Hadrian visiting a Roman fort. These reconstructions require a lot of historical detail about ancient peoples’ etiquette, fashion, and more. It’s “that sort of everyday lived history,” she says, that she loves digging into the most.

Allison Parshall is an associate editor at *Scientific American* covering mind and brain and she writes the weekly online Science Quizzes. As a multimedia journalist, she contributes to *Scientific American*'s podcast *Science Quickly*. Parshall's work has also appeared in *Quanta Magazine* and Inverse. She graduated from New York University's Arthur L. Carter Journalism Institute with a master's degree in science, health and environmental reporting. She has a bachelor's degree in psychology from Georgetown University.

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https://www.scientificamerican.com/article/contributors-to-scientific-americans-july-august-2025-issue

Readers Respond to the March 2025 Issue

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

By Aaron Shattuck

Scientific American, March 2025

FINDING A TOXIC SOURCE

In "Penguin Cartography" [Advances], Gayoung Lee reports on research by marine biologist John Reinfelder and his colleagues about the accumulation of mercury in penguins. The story highlights gold mining as a source of such mercury. But according to an October 2010 article in the Woods Hole Oceanographic Institution's (WHOI's) journal *Oceanus*, most of the mercury in the oceans has been created by coal power plants. This link is important because burning coal is also a major source of the carbon in the atmosphere that is causing climate change.

TERRENCE DUNN *VANCOUVER, WASH.*

REINFELDER REPLIES: *The WHOI article Dunn notes was published before the United Nations Environment Program's* Global Mercury Assessment 2018*, which shows that artisanal and small-scale gold mining constitute the largest single source of anthropogenic mercury emissions (representing 38 percent of such emissions). Coal combustion is the second-largest source (representing 21 percent).*

INSIGHT ON INSIGHT

In "The Wonder of Insight," John Kounios and Yvette Kounios explore the neurocognitive underpinnings of the "aha! moment." I wonder whether the authors—or others in the field—have explored similar neurocognitive mechanisms in the experience of humor, particularly the moment of "getting" a joke. Much like insight, the punchline of a joke often reconfigures our understanding of preceding information, and the moment of laughter seems to share the element of sudden recognition or restructuring.

MARK HALLIWELL SMITH *BEVERLY HILLS, CALIF.*

The authors assert that "messages about rewards can enhance insight—but only when they are displayed so briefly that a person cannot consciously perceive them." Yet rewards' effect on insight is nuanced and context-dependent. Highly important rewards might sometimes shift focus toward immediate goals and thus limit the broad, exploratory thinking that is beneficial for insight. But in other contexts, they can boost motivation, persistence and creative problem-solving. Moreover, the authors seem to present a strict dichotomy by suggesting that only subliminal rewards can boost insight, potentially overlooking the role of conscious incentives.

JAMAL I. BITTAR *TOLEDO, OHIO*

Up to my early 20s, I was a highly creative person and produced beautiful paintings. Since I finished college and went into a line of

work that requires a lot of analytical thinking, I have struggled to be artistically creative again. Until now, I thought I was just too mentally exhausted to produce new ideas. But after reading this article, I wonder if highly analytical tasks and constant deadlines at work are suppressing the part of my brain that used to make me creative.

AILYN MONTES *MIAMI, FLA.*

THE AUTHORS REPLY: *Smith likens jokes to puzzles and suggests their punchlines can cause one's initial understanding to become restructured. There is a fair amount of research on this topic. But "getting" a joke can impose a burden on the would-be life of the party: When you haven't rehearsed the joke sufficiently, you might mentally fixate on the punchline and give away the meaning of the joke while telling it. When you see something in a new light, it can be hard to remember it in the old light.*

Bittar argues that explicit rewards can motivate creativity. Research shows that the prospect of such a reward can incentivize people to persist on solving a problem, making them more likely to come up with a good idea. Research also shows, however, that offering explicit rewards can narrow the scope of thought to ideas closely related to the goal, making it more difficult for a person to explore remote associations and fringe ideas that could be fodder for a creative insight. And recent research does suggest that subliminal rewards, in particular, can energize thought without narrowing one's thinking. Outside-the-box thinking is more likely when one's eyes are not on the prize.

Montes's reflections on how work-related pressures can sap one's creativity will ring true for many people. The kind of relaxed reverie that can give birth to an insight can be easily crushed by anxiety, the constant pressure to stay on task and a lack of sleep. That's why many creative ideas unexpectedly emerge during

vacations. It's also why some businesses take their creative teams on vacationlike retreats.

AH, SUGAR, SUGAR

"Sweet Surprise," by Saima S. Iqbal [Advances; February], reports on a study on exposure to sugar restrictions among mid-20th-century infants in the U.K.: economist Tadeja Gračner and her team found that such exposure mitigated chronic ailments later in life. Is the relevant "sugar" sucrose, which is 50 percent glucose and 50 percent fructose? If so, is glucose or fructose, or both, the culprit for subsequent ailments?

RAJESH KULKARNI *VIA E-MAIL*

GRAČNER REPLIES: *Throughout the article, "sugar" refers primarily to added sugar—sugar that is added to foods rather than naturally occurring, or intrinsic, sugar. These additives can come in many forms, including but not limited to honey, table sugar, molasses and high-fructose corn syrup. Our study did not specifically examine the exact sources of added sugar.*

OBJECTIVE SPHERICITY

"The Roundest Object in the Universe," by Phil Plait [The Universe; February], asserts that, among known astronomical objects, the sun is the closest to a perfect sphere. I realize Plait was talking about natural objects, but I was surprised that he made no mention of Gravity Probe B. That orbiting experiment, which tested predictions of Einstein's general theory of relativity, used four fused quartz spheres as its gyroscopes, and these objects were more spherical than the sun.

DON JENNINGS *COLLEGE PARK, MD.*

PLAIT REPLIES: *I should have made it clear that I was exploring the question of the most spherical natural object. As many people have noted, there are some artificial objects vying for the title. They indeed include the gyroscopic rotors developed for NASA's Gravity Probe B mission, which launched in 2004. These ball-bearing-like gyroscopes were 3.8 centimeters across and deviated from sphericity by the thickness of just a few atoms. Unfortunately, there wasn't room in the article to mention them. So right after it was published online in November 2024, I followed up with more information in issue number 801 of my* Bad Astronomy Newsletter. *Other contenders for roundest object are the spheres used to measure Avogadro's constant, the number of atoms or molecules in one mole of a given substance. Having a nearly perfectly round object isn't just a matter of idle interest; our understanding of the universe can depend on it!*

CLARIFICATIONS

In "The Traumatic Roots of Addiction" [October 2024], Maia Szalavitz refers to the train bound for Auschwitz with her father and his mother onboard as what was abandoned by the Nazis in 1944.

The online version of "Deep-Sea Mining Begins," by Willem Marx [May], now describes Alisher Usmanov as a businessperson.

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

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

Ecology

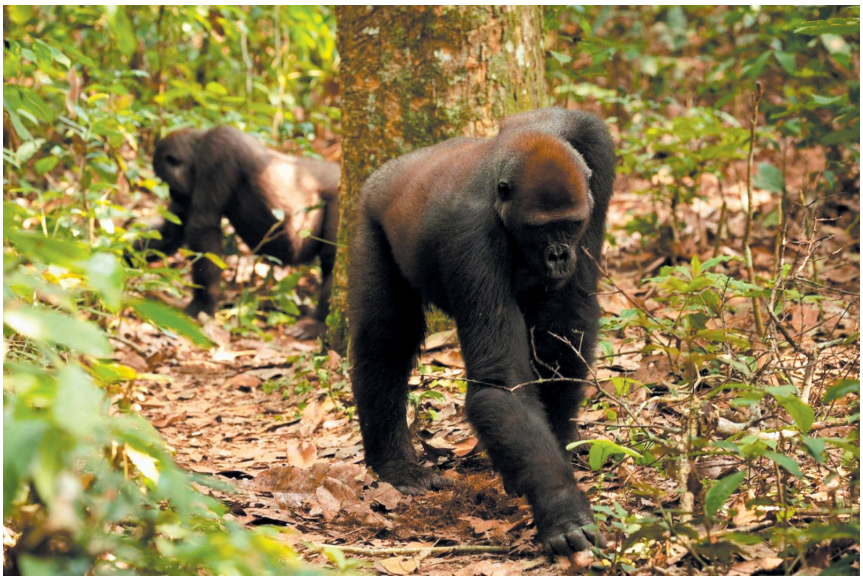
- ## Gorilla Gourmets Are Actually Truffle Hunting

  Researchers followed gorillas for years to uncover truffle-hunting behavior—and it may be socially transmitted

Gorilla Gourmets Really Dig Their Truffles, Study Finds

Researchers followed gorillas for years to uncover truffle-hunting behavior—and it may be socially transmitted

By Rachel Nuwer edited by Sarah Lewin Frasier



Soil-scratching gorillas.
© Guuilhem Duvot/WCS

Gaston Abea remembers his grandfather telling him that the gorillas living near their village in the northern Republic of the Congo were digging at the soil in search of tasty ants. Abea believed this explanation for the odd behavior—until he watched it closely himself and decided it didn't quite line up with the reason given by his grandfather or other members of his Indigenous Ba'Aka community.

"The gorillas were putting the leaves aside and really scratching the soil," Abea says. "That's not how you'd search for ants: you'd just pick them up."

Abea, now a Wildlife Conservation Society research assistant in Congo's Nouabalé-Ndoki National Park, was intensely curious about what the gorillas were actually up to. After several years of study, he and his colleagues revealed the answer in the journal *Primates*, offering a rare glimpse into gorilla diet and culture: the great apes were foraging for truffles.

Other researchers had observed gorillas scratching at soil in a few places in Congo, Gabon and the Central African Republic, and they had also assumed it was an insect-foraging strategy. Abea and his colleagues cleared things up by following four groups of Ndoki gorillas for years, documenting their actions and collecting specimens of the small, round objects they saw the apes picking up and eating from the scratched earth.

Taxonomic and molecular analysis revealed that the subterranean morsels were *Elaphomyces labyrinthinus*, a truffle species that looks like a smaller version of the kind humans eat. Not all the area's gorilla groups engaged in regular soil scratching, but all seemed capable of it. One individual doubled the time she spent consuming truffles after she switched from a group that rarely foraged for the fungi to one that frequently did. Such observations suggest that truffle-foraging strategies are flexible and might be socially transmitted rather than linked to some environmental factor.

Culture is less well studied in gorillas than in other great apes. Primatologists have also traditionally written off gorilla feeding habits as less interesting than those of chimpanzees and orangutans, which have more varied diets and are avid tool users. The new paper adds evidence, however, that gorilla diets "are remarkably diverse and that there may be cultural preferences for certain foods in certain social groups," says Stacy Rosenbaum, a biological anthropologist at the University of Michigan, who was not involved in the new study.

Scientists don’t yet know why these difficult-to-find delicacies would be on a gorilla’s menu. Some research suggests truffles might have antimicrobial, antioxidant and anti-inflammatory properties, Rosenbaum says—so “an intriguing, if speculative, possibility is that they might have medicinal benefits.” Or it could be that some gorillas, like some humans, simply find them delicious.

Rachel Nuwer is a science journalist and author. Her latest book is *I Feel Love: MDMA and the Quest for Connection in a Fractured World* (Bloomsbury, 2023). Follow her on Bluesky @rachelnuwer.bsky.social

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https://www.scientificamerican.com/article/gorilla-gourmets-are-actually-truffle-hunting

Education

- **American Education Demands a Fact-Based Curriculum, Not Religious Ideology**
  One hundred years after the Scopes trial, religious ideologues are still trying to supplant evidence-based curricula with myths, to the detriment of a well-informed society
- **Keeping Kids Interested in Science Is a Matter of Language**
  As children get older, their understanding of science and being a scientist changes. The words adults use are a critical part of keeping them engaged in discovery

American Education Demands a Fact-Based Curriculum, Not Religious Ideology

One hundred years after the Scopes trial, religious ideologues are still trying to supplant evidence-based curricula with myths, to the detriment of a well-informed society

By The Editors

Martin Gee

In July of 1925 hundreds of reporters and other onlookers crowded into a sweltering courtroom in Dayton, Tenn., to watch what would become widely recognized as the trial of the century. Against a backdrop of societal anxieties over cultural upheaval, the Scopes “monkey trial,” as it was dubbed in the press, pitted the authority of the Bible against the evidence-based science behind evolution. At the center of the trial was John Scopes, a 24-year-old teacher accused of teaching human evolution at a public school, in violation of a religiously motivated state law against it.

Opinions on who won the case differ depending on whom you ask. Technically the defense lost—the jury found Scopes guilty of breaking the law, and the judge ordered him to pay a $100 fine (a ruling that was later overturned on a technicality). But defense attorney Clarence Darrow's arguments raised public awareness of the evidence supporting evolution and the threat that religious dogma posed to science education, academic freedom and individual liberty. Still, for decades after the trial, discussion of evolution in high school textbooks declined, and in many cases, it was omitted altogether.

One hundred years after that famous trial, education in the U.S. is still under attack from the same antiscience political forces, which are continuously using state and federal courts to assail the roles of critical thinking, inquisition and curiosity in schools in favor of religious instruction. Those who value public education must redouble their efforts to fight those forces.

> In theory, the teaching of religion in public schools should not be up for debate. Separation of church and state is a pillar of our democracy.

In theory, the teaching of religion in public schools should not be up for debate. Separation of church and state is a pillar of our democracy. The Establishment Clause of the First Amendment forbids the government from favoring a particular religion, and this clause has long been interpreted in courts as prohibiting the establishment of religion in publicly funded institutions, including schools. Yet just last year West Virginia passed a law that, according to its supporters, allows public school educators to discuss faith-based notions such as intelligent design (another name for creationism, the conservative Christian idea that God created all species in their current form and that humans did not evolve from other species) as scientific theories. Tennessee, Louisiana and Mississippi have enacted similar laws.

Some recent attempts to inject religious ideas about the origin of life into public school science curricula have failed. In February, North Dakota's Senate Bill 2355, which would have required the state superintendent of public instruction to include intelligent design in the state science-content standards, was defeated in the Senate. In April, a Minnesota bill that would have required the state's school districts to instruct students about "the Creator" met its end in committee.

But lest we become too optimistic about these outcomes, other efforts to erode the division between church and state have proved worryingly successful. In April, Arkansas governor Sarah Huckabee Sanders signed a bill into law that mandates the display of posters bearing the Ten Commandments and "In God We Trust" in the state's classrooms. A similar law was passed in Louisiana last year but was later blocked by a federal judge who called it "overtly religious" and "unconstitutional on its face." At press time, a Texas bill that would require public schools to display the Ten Commandments was making its way through the legislature, as was a bill to allow prayer and Bible-reading sessions in public schools.

It's not just posters and prayer time. The U.S. Supreme Court is hearing a case about whether tax dollars can be used to fund religious schools, and some justices are using the case to field the idea that separation of church and state should not be allowed. The Catholic Church is asking Oklahoma to recognize its St. Isidore of Seville Catholic Virtual School as a religious charter school. Charter schools are publicly funded. Writing about the case in the *New Yorker*, Ruth Marcus observed that at St. Isidore, "introductory high-school science would 'reveal God's orderly creation of the universe,' while physiology would adopt 'a faith-based approach to the value of human life from the beginnings of a cell.' The school would be open to all applicants, whether Catholic or not, but students would be required to attend Mass...." If St. Isidore is successful in its bid, the case will force taxpayers to subsidize a religious education for students that may not align with

their own beliefs, diverting funds from inclusive secular schools toward sectarian ones that discriminate against those who do not share their faith.

Another clause in the First Amendment, the so-called Free Exercise Clause, protects the right to practice one's religion (or lack thereof) without government interference. Many new attempts to infuse religion into public schools try to present themselves as efforts toward this end, arguing that excluding religious teachings from public funding amounts to discrimination. We cannot fall for that argument. Children go to school to attain knowledge. They need to learn facts and figures, yes, but perhaps more important, they need to learn how to evaluate evidence and arguments, not to uncritically accept the teachings of a particular faith.

Religious freedom—actual religious freedom—depends on preventing the incursion of any and all religious beliefs, whether they are masquerading as alternative scientific theories or blatantly evangelizing, into public schools. We must protect every child's right to a public education that is free of religious indoctrination and prepares them to navigate the many challenges of the real world as modern science understands it.

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https://www.scientificamerican.com/article/american-education-demands-a-fact-based-curriculum-not-religious-ideology

Keeping Kids Interested in Science Is a Matter of Language

As children get older, their understanding of science and being a scientist changes. The words adults use are a critical part of keeping them engaged in discovery

By Ryan F. Lei edited by Megha Satyanarayana

MashaStarus/Getty Images

One of the best parts of being a parent has to be watching children discover the world around them. After all, kids are endlessly curious, and part of the fun is seeing the wonder on their faces as they learn about even simple objects and ideas. “What’s that in your hand? Is it—a *ball*? Do you think it will roll down this hill?” you might ask your toddler. Then you get to enjoy their shouts of delight as they explore just that. This is science in action—making an observation, testing an idea, seeing what happens and then asking the next question.

Yet over time parents may find that their child is becoming less interested in exploring the world around them and less likely to

investigate the underlying “why” of things—that is, less curious about science. Why does this shift happen?

There are, of course, a number of different factors at play, but in the research my colleagues and I have done, we have found something that might surprise some folks: this loss of interest may be partly the result of subtle language cues children hear. And these cues don’t come just from parents; they can also come from media kids consume or from schoolteachers or curricula that treat science as an identity rather than a process.

All youngsters can do science, but over time they begin to think of *being* a scientist as something reserved for only certain kinds of kids. Based on what my colleagues and I have learned, however, there are some steps you can take to keep the curiosity alive and the science flowing.

When talking to children, many adults might say things like “Let’s be scientists today!” (to promote curiosity) or “You’re such a good scientist!” (to praise a child). But this kind of language, which focuses on science as an identity rather than a set of activities and actions that people do, can be demotivating. One study showed that girls (but not boys) as young as four persisted longer when their cue to participate in science activities was “Let’s do science” rather than “Let’s be scientists.”

One possibility is that when thinking of a scientist, children might be calling to mind a (white) man. If they don’t share that identity, they might disengage from an activity designed “for scientists.” Relatedly, children might believe that being a scientist requires special intellectual abilities—ones they think certain groups, such as (white) men, have but others don’t.

This stereotypical belief that science is reserved for only certain kinds of people emerges surprisingly early. By first grade, girls say they are less interested in computer science and engineering.

Perhaps more on the nose, when asked to draw a scientist, children tend to draw men, although this bias has improved over time.

This kind of stereotyping has a cumulative effect such that by high school, girls who are at the 80th percentile of science ability (an index of standardized test scores and grades in high school classes that are related to STEM, or science, technology, engineering and mathematics) have the same likelihood of majoring in certain STEM fields as boys in the lowest percentile.

The good news is that subtle linguistic cues can also be harnessed to promote engagement with science in surprisingly potent ways. Framing science as actions that we take, for example, seems to protect children's interest in and motivation to engage with science over time. Even outside of more controlled laboratory settings, students whose teachers use more action-focused language (such as "let's do science") have been found to persist longer in a novel science game than students whose teachers use more identity-focused language.

Perhaps now you are thinking, "Great, I will just focus on doing science and the actions that make up the scientific process!" And that is certainly likely to be effective with children even as they transition from childhood to adolescence and head into early adulthood.

But it's also true that during adolescence, your kids are actively trying on and ultimately forming different identities for themselves. So in contrast to its demotivating effects on young children, identity-focused language may help teens stay interested in science. In one study, cueing a future identity based on science (such as "scientist" or "doctor") motivated middle schoolers to do more homework and was associated with higher grades. That might be because if teens think of themselves as scientists, then they are willing to do what it takes to be the person they want to become.

Ultimately, parents want their children to enjoy learning, exploring and figuring things out for themselves. Those activities just happen to be critical pieces of the scientific process. Focusing on these actions when children are young might help them persist in hard tasks or lessons. But as older children gain experience in these areas and start forming ideas of whom they want to become, emphasizing future science-dependent identities might also be helpful in maintaining an interest in science.

How these two versions of subtle language cues might work together (or not) has yet to be tested; perhaps this research could be done by your future scientist.

Ryan F. Lei is an associate professor of psychology at Haverford College. He has a B.A. from the University of North Carolina at Chapel Hill and a Ph.D. in social psychology from Northwestern University. He completed postdoctoral training in developmental psychology at New York University. Follow him on Bluesky @ryanlei.bsky.social

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https://www.scientificamerican.com/article/keeping-kids-interested-in-science-is-a-matter-of-language

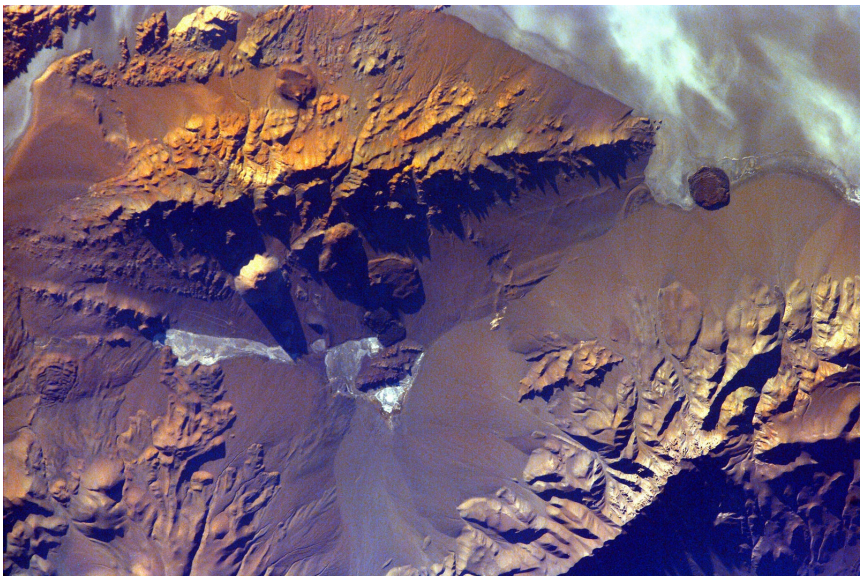
Geology

- **Tectonic Plates Can ‘Infect’ One Another with Earth-Shaking Subduction Zones**
  Evidence from Earth’s deep past suggests dramatic subduction zones can spread like a contagion
- **Animals Expend 76,000 Gigajoules of Energy Sculpting Our Planet Every Year**
  This tally of animals’ effect on Earth’s geology, equivalent to that of thousands of extreme floods, most likely is an underestimate

Tectonic Plates Can ‘Infect’ One Another with Earth-Shaking Subduction Zones

Evidence from Earth’s deep past suggests dramatic subduction zones can spread like a contagion

By Evan Howell edited by Sarah Lewin Frasier



The Andes Mountains formed from the convergence of the Nazca plate and the South American plate. Aracar, seen in a satellite image from February 20, 2000, is one of many volcanoes in the Andes range.
Universal History Archive/Universal Images Group via Getty Images

Subduction zones, where one tectonic plate dives underneath another, drive the world’s most devastating earthquakes and tsunamis. How do these danger zones come to be? A study in *Geology* presents evidence that subduction can spread like a contagion, jumping from one oceanic plate to another—a hypothesis previously difficult to prove.

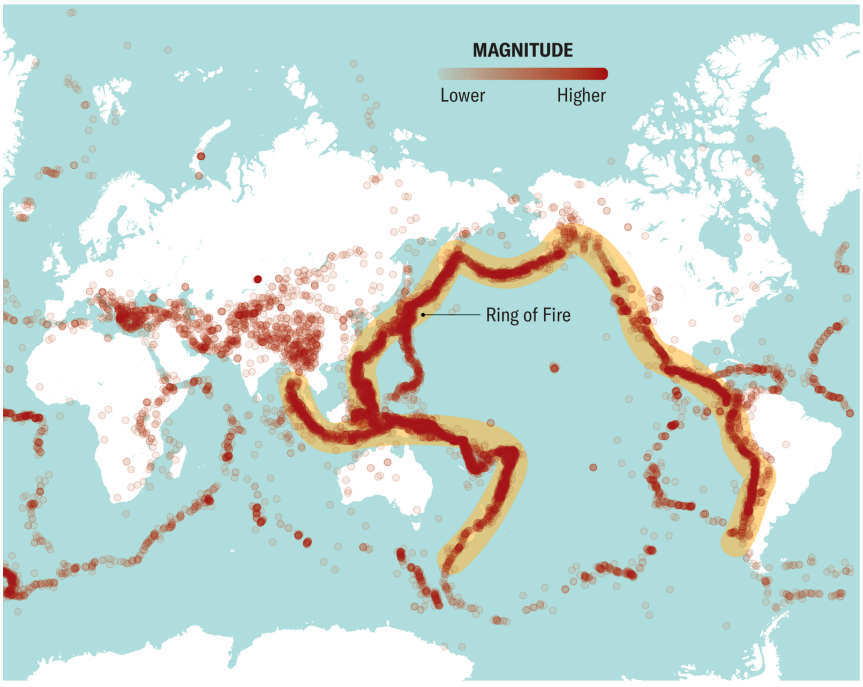
This result “is not just speculation,” says University of Lisbon geologist João Duarte, who was not involved in the research. “This study builds an argument based on the geological record.”

Because subduction drags crust deep into the earth, its beginnings are hard to examine. The new study provides a rare ancient example of potential subduction “infection.” Its authors say they’ve discovered evidence that neighboring collisions triggered East Asia’s “Ring of Fire,” a colossal subduction system currently fueling earthquakes and volcanoes from Alaska to the southern Indian Ocean.

Nearly 300 million years ago China was a scattering of islands separated by the ancient Tethys and Asian oceans. Established subduction zones consumed these oceans, welding the landmasses into a new continent and raising mountains from Turkey to China. By 260 million years ago this subduction seems to have spread and begun pulling down the neighboring Pacific plate.

Earthquakes from 1900 to Present

Each dot represents one earthquake event greater than 5.8 magnitude—many clustering around the Pacific's “Ring of Fire.”



Ripley Cleghorn; Source: USGS Earthquake Catalog (*data*)

“The dying act of those closing oceans may have been to infect the Pacific plate and start it subducting westward under the Asian continent,” says study lead author Mark Allen, a geologist at

Durham University in England. “In one form or another, it’s been diving down ever since.”

The smoking gun in this case is the “Dupal anomaly,” identified by a geochemical fingerprint from the ancient Tethys Ocean and what is now the Indian Ocean. When the study authors unexpectedly found this signature in volcanic rocks from the western Pacific, they surmised that material from the Tethys had spread eastward across a plate boundary from one subduction zone to another—triggering the neighboring plate’s descent. “It’s like seeing someone’s fingerprint at a crime scene,” Allen says.

But the mechanism of spread remains mysterious. The researchers suspect that transform faults—boundaries where plates slide past one another, like the San Andreas Fault—may act as weak spots where slight changes in collision angle or speed can destabilize dense oceanic crust, causing it to sink. Duarte compares the scenario to aluminum foil in water. “The foil floats,” he says, “but the slightest tap will cause it to sink.”

If subduction spreads this way, could the Atlantic Ocean’s relatively quiet plate margins be next? The massive 1755 Lisbon earthquake hints at early subduction invasion there. Duarte suggests parts of Iberia and the Caribbean are undergoing this process’s initial stages: “In another 100 million years a new Atlantic ‘Ring of Fire’ may form—just as it once did in the Pacific.”

Evan Howell is a Colorado-based freelance science journalist focused on Earth science. He can be found at evanhowellwriter.com

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https://www.scientificamerican.com/article/tectonic-plates-can-infect-one-another-with-earth-shaking-subduction-zones

See How Animals Sculpt the Planet

This tally of animals' effect on Earth's geology, equivalent to that of thousands of extreme floods, most likely is an underestimate

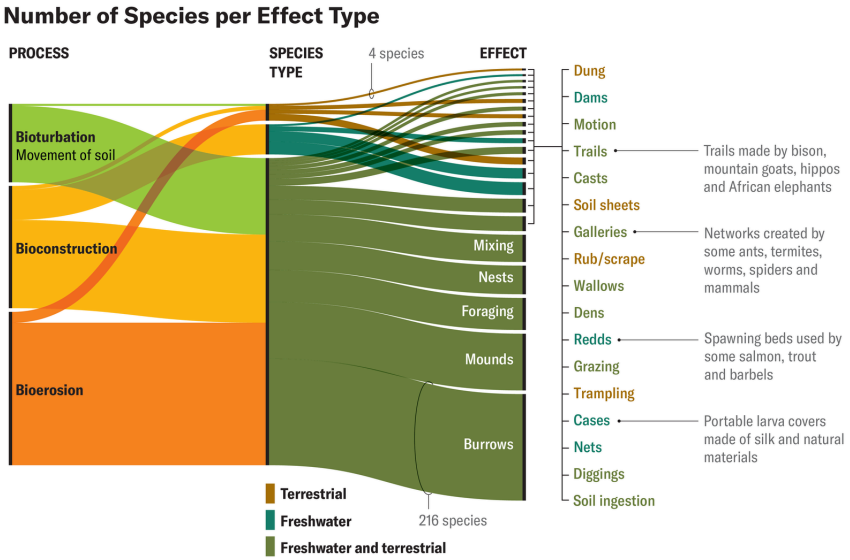
By Cody Cottier edited by Sarah Lewin Frasier

Kenyan termite mound.
Vicki Jauron/Babylon and Beyond Photography/Getty Images

Earth's surface is a work forever in progress. Boulders tumble down mountain slopes raised by colliding tectonic plates. Glaciers grind the boulders into dust. Wind, rain and rivers carry that dust to the sea, where it becomes sediment. These are among the traditional ways landscapes are known to change. But new research suggests there's a mighty force of nature missing from this picture: animals.

In a study published in the *Proceedings of the National Academy of Sciences USA*, researchers estimate that wild freshwater and terrestrial species, ranging from salmon to elephants, expend 76,000 gigajoules of energy to alter the land around them every year—the equivalent of thousands of extreme floods.

Beavers are, of course, famous for their engineering feats. But when it comes to other animals, no matter how extensive their nest building or den digging is, “the perception has been that they’re interesting curiosities but really not that important globally,” says the study’s lead author, Gemma L. Harvey, a physical geographer at Queen Mary University of London. “This paper challenges that.”



Ripley Cleghorn; Source: “Global Diversity and Energy of Animals Shaping the Earth’s surface,” by Gemma L. Harvey et al., in *Proceedings of the National Academy of Sciences USA*, Vol. 122; February 18, 2025 (*data*)

The study of landform evolution is called geomorphology, and when the changes are caused by animals, we tack on another prefix: zoogeomorphology. As early as 1881, Charles Darwin recognized earthworms’ role in soil formation. But it wasn’t until 1992 that physical geographer David Butler, now a professor emeritus at Texas State University, coined the term for the effect.

He debuted this scientific mouthful that year in a paper on “the grizzly bear as an erosional agent,” in which he calculated that the bears in Glacier National Park had, over the course of 100 years, moved about 15,000 dump-truck loads of dirt downslope while foraging for food and excavating their dens. “It made me suspect that if you did this worldwide for hundreds of species, you would come up with astonishing numbers,” he says.

The data needed for this kind of investigation weren't available then, but three decades later Harvey's team found enough to analyze 500 species. The researchers learned that trampling hippos create entirely new river channels, and burrowing crayfish widen the banks of existing ones. They found that hulking termite mounds cover an Iceland-size patch of Brazil. "Those are huge areas," Harvey says, "huge amounts of soil being transformed."

Brian Yanites, a geomorphologist at Indiana University Bloomington, who was not involved in this study, notes that such research is often hyperlocalized to "one type of animal, one specific location or particular landform." But he says the new work "is a really elegant way to approach the problem from a macro level."

If anything, the authors think 76,000 gigajoules is probably a wild underestimate; they excluded vast biodiversity hotspots in Africa, South America and Asia because there are few published studies on how living creatures reshape lands in those regions. Although many experts disregard animals as a source of profound landscape change, Butler says, "I think this study could be a 'Holy crap!' moment for them."

Cody Cottier is a freelance journalist based in Fort Collins, Colo.

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https://www.scientificamerican.com/article/animals-expend-76-000-gigajoules-of-energy-sculpting-our-planet-every-year

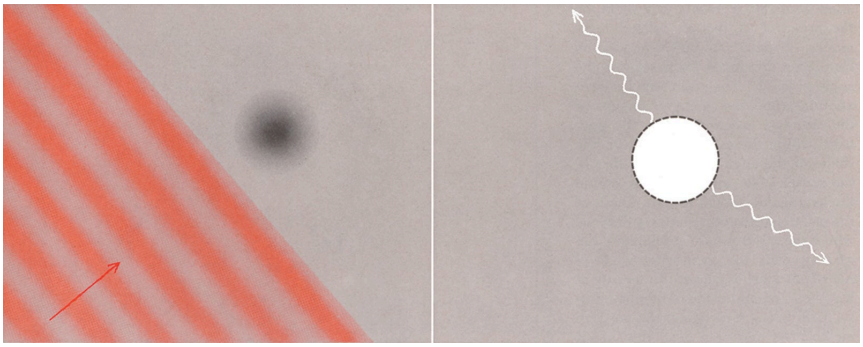
History

- **July/August 2025: Science History from 50, 100 and 150 Years Ago**
  Toxic cigars; dueling with a swordfish

July/August 2025: Science History from 50, 100 and 150 Years Ago

Toxic cigars; dueling with a swordfish

By Mark Fischetti



1975, Particle Annihilation: “A positron propagates as a wave toward an electron in the bulk of a crystal (*left*). When the two particles annihilate each other, the resulting gamma rays carry away the momentum of the electron at an angle different from 180 degrees (*right*).”
Scientific American, Vol. 233, No. 1; July 1975

1975

Kennedy Protects Science Funding

“When a scientist seeks public financing for research, the request is judged by the review panels for the National Institutes of Health, the National Science Foundation and other Federal granting agencies. The 94th Congress has given numerous signs that it might like to make such judgments itself. The House of Representatives, in passing a bill authorizing $755.4 million for the NSF for fiscal year 1976, adopted an amendment that would give Congress veto power over any grant. The Senate adopted an authorization bill that did not include an amendment. Senator Edward M. Kennedy, Democrat of Massachusetts, chairman of the subcommittee that prepared the bill, said the Committee on Labor and Public Welfare unanimously regarded the amendment as ‘not

only unworkable but contrary to the principles which have brought this nation to its leadership position in scientific research.’”

Accurate Missiles

“Secretary of Defense James R. Schlesinger announced the intention of the U.S. to develop a new generation of long-range ballistic missiles capable of delivering nuclear warheads against distant targets with unprecedented accuracy. An ‘active’ guidance system that could supplement a missile’s basic inertial guidance system by generating corrections in the trajectory of the warhead as it reenters the atmosphere is under development and should be capable of achieving near-perfect accuracy.”

1925

Nothing Magnetic in This Ship

“The *Carnegie*, a scientific research vessel constructed entirely of wood and other nonmagnetic materials, has been making a magnetic survey of the ocean. The timbers in her hull are fastened with bronze spikes and bolts, the rigging is hemp instead of steel, the cookstoves are built of brass and copper, the anchors are bronze, each weighing 1,900 pounds, and the anchor chains are not chains at all but are manila rope hawsers 11 inches in circumference. Because of this method of construction, no corrections on account of the presence of iron or other magnetic material need be applied to the results obtained with the various magnetic instruments onboard. The yacht is charged with the study of the Earth’s magnetism and with seeking out the cause of variations in its magnetic and electric fields.”

1875

Oil Wells Waste Gas

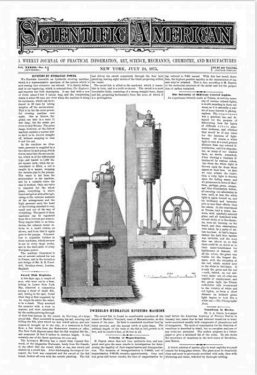
“There is little doubt that the gas escaping constantly from oil wells is of nearly or quite as much value as the oil itself. It is a wonder that means have not long since been adopted to utilize this immense product of the Earth. For years the gas has been allowed to pass away into the air uselessly. One well in the Butler oil region of Pennsylvania flows with a pressure of 300 pounds to the square inch and is estimated to yield a million cubic feet of gas every 24 hours.”

A Toxic Mouthful for Cigar Smokers

“The products of smoking tobacco in cigars are quite numerous and complex. Distinct products in the smoke include cyanhydric acid; sulphuretted hydrogen; the fatty acids formic, acetic, propionic, butyric and valerianic; carbolic acid; creosote; pyridine, picolin, collidin and other similar alkaloids. Also found are ammonia, nitrogen, oxygen and small quantities of marsh gas and carbonic oxide.”

Swordfish Duel

“A few days ago a couple of men in a boat fishing in Lower New York Bay found what they supposed, by its single fin above the water, to be a shark. They attacked the monster, and were astonished by the sudden piercing through of their boat bottom by the sword, 4.5 feet long, of a large swordfish. They succeeded in noosing its tail and killing the fish, after which it was brought to a restaurant a few doors from the *Scientific American* office. The New York *Express* states that the fish weighed 390 lbs., and measured 19 feet 8 inches. It was certainly one of the finest specimens we ever saw. The swordfish is allied to the mackerel, which it resembles in form, and is a swift swimmer. The sword consists of a strong straight bone, sharp and flat. The ordinary length of a fish body at full growth is 14 feet, and its sword 6 feet, or 20 feet in all.”



Mark Fischetti has been a senior editor at *Scientific American* for 17 years and has covered sustainability issues, including climate, weather, environment, energy, food, water, biodiversity, population, and more. He assigns and edits feature articles, commentaries and news by journalists and scientists and also writes in those formats. He edits History, the magazine's department looking at science advances throughout time. He was founding managing editor of two spinoff magazines: *Scientific American Mind* and *Scientific American Earth 3.0*. His 2001 freelance article for the magazine, "Drowning New Orleans," predicted the widespread disaster that a storm like Hurricane Katrina would impose on the city. His video *What Happens to Your Body after You Die?*, has more than 12 million views on YouTube. Fischetti has written freelance articles for the *New York Times, Sports Illustrated, Smithsonian, Technology Review, Fast Company,* and many others. He co-authored the book *Weaving the Web* with Tim Berners-Lee, inventor of the World Wide Web, which tells the real story of how the Web was created. He also co-authored *The New Killer Diseases* with microbiologist Elinor Levy. Fischetti is a former managing editor of *IEEE Spectrum Magazine* and of *Family Business Magazine*. He has a physics degree and has twice served as the Attaway Fellow in Civic Culture at Centenary College of Louisiana, which awarded him an honorary doctorate. In 2021 he received the American Geophysical Union's Robert C. Cowen Award for Sustained Achievement in Science Journalism, which celebrates a career of outstanding reporting on the Earth and space sciences. He has appeared on NBC's Meet the Press, CNN, the History Channel, NPR News and many news radio stations. Follow Fischetti on X (formerly Twitter) @markfischetti

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https://www.scientificamerican.com/article/july-august-2025-science-history-from-50-100-and-150-years-ago

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Language

- **Science Crossword: Throwing Shades**
  Play this crossword inspired by the July/August 2025 issue of Scientific American

Science Crossword: Throwing Shades

By Aimee Lucido

This crossword is inspired by the July/August 2025 issue of Scientific American. *Read it here.*

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.

https://www.scientificamerican.com/article/science-crossword-throwing-shades

Materials Science

- **How Velvet Worm Slime Hardens in Seconds to Trap Prey**
  The velvet worm’s extraordinary goo could inspire recyclable bioplastics

Velvet Worm Slime Reveals Its Sticky Secrets

The velvet worm's extraordinary goo could inspire recyclable bioplastics

By Elizabeth Anne Brown edited by Sarah Lewin Frasier

Velvet worms like this one "sneeze" out a sticky goo with intriguing properties.
Nicky Bay

The velvet worm, a squishy little predator that looks like the stretch-limo version of a caterpillar, has a whimsical MO: it administers death by Silly String.

In the leaf litter of tropical and temperate forests around the world, velvet worms stalk the night on dozens of stubby legs. The pocket-size predator—whose species range from less than half an inch to eight inches long—can barely see, so it bumbles around, hoping to literally bump into an edible bug such as a cricket or a woodlouse. When it finds one, the velvet worm uses nozzles on either side of its face to shoot jets of sticky slime at its victim.

"It happens so fast it's almost like they're sneezing," says Matthew Harrington, a biochemist at McGill University who has studied

velvet worms for a decade.

At first, the goo is a watery liquid, but in midair it transforms into jellylike ropes that ensnare the unlucky creature and stick it to the ground. As the prey struggles, the slime forms fibrous threads, and within seconds the substance hardens into a glasslike solid.

Scientists have been intrigued by velvet worm slime's adhesive properties for more than a century. (In the 1870s researchers puzzling over what makes it stick tried tasting it. The verdict: bitter.) Recent findings suggest the phase-shifting goo could inspire a new generation of recyclable bioplastics, according to research published by Harrington and his colleagues in the *Proceedings of the National Academy of Sciences USA*.

Previously, the researchers discovered that soaking the hardened fibers in water returned them to their liquid state—and by rubbing the resultant mess between their fingertips, they could get fibers as strong as nylon to re-form. That means "everything we need to know about making these fibers is encoded in the proteins themselves," Harrington says.

But isolating those proteins is easier said than done, the scientists found. The slime is so sensitive to touch that even standard laboratory techniques such as pipetting can trigger its phase shift. To avoid that sticky situation altogether, the scientists sequenced the RNA of proteins from the slime of velvet worms collected in Barbados, Singapore and Australia. Then they fed the RNA sequences into AlphaFold3, a program that uses artificial intelligence to predict protein shapes. For all three species, it "spit out this horseshoe shape" rich in the amino acid leucine, Harrington says.

Although this structure is novel to materials scientists, it's old hat to evolution. A similar protein called a toll-like receptor is part of an ancient immune system feature found across plants,

invertebrates and vertebrates. These receptors sit on the surface of immune cells, binding tightly to pieces of invading microbes and releasing them later. Harrington and his team suggest the horseshoe-shaped protein may use a similar “host-guest” dynamic to grab onto other proteins in the slime, binding strongly but reversibly to form the powerful fibers. Those are magic words to materials scientists working on developing replacements for plastic that can be broken down easily and re-formed into new shapes.

These horseshoe proteins are a significant find, says Yendry Corrales Ureña, a researcher at Costa Rica’s National Laboratory of Nanotechnology who studies velvet worm slime but wasn’t involved in the study. She adds, however, that these proteins don’t account for important properties of the slime such as its toughness or elasticity. “They are just one piece of the larger puzzle.”

Julian Monge Najera, an ecologist at the University of Costa Rica who researches invertebrate evolution, says the fact that three velvet worm species from different continents have the same protein shape in their slime underscores how incredibly ancient velvet worms are and how long ago their chemical R&D must have occurred.

The fossil record shows that velvet worms have existed almost exactly as they do now for at least 300 million years, predating both dinosaurs and today’s continents. “If I could go back in a time machine, the velvet worms I would catch in the post-Cambrian period would be identical to the ones in Costa Rica’s cloud forests today,” Monge Najera says—phase-shifting slime and all.

Harrington and his team are working to purify the horseshoe protein from the slime and confirm its structure via electron microscopy. “We won’t be milking velvet worms for slime to replace plastics,” Harrington says. “But we hope to copy their chemical tricks.”

Elizabeth Anne Brown is a freelance science journalist based in Copenhagen, Denmark. Her work has appeared in *National Geographic*, the *New York Times*, the *Washington Post*, and many other outlets. Read more at elizabeth-anne-brown.com, and follow her on X @eabrown18

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https://www.scientificamerican.com/article/how-velvet-worm-slime-hardens-in-seconds-to-trap-prey

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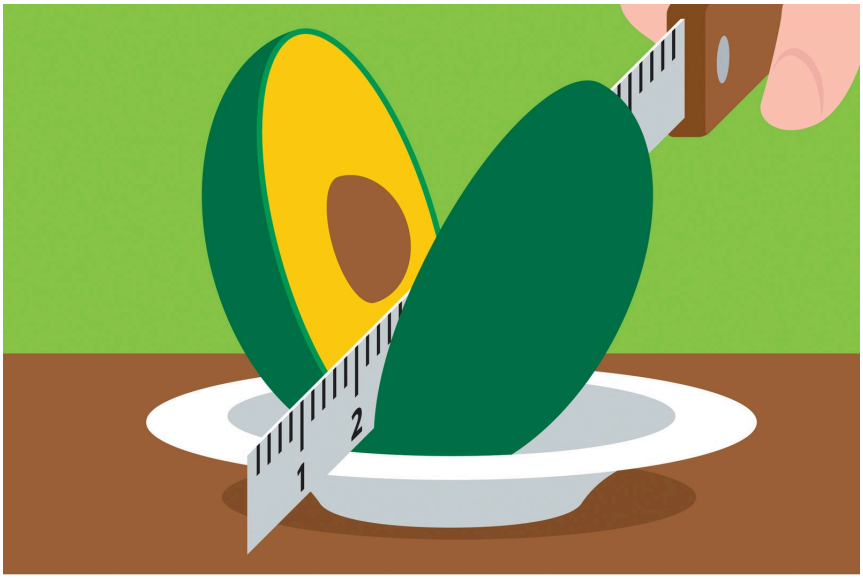
Mathematics

- **Mathematicians Solve Multidimensional Shape-Slicing Dilemma**
  A 40-year-old conjecture on shapes' cross sections is finally proven
- **Math Puzzle: Fill the Polygon**
  Puzzle out the sequence of numbers that fill these polygons
- **Venn Diagrams' History and Popularity Outside of Math Explained**
  A look at the curious history of Venn diagrams and the way they blend logic with geometry

Mathematicians Solve Multidimensional Fruit-Slicing Dilemma

A 40-year-old conjecture on shapes' cross sections is finally proven

By Max Springer edited by Sarah Lewin Frasier



Thomas Fuchs

In 1986 Belgian mathematician Jean Bourgain posed a seemingly simple question that continued to puzzle researchers for decades. No matter how you deform a convex shape—consider shaping a ball of clay into a watermelon, a football or a long noodle—will you always be able to slice a cross section bigger than a certain size? A paper by Bo'az Klartag of the Weizmann Institute of Science in Rehovot, Israel, and Joseph Lehec of the University of Poitiers in France, posted to the preprint site arXiv.org, has finally provided a definitive answer: yes.

Bourgain's slicing problem asks whether every convex shape in *n* dimensions has a "slice" such that the cross section is bigger than some fixed value. For three-dimensional objects, this is like asking whether an avocado of a given size, no matter the exact shape, can

always be split into two halves with each side revealing at least some sizable slice. Bourgain, a titan of mathematics, is said to have spent more time on this problem than any other; although it may seem deceptively easy to resolve in the physical world's two or three dimensions, it quickly balloons in difficulty when we consider four or five. This added complexity makes determining *anything* in *n*-dimensional space seem impossible. "If you believe in this so-called curse of dimensionality, you might just give up," Klartag says. Fortunately, he adds, he and Lehec "belong to a different school of thought."

The pair's breakthrough builds on recent progress by mathematician Qingyang Guan of the Chinese Academy of Sciences, who approached the problem with a technique based on physics rather than geometry. Specifically, Guan showed that modeling how heat diffuses out of a convex shape can reveal hidden geometric structures. Researchers could calculate filling any convex shape with warm gas and carefully observe the heat's dissipation according to physical laws. Guan's key insight—a precise limit on how rapidly the rate of dissipation changes during this heating process—proved to be just what Klartag and Lehec needed. "Guan's bound tied together all the other key facts" known for the problem, says mathematician Beatrice-Helen Vritsiou of the University of Alberta.

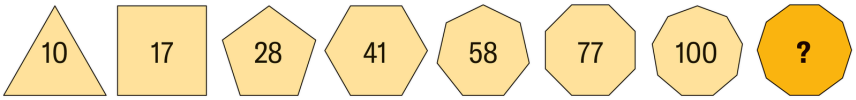
The result let Klartag and Lehec resolve the problem in only a few days. Klartag notes that "it was lucky because we knew [Guan's result] was exactly one of the things we needed" to connect several seemingly disparate approaches to the puzzle. With this final piece in place, the geometry of convex bodies in high dimensions is now a little less mysterious—although, as always in mathematics, each new slice reveals more questions to explore.

Max Springer is a Ph.D. candidate in applied mathematics at the University of Maryland and was a 2024 AAAS Mass Media Fellow at *Scientific American*.

https://www.scientificamerican.com/article/mathematicians-solve-multidimensional-shape-slicing-dilemma

Math Puzzle: Fill the Polygon

By Hans-Karl Eder

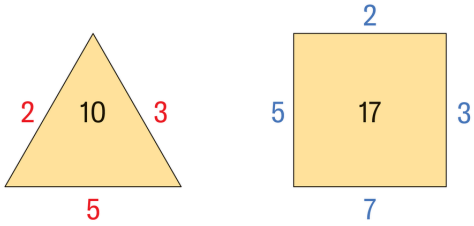


What number should replace the question mark?

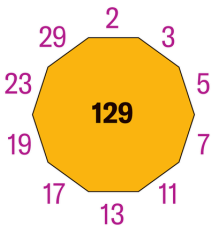
The number 129 replaces the question mark. The key is the sequence of prime numbers:

2, 3, 5, 7, 11, 13, 17, 19, 23, 29, …

The number in each polygon with *n* sides is the sum of the first *n* prime numbers' values.



The following applies to the decagon:



2 + 3 + 5 + 7 + 11 + 13 + 17 + 19 + 23 + 29 = **129**

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

This puzzle originally appeared in Spektrum der Wissenschaft *and was reproduced with permission.*

Hans-Karl Eder is a German mathematician, educator and author who also works as a MINT ambassador to get young people interested in mathematics, computer science, natural sciences and technology.

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https://www.scientificamerican.com/article/math-puzzle-fill-the-polygon

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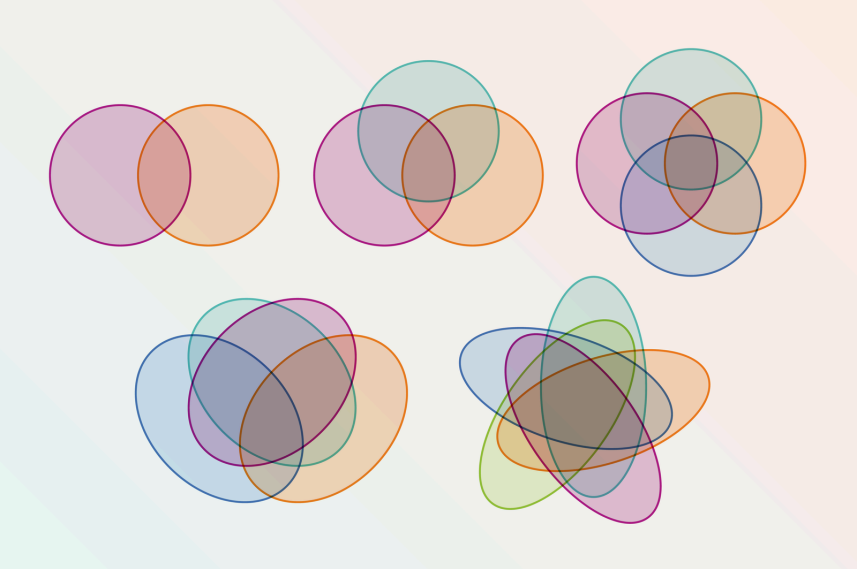
The Curious History of Venn Diagrams

A look at the curious history of Venn diagrams and the way they blend logic with geometry

By Jack Murtagh edited by Jeanna Bryner



Amanda Montañez

In his book *The Mathematical Universe*, mathematician William Dunham wrote of John Venn's namesake legacy, the Venn diagram, "No one in the long history of mathematics ever became better known for less." While Venn diagrams may not have solved any long-standing open problems, surely these interlocking rings deserve more credit. Their compact representation of group relationships explains their enduring appeal in classrooms, infographics and Internet memes.

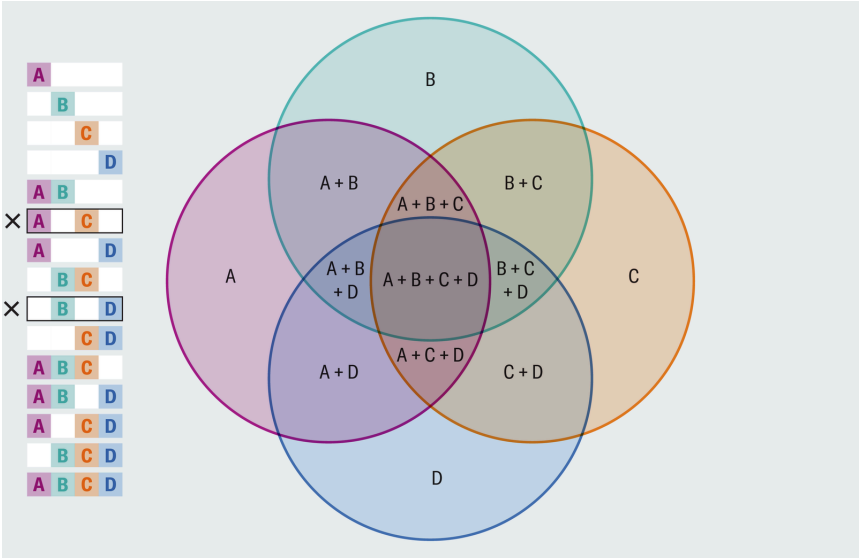
Not merely visual aids, Venn diagrams can help us solve everyday logic problems, and they give rise to surprising geometric questions. Have you ever seen a proper Venn diagram with four overlapping circles? No, because it's impossible. Venn himself discovered this and came up with a clever fix, but this only begot deeper geometric puzzles that mathematicians still study today.

Venn debuted his diagrams in 1880 as a method for visualizing contemporary advances in logic. They then found application in the closely related branch of math called set theory, which focuses on collections of objects. Venn diagrams typically consist of overlapping circles, with each representing some set of elements, (e.g., things that are cuddly or Broadway shows). The overlapping region between two circles contains elements that belong to both sets (e.g., “cats”). Much like in using scatter plots in statistics or drawing shapes in geometry, *seeing* one’s problem often clarifies it.

Imagine you’re planning a dinner party and navigating your friends’ fickle preferences. If Wilma attends, then so will Fred. If Barney attends, then so will somebody else. Barney won’t come if Wilma comes, but he will if she doesn’t. If Fred and Barney both attend, then so will Wilma. Who should you expect to show up? This poser is hard to work through when we are only given the text. A Venn diagram provides a systematic way to visualize and solve it. Each statement precludes some possible outcomes, which we indicate by shading the corresponding regions of the Venn diagram.

Amanda Montañez

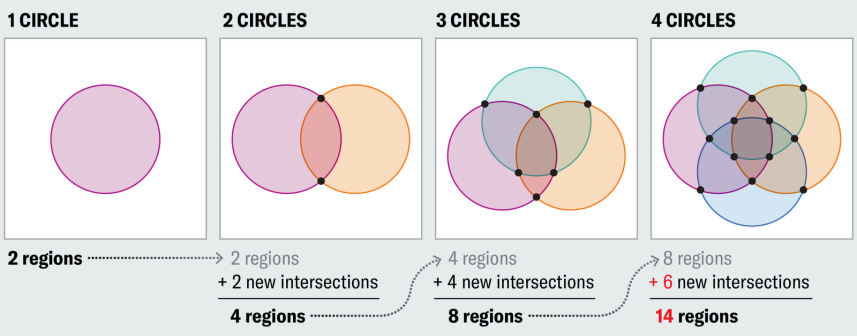
Most Venn diagrams you encounter depict either two or three overlapping circles, but what if you have four or more sets to consider?



Amanda Montañez

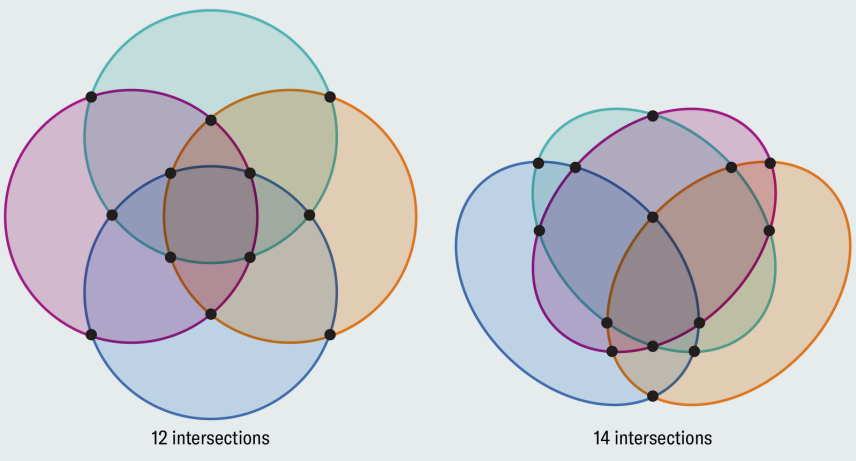
Did you spot the problem? There is no region where only A and C overlap that doesn’t also include another region, and likewise for B and D. A proper Venn diagram depicts every combination of intersections. Rejiggering the layout won’t help. Every four-circle drawing suffers the same flaw.

To see why, start with a single circle and note that it establishes two regions—interior and exterior. When we add a second set of elements (a new circle), we double the possibilities, so we need to double the number of regions (first set, second set, both sets and neither set). The only way to do this is to have the second circle intersect the first at two points (touching at only one point would result in only three regions: first set, second set or neither). This trend continues, where each new circle must double the number of regions if we want to represent all logical possibilities. But the number of new regions cannot exceed the number of new *intersections*, and a new circle can intersect the existing circles at only two points each. This works fine when adding a third circle because we need to add four regions, and the new circle can intersect the two existing circles at two points each for four total new intersection points. But it breaks down with a fourth circle, where we need eight new regions but can only muster six new points of intersection.



Amanda Montañez

Of course, we don't need to restrict ourselves to circles. We could easily trace a wiggly loop through a three-circle diagram so that it carves out the necessary number of regions, but we would lose the elegance in the diagram. Four intersecting *spheres* can also represent the right number of regions, but three-dimensional visuals are hard to parse. John Venn knew of the shortcoming with circles, so he proposed ellipses to represent four sets.



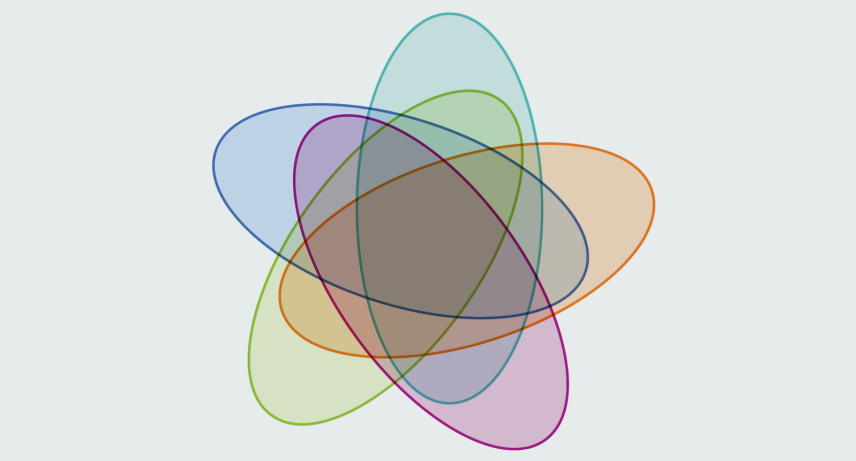
Amanda Montañez; Source: "Venn Diagrams and Independent Families of Sets," by Branko Grünbaum in *Mathematics Magazine,* Vol. 48, No. 1; January 1975 (*reference*)

Unlike circles, two ellipses can intersect at *four* points. This overcomes the limitations with circles but only temporarily. Ellipses work for four and five sets before failing in the same way that circles did. As the number of sets grows, we need more and more exotic shapes to portray them.

One could reasonably argue that beyond four sets of elements, Venn diagrams lose their utility. The four-ellipse image is already pretty chaotic. Maybe for five-plus sets we should abandon visual

representations. But utility does not animate the mathematician so much as beauty and curiosity. Although Venn diagrams initially applied to logic and set theory, the four-circle conundrum raised an interesting geometry question. That seed has blossomed into a fascinating investigation into the geometry of Venn diagrams that continues today.

Venn and his successors believed that ellipses couldn't portray all 32 regions required for a five-set diagram. Not until 1975 did mathematician Branko Grünbaum prove them wrong by example:



Amanda Montañez; Source: "Venn Diagrams and Independent Families of Sets," by Branko Grünbaum in *Mathematics Magazine,* Vol. 48, No. 1; January 1975 (*reference*)

Notice also that Grünbaum's diagram displays a pleasing rotational symmetry. Spinning it one fifth of a full rotation lands it back on itself, leaving the original shape unchanged. Typical two- and three-circle Venn diagrams share this property. Rotate a two-circle Venn diagram by 180 degrees (or a three-circle one by 120 degrees), and it looks the same. But the four-ellipse diagram doesn't have rotational symmetry. Can that be fixed? What do two, three and five have in common that four doesn't?

In 1960 a then undergraduate student at Swarthmore College, David W. Henderson, answered this question with a surprising discovery (Stan Wagon and Peter Webb filled in some gaps later): Rotationally symmetric Venn diagrams are possible only when the number of sets is a prime number—a number divisible only by 1

and itself, such as 2, 3 and 5 but not 4. Henderson only showed that a prime number of sets is necessary, not that you can always design a symmetric Venn diagram for every prime number. Thus began a contest to find larger and larger examples. Here's a wild-looking 11-set Venn diagram from Peter Hamburger.

Mathematicians at the University of South Carolina settled the question in 2004 by showing that rotationally symmetric Venn diagrams exist for every prime number of sets. If you think this caused mathematicians to pack up their pencils and lay the study of Venn diagrams to rest, then you haven't been following along. Instead the community has raised their aesthetic standards, seeking figures with even more refined properties.

Our opening quote contended that Venn diagrams are overrated. Even those who agree must admit that they have a curious allure. Take the sets of interesting topics in logic, in geometry and in visualization, and you'll find Venn diagrams at the intersection.

A version of this article entitled "The Curious History of Venn Diagrams" was adapted for inclusion in the July/August 2025 issue of Scientific American.

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 Jack on X @JackPMurtagh

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https://www.scientificamerican.com/article/venn-diagrams-history-and-popularity-outside-of-math-explained

Neuroscience

- **When Letting Your Mind Wander Helps You Learn**
  Zoning out reveals hidden patterns in tasks

What a Wandering Mind Learns

Zoning out reveals hidden patterns in tasks

By Nora Bradford edited by Sarah Lewin Frasier

Thomas Fuchs

While you do the dishes or drive to work, your mind is likely not on the task at hand; perhaps you're composing a grocery list or daydreaming about retiring in Italy. But research published in the *Journal of Neuroscience* suggests you might be taking in more than you think.

During a simple task that requires minimal attention, mind wandering may actually help people learn probabilistic patterns that let them perform the task better.

"The idea to study the potentially beneficial influence of mind wandering on information processing occurred to us during the COVID pandemic, when we had plenty of time to mind wander," says Péter Simor, lead author of the recent study and a psychology researcher at Eötvös Loránd University in Budapest. Study participants practiced a simple task in which they pressed keyboard

buttons corresponding to the direction of arrows that lit up on a screen. But there were patterns hidden within the task that the participants were unaware of—and they learned these patterns without consciously noticing them. The researchers found that when participants reported letting their minds wander, they adapted to the task's hidden patterns significantly faster.

"This is an exciting and important piece of work, especially because the authors opted for a nondemanding task to check how [mind wandering] would affect performance and learning," says Athena Demertzi, a cognitive and clinical neuroscientist at the University of Liège in Belgium. Previous related research focused more on long and demanding tasks, she says—on which zoning out is typically shown to have a negative effect.

But the results are not clear-cut, says Jonathan Smallwood, a psychology researcher at Queen's University in Kingston, Ontario. "I don't think that this means the spontaneous mind-wandering episodes themselves cause implicit learning to occur," he says. "Rather both emerge at the same time when people go into a particular state." Neither Smallwood nor Demertzi was involved in the new study.

Simor, who studies sleep, was interested in whether participants' mind wandering displayed any neural hallmarks of dozing off. Using electroencephalogram recordings, the team showed that in those test periods, participants' brains produced more of the slow waves that are dominant during sleep. Perhaps, the researchers say, mind wandering is like a form of light sleep that provides some of that state's learning benefits. To better understand whether mind wandering might compensate for lost sleep, Simor and his colleagues next plan to study narcolepsy and sleep deprivation.

"We know that people spend significant amounts of time not focused on what they are doing," Smallwood says. "The authors' work is important because it helps us understand how reasonably

complex forms of behavior can continue when people are focused on other things—and that even though our thoughts were elsewhere, the external behavior can still leave its mark on the person.”

Nora Bradford is the current news intern at *Scientific American*, a freelance science writer and a Ph.D. student in cognitive science. Follow Bradford on Bluesky @norabradford.bsky.social

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https://www.scientificamerican.com/article/when-letting-your-mind-wander-helps-you-learn

Psychology

- **To Win Trust and Admiration, Fix Your Microphone**
  From job interviews to dating, we subconsciously judge one another based on sound quality when we interact digitally
- **People Likely Aren’t as Susceptible to False Memories as Researchers Thought**
  New studies underscore the difficulty of implanting entirely fictional events in a person’s recollection

To Win Trust and Admiration, Fix Your Microphone

From job interviews to dating, we subconsciously judge one another based on sound quality when we interact digitally

By Rachel Nuwer edited by Sarah Lewin Frasier

Pavliha/Getty Images

Like hundreds of millions of other people around the world, Brian Scholl, a psychologist and cognitive scientist at Yale University, spent much of the COVID pandemic on Zoom. But during one digital faculty meeting, he found himself reacting unexpectedly to two of his colleagues. One was a close collaborator with whom Scholl usually saw eye to eye, and the other was someone whose opinions tended to differ from his own. On that particular day, though, he found himself siding with the latter colleague. “Everything he said was so rich and resonant,” Scholl recalls.

As he reflected afterward, Scholl realized there was a key underlying difference between the two men’s delivery: the colleague with whom Scholl usually agreed had been using the

junky built-in microphone of an old laptop, whereas the one with whom he typically disagreed had called in from a professional-grade home-recording studio. Scholl began to suspect that it was the quality of their sound, rather than the content of their arguments, that had swayed his judgment.

Research published earlier this year in the *Proceedings of the National Academy of Sciences USA* suggests Scholl's hunch was correct. In a series of experiments, he and his colleagues found that poor audio quality consistently caused listeners to negatively judge speakers in a variety of contexts—even if the message was exactly the same in all of them.

"When chatting on Zoom, everyone is familiar with how they look, but we don't typically take into account how we sound to other people," Scholl says. "It turns out this can really drive people's impressions of how intelligent you are, how credible you are, and how datable and hirable you are."

The human brain evolved to make intuitive judgments about people not solely on the basis of what they say but also according to how they sound. Ample research has shown that factors such as how confident a person sounds or whether they have an accent influence how others perceive them. Scholl wanted to see whether this tendency would hold when the only difference was technological distortion.

Scholl, working with Robert Walter-Terrill and Joan Danielle Ongchoco, both then at Yale, created audio recordings in which a human man or woman or a computerized male or female voice read one of three scripts. Each script dealt with a different topic: the reader posed as a job applicant, a potential romantic partner or someone describing a car accident. Some of the recordings were clear; others were manipulated to sound tinny. "We tried to use a manipulation that's relevant to daily life," Scholl says. "If you

spend time on Zoom, you probably know tons of people who sound like this."

yasinemir/Getty Images

The researchers recruited more than 5,100 people online. Each participant listened to one script and then answered simple questions about their judgment of the speaker by choosing a rating on a continuous scale. The team ensured that the participants actually understood what they had heard by asking some of them to transcribe the recording they had listened to after they answered the questions.

Across all three scripts and for both human and computerized voices, participants consistently rated the tinny voices as less hirable, datable, credible and intelligent. The findings speak to the "deep power of perception," Scholl says, and its ability to make us behave irrationally. "Everybody knows that this kind of auditory manipulation does not reflect on the person," he says. "But our perception is operating, in some ways, autonomously from higher-level thought."

Nadine Lavan, a psychologist at Queen Mary University of London, who was not involved in the research, says the findings are somewhat expected given what researchers already knew about

how we evaluate other people. “But a lack of surprise doesn’t mean the results are not important or interesting,” she says.

The study raises questions, Lavan continues, about how much of an effect microphone quality may have in more complicated real-world settings. Job applicants, for example, “don’t tend to read out their applications; they tend to give more spontaneous answers,” she says. “Also, abstract ratings of credibility and of being hirable are informative, but real-life hiring decisions tend to include higher stakes and much more complex trading off of different factors.”

Assuming the findings do hold in the real world to some extent, Scholl says the takeaway lesson is clear: “You should really find out how you sound to other people online. And if you don’t sound good, take some remedial action,” he says. Scholl adds that this idea worked for his tinny-sounding colleague, who eventually upgraded to a better microphone.

Rachel Nuwer is a science journalist and author. Her latest book is *I Feel Love: MDMA and the Quest for Connection in a Fractured World* (Bloomsbury, 2023). Follow her on Bluesky @rachelnuwer.bsky.social

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https://www.scientificamerican.com/article/to-win-trust-and-admiration-fix-your-microphone

People Likely Aren’t as Susceptible to False Memories as Researchers Thought

New studies underscore the difficulty of implanting entirely fictional events in a person’s recollection

By Bernice Andrews & Chris R. Brewin edited by Daisy Yuhas & Madhusree Mukerjee

Francescoch/Getty Images

How much can we trust our memories? We know that our mind keeps an imperfect record of the past. We can forget or misremember details, with frustrating consequences. Our attention can be diverted in ways that make it all too easy to miss key events.

But a particularly disturbing idea is that we readily form false memories—that is, that we can become convinced we experienced something that never actually occurred. The suggestion that it is easy to create false memories of entire events is often used to cast doubt on the reliability of a plaintiff’s testimony in a court case. For example, lawyers representing movie executive Harvey Weinstein cited this idea to raise questions about several women’s allegations against him.

Recently we had the opportunity to take a closer look at this concept by analyzing data from a study designed to replicate one of the most iconic experiments on false memories to date.

This experiment, by American psychologists Elizabeth Loftus and Jacqueline Pickrell, was published in 1995. Loftus had demonstrated decades earlier that one can manipulate people's memories of visual details by posing questions that contain misinformation. She then wanted to learn whether it was possible to implant an entire false memory for a childhood event that had never happened. To that end, in the 1995 study, she and Pickrell misled participants into believing that, according to their parents or older sibling, when they were about five years old they had been lost in a shopping mall and then found by an older woman.

Over the course of two sessions the researchers strongly encouraged 24 participants to remember and describe all that they could about this experience (which the parents or older sibling denied had actually happened). The experimenters evaluated the participants' responses and concluded that one quarter of them had been led to remember the suggested fake event either partially or fully. Loftus had previously claimed that some therapists could implant false memories of childhood sexual abuse in their clients. This "lost in the mall" experiment offered evidence that such a thing might indeed be possible. Over the years other scientists have established false memories of events in study participants, such as knocking over a punch bowl at a wedding, traveling in a hot air balloon or putting slime in a teacher's desk.

In a 2017 paper, we identified two big questions that have been hanging over these studies. The first is: How confident can we be in the experimenters' false-memory judgments? For example, would the participants agree that they not only believed in the false event on their relative's say-so but had an actual memory of it? And second, what exactly was it that the participants remembered? Could some of those recollections have been true memories? What

does a “partial” false memory consist of? Our analysis digs into these questions and suggests that the body of research on false-memory induction must be treated with caution; it is probably much more difficult to convince someone of a false memory than past work has suggested.

In 2023 Irish psychologist Gillian Murphy and her colleagues closely repeated the “lost in the mall” study, following the original methods. They used a larger sample of 123 people and reported that 35 percent of participants had a false memory, 10 percent more than in the original study. When asked, however, less than half as many participants (14 percent) said they had a memory of the fake event.

The data that were gathered by Murphy’s team and transcriptions of what participants had actually said were made freely available to other researchers, reflecting a move toward greater transparency in psychological research. We were impressed by this open approach to science, which is the only way to establish whether the claims made for memory implantation stand up to the scrutiny of independent researchers. For the first time, it was possible to examine what was really going on.

Before reanalyzing the data, we broke the “lost in the mall” story down into its six core elements: the person was around age five, was lost for an extended period, had cried, was found by an older woman and was reunited with their family, and this event occurred in the specifically suggested shopping location.

> Our findings raise serious questions about claims made in court that it is easy to impart false memories.

To our surprise, none of the participants in the study remembered all six elements. Those rated as having a full false memory recalled fewer than three of the details on average, and those described as having a partial false memory recalled about one detail. Even more

strikingly, 20 percent of those with a “full” memory and 60 percent of those with a “partial” memory did not explicitly remember the defining detail of being lost.

We also found that half of those judged to have a false memory had actually been lost before or experienced an analogous situation but not in a way suggested by the experimenters. In all cases, these participants described real events that they clearly distinguished from the suggested fake event. One participant said, “My memory is completely different than the other [suggested] memory.” Another said, “I don’t really remember that one.... But me getting lost in the shop was a regular occurrence.” Others were so uncertain about the suggested details in the fake story that their testimony would have little value in court. One participant commented, “I don’t even know if I ever did get lost in the shop before, so I’m not sure if it’s completely constructed or whether it’s the right memory.”

Taking everything into account, we estimated that only five participants could reasonably be claimed to have a false memory, rather than the 43 that were originally claimed. The participants were clearly very engaged by the study and approached the task of weighing up what, if anything, they remembered about the suggested event in a sophisticated way. Their comments revealed, for example, that they compared the scenario with other episodes of being lost, thinking about who would have been present and considering whether the mall was as suggested. Labeling their musings as a false memory does not capture these important aspects of their experience.

Our findings raise serious questions about claims made in court that it is easy to implant entire false memories in others. The great majority of these so-called false memories were much more limited, and held with much less conviction, than reports about this type of experiment led us to expect. As long as these questions remain open, psychologists should be very cautious about how they

present findings on memory implantation to others. It is easy to overstate the relevance or generalizability of scientific evidence.

Nonpsychologists can take comfort in these findings. Although memory is limited and sometimes wrong, completely false memories are not easy to implant. Most of the time memory does a good enough job. And although it is valuable to apply critical distance and skepticism when considering the reliability of memory —particularly in legal contexts—we should not be too quick to throw out a person's testimony simply because it could be imperfect.

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.*

Bernice Andrews is an emeritus professor of psychology at Royal Holloway, University of London. She studies memory, adverse life experiences, post-traumatic stress disorder and research methodology.

Chris R. Brewin is an emeritus professor of clinical psychology at University College London. He studies post-traumatic stress disorder, trauma and memory.

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https://www.scientificamerican.com/article/people-likely-arent-as-susceptible-to-false-memories-as-researchers-thought

Public Health

- **Hotter Nights after Scorching Days Threaten Heart Health and Mental Well-Being**
  When nights stay hot, more people die, many from cardiovascular problems. But there are simple methods you can use to stay cooler and healthier

Hotter Nights, Brought on by Climate Change, Pose More Health Threats

When nights stay hot, more people die, many from cardiovascular problems. But there are simple methods you can use to stay cooler and healthier

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.*

If the summer of 2025 is anything like last year’s, get ready to sweat. July and August of 2024 were among the hottest months on record in the U.S. Phoenix, Ariz., saw daytime temperatures higher than 100 degrees Fahrenheit for more than 100 days. But now

temperatures are staying high at night, too, which increases health dangers. When it stays hot after the sun goes down, more people die than typically would. Emergency room visits and hospital admissions go up. Premature births increase. Sleep and mental health suffer. But there are simple and practical methods you can use to stay cooler and healthier, beyond cranking up your expensive air conditioner.

“Most heat exposure is chronic,” says Ashley Ward, director of the Heat Policy Innovation Hub at Duke University’s Nicholas Institute. She and others are increasingly focused on the cumulative effect of warmer nights following warmer days. Nighttime temperatures are rising twice as fast as daytime temperatures because increasing cloud cover at night, created by the greenhouse effect, traps heat and sends it back to the ground. In parts of the Southeast, for example, there are now more than 30 days a year when the temperature stays above 75 degrees F at night, Ward says. Urban heat islands, which are parts of cities with lots of concrete and few shade trees, trap warmth and add to the effect, but rural areas are also suffering.

“If it doesn’t cool down at night, then your core body temperature can’t really get back to what is normal for you,” says epidemiologist Kristie Ebi of the Center for Health and the Global Environment at the University of Washington. “You’re starting the next morning with a higher baseline.” That’s why death rates start to increase after about 24 hours during heat waves. “It’s not the instantaneous exposure; it’s the buildup over the course of a day, not getting relief at night. That starts affecting the cells and organs,” Ebi says.

Core body temperature is important because it’s the heat of your internal organs rather than your more obvious skin temperature. “Heat is called a silent killer because humans are not terribly good at determining if their core body temperature is rising,” Ebi says. “It has to stay within a narrow range to protect us and our organs.”

That range is roughly from 97 to 99 degrees F, but it varies throughout the day and from person to person.

> When your face turns red in the heat, it’s because your body is pushing blood to the surface to cool it. Likewise, when sweat evaporates from the skin, it takes body heat with it.

Bodies are designed to cool down through tricks such as flushing and sweating. When your face turns red in the heat, it’s because your body is pushing blood to the surface to cool it. Likewise, when sweat evaporates from the skin, it takes body heat with it. But the body can’t always keep up. The process of thermoregulation can strain the heart, which must work harder at pumping blood, and harm the kidneys, which can be injured by dehydration.

Sleep habits, critical for overall health, suffer in the heat, too. Recent global studies using survey data and billions of measurements from fitness bands found that people sleep less well as temperatures go up, says Nick Obradovich, chief scientist for environmental mental health at the Laureate Institute for Brain Research in Tulsa, Okla. Heat makes it harder to fall asleep and causes people to wake a little earlier than usual. “It increases the probability that people have what we define as short sleep, or less than seven hours a night,” Obradovich says. Furthermore, the more hotter nights pile up, the worse people sleep. Inadequate sleep damages the immune system and is linked to higher risk for cancer and Alzheimer’s disease. It is also tied to poorer mental health.

The emotional and behavioral problems associated with rising temperatures include an increased risk of suicide. Again, the longer those temperatures persist, the stronger the psychological consequences. In general, “you’re much more likely to have a mental health episode by the sixth day [of a heat wave] than you are on the first day,” Obradovich says.

To make matters worse, rising temperatures are colliding with poverty, age, and other social determinants of health, Ward says. Many people in the least energy-efficient housing are also least able to afford air-conditioning. Older adults are more likely to have underlying heart or artery diseases, diabetes or respiratory illnesses that make them more susceptible to heat. Prescription drugs, such as those used to treat Parkinson's disease and beta blockers used for hypertension, reduce the body's ability to thermoregulate.

Geography matters, too. High humidity, often found in the southeastern U.S., is especially dangerous because it makes it harder for sweat to evaporate. In the dry heat of the Southwest, sweat evaporates fast, dehydrating you before you realize it.

Fortunately, people can help their body make the most of its natural cooling strategies with some scientifically proven tactics. Immersing your hands and feet in cool water—not icy cold—triggers a response from special types of blood vessels that release internal heat to the surface, where it can dissipate fast. The method is used regularly by the military. And after a hot day of yard work, Ward says, it's much more effective to take a cool shower than to open a cold beer—the former will lower body temperature, whereas the latter is a diuretic. Staying hydrated (with water!) reduces strain on the kidneys. If access to air-conditioning in your home is limited, concentrate on lowering the bedroom temperature rather than other rooms. That will offer you a better chance to sleep, perchance to dream of cooler nights to come.

Lydia Denworth is an award-winning science journalist and contributing editor for *Scientific American*. She is author of ***Friendship*** (W. W. Norton, 2020).

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https://www.scientificamerican.com/article/hotter-nights-after-scorching-days-threaten-heart-health-and-mental-well

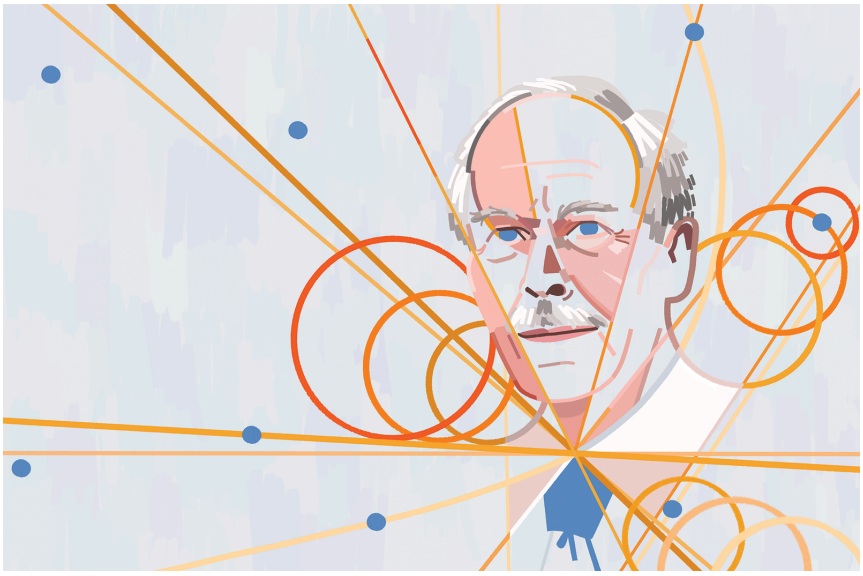
Quantum Physics

- **Breakthrough Prize Winner Gerard ’t Hooft Says Quantum Mechanics Is ‘Nonsense’**
  After netting the world’s highest-paying science award, preeminent theoretical physicist Gerard ’t Hooft reflects on his legacy and the future of physics

Quantum Physics Is on the Wrong Track, Says Breakthrough Prize Winner Gerard ’t Hooft

After netting the world’s highest-paying science award, preeminent theoretical physicist Gerard ’t Hooft reflects on his legacy and the future of physics

By Lee Billings edited by Clara Moskowitz



Shideh Ghandeharizadeh

In the pantheon of modern physics, few figures can match the quiet authority of Gerard ’t Hooft. The theoretical physicist, now a professor emeritus at Utrecht University in the Netherlands, has spent much of the past five decades reshaping our understanding of the fundamental forces that knit together reality. But ’t Hooft’s unassuming, soft-spoken manner belies his towering scientific stature, which is better revealed by the mathematical rigor and deep physical insights that define his work—and by the prodigious numbers of prestigious prizes he has accrued, which include a Nobel Prize, a Wolf Prize, a Franklin Medal, and many more.

His latest accolade, announced last April, is the most lucrative in all of science: a Special Breakthrough Prize in Fundamental Physics,

worth $3 million, in recognition of ’t Hooft’s myriad contributions to physics across his long career.

His most celebrated discovery—the one that earned him, along with his former Ph.D. thesis adviser, the late Martinus Veltman, the 1999 Nobel Prize in Physics—showed how to make sense of non-Abelian gauge theories, which are complex mathematical frameworks that describe how elementary particles interact. Together, ’t Hooft and Veltman demonstrated that these theories could be renormalized, meaning intractable infinite quantities that cropped up in calculations could be tamed in a consistent and precise way. This feat would change the course of science history, laying the groundwork for the Standard Model, the reigning paradigm of particle physics.

But beyond this achievement, ’t Hooft has made many other breakthroughs, which are too numerous—and, in most cases, too technical—to thoroughly describe here. Among the most notable is his proposal of the holographic principle in the 1990s. According to this notion, all the information within a three-dimensional volume of space can be encoded on a surrounding two-dimensional surface, akin to a hologram. The idea has since become central to many efforts to unify quantum mechanics and Einstein’s general theory of relativity in an all-encompassing theory of quantum gravity.

In a conversation with *Scientific American*, ’t Hooft spoke about his Breakthrough Prize, his optimism for the future of particle physics, his dissatisfaction with quantum mechanics, and the scientific and cultural effects that have arisen from some of his most provocative ideas.

An edited transcript of the interview follows.

Gerard ’t Hooft.
Courtesy of Puja Sonneveld

It seems you’ve won practically all the big physics prizes at this point.

Some are still missing! But, yeah, I’ve won quite a few prizes. What worries me a little bit is that most of them were for the same thing. You get prize after prize for something that has already been recognized, whereas other things I’ve done in science are not as well known—not by the general public, at least. But anyway, the Breakthrough Foundation has made a summary of my work for which they gave this prize, and that contains practically all I have done!

Yes, the foundation included it all! But given how many prizes you have won, does this one feel like just another notch in your belt? Has this all become routine for you, or is it still exciting?

I can assure you: nothing is routine. All these things are different. The climax really was the Nobel Prize itself, which is granted to only a very few people every year. And that’s something very special. But this one is also very special. It’s a big prize, literally speaking.

Your work in the 1970s with Martinus Veltman is celebrated in part because of its importance for the Standard Model of particle physics, the most well-tested and successful scientific theory ever devised. But in some respects the Standard Model has become notorious, too, as its myriad validations have seemingly left physicists with no obvious path forward to further breakthroughs. Does this aspect of the Standard Model's decades-long dominance worry you?

No, not at all. I think it is natural for science that we cannot always have an infinitely continuous stream of discoveries and new insights. There will be periods, like the one we are in now in particle physics, where things seem to be quieter. I just saw the news from CERN, for instance, that at the Large Hadron Collider, they've detected in new channels the absence of CP [charge parity] symmetry. This is a very important finding but not an earth-shattering one. It seems we're in a period where scientists in my field make many smaller discoveries that, in themselves, are very pleasing because they make our understanding more complete. But I think history shows it won't always be like this. There will be more fundamental findings that will again change our views on what is going on.

In the past few centuries there were long periods in which very little seemed to be happening. James Clerk Maxwell joined electricity and magnetism in the late 1800s, and around 1900 Max Planck made the first observations about energy being quantized. In reality, of course, many things did happen in other fields such as statistical physics and other fundamental branches of science. And both then and now, there's been steady progress in those domains. Look at astronomy right now; the astronomers have their great moments all the time, and you can't say there's a dull moment at all! They're discovering many new things in the universe as their telescopes become bigger and more accurate and as they use more and more fundamental scientific techniques to enhance their

resolution. You can say much the same thing about biophysics or medicine, where discoveries are made nearly every day.

But in my field, you're right, it seems to be that nothing is happening. I don't agree with that, though. Things are happening, just at a more modest scale.

Are you optimistic, then, that this situation will change, and we'll see a resurgence in big particle physics discoveries?

That's a very good question because it looks as if there's nothing we can do. If the situation proceeds in such a way that every new breakthrough requires a 10-fold, or even larger, increase in the size, power and cost of machines, then clearly we won't get much beyond where we are now. I cannot exclude such obstacles standing in the way of progress, but the history of science suggests that in such a case progress will simply go in different directions. One may think of not only precision improvements but also totally different avenues of discovery such as cosmology and black hole physics.

I would like to advise the new generation of scientists: don't worry about that, because the real reason there's nothing new coming is that everybody's thinking the same way!

I'm a bit puzzled and disappointed about this problem. Many people continue to think the same way—and the way people now try to introduce new theories doesn't seem to work as well. We have lots of new theories about quantum gravity, about statistical physics, about the universe and cosmology, but they're not really "new" in their basic structure. People don't seem to want to make the daring new steps that I think are really necessary. For instance, we see everybody sending their new ideas first to the preprint server arXiv.org and then to the journals to have them published. And in arXiv.org, you see thousands of papers coming in every year, and none of them really has this great, bright, new, fine kind

of insight that changes things. There are insights, of course, but not the ones that are needed to make a basic new breakthrough in our field.

> "We know superposition in the macroscopic world is nonsense. That's clear. And I believe that in the microscopic world it's clearly nonsense, too." —Gerard 't Hooft, *theoretical physicist*

I think we have to start thinking in a different way. And I have always had the attitude that I was thinking in a different way. Particularly in the 1970s, there was a very efficient way of making further progress: think differently than your friends, and then you find something new!

I think that is still true. Now, however, I'm getting old and am no longer getting brilliant new ideas every week. But in principle, there are ways—in, one could argue, quantum mechanics, cosmology, biology—that are not the conventional ways of looking at things. And to my mind, people think in ways that are not novel enough.

Could you give an example of the novelty or difference you're referring to?

Sure. My way of thinking about the world, about physics, about the other disciplines related to physics is that everything should be much more logical, much more direct, much more "down to Earth."

Many people who write papers on quantum mechanics like to keep some sense of mysticism about it, as if there's something strange, almost religious, about the subject. I think that's totally false. Quantum mechanics is based on a mathematical method used to describe very ordinary physical effects. I think the physical world itself is a very ordinary one that is completely classical. But in this completely classical world, there are still too many things that we

don’t know today; there are steps we’re basically missing on our path to deeper understanding.

What kinds of steps?

I’m talking about steps that would exploit the fact that the whole world is very simple and straightforward. The trouble is, the world still appears complicated to us now, which is why we’re in this situation.

You already mentioned the Standard Model, this marvelous discovery from the previous century. It’s an instructive example because, basically, it’s very simple, but if you look deeper, you see there’s something very important missing from it. The Standard Model is based on quantum mechanics, and quantum mechanics tells you what happens when particles approach one another and scatter. But they can scatter in many different ways; they have a large number of choices about it, and the Standard Model doesn’t give any sound prediction there. It gives you only statistics. The Standard Model is a fantastic theory that handles the statistics of what things are doing. But the theory never tells you with infinite precision which choice nature makes; it tells you only that these different possibilities are there at a certain probability amplitude. That is the world as we know it. That’s how we know how to phrase the laws of nature. But it’s not the laws of nature themselves.

What’s missing is our understanding of what it is that makes a particle go sometimes this way, sometimes that way. Well, you can easily argue particles can hit each other at a tiny distance. They don’t hit each other directly head-on but hit at some angle, and then they scatter away at some angle. That may be true. But what the theory today is not saying is what I should actually be looking at if two particles approach each other so I can predict how they’ll scatter ahead of time.

Imagine if you knew the way such interactions would go as precisely as you could know what will happen when two grand pianos hit each other. In principle, for the pianos, you could say exactly which wire will hit each other wire; you could predict exactly what happens when two grand pianos collide. Could it be the same with particles? In practice, such predictions for particles are considered to be too hard, and you turn to statistics, and you conclude that your piano particles can scatter in all directions, and that's all there is to be said. Well, for looking at pianos, maybe you can say something more. If you know exactly where and at which angle they will hit each other, you can predict ahead of time how they will scatter. And that should be in our theories of the elementary particles as well—and it isn't.

I'm saying we should start to think in these ways. People refuse because they think quantum mechanics is too beautiful to be wrong, whereas I believe quantum mechanics is not the right way of ultimately saying what basic laws objects obey when they hit each other.

While I was preparing for this interview, I found a conversation you had in 2013 with one of my predecessors here at *Scientific American*, George Musser. And one of the things you discussed was the work of physicist John Bell and its implications for the nature of reality. You said that you considered locality to be "an essential ingredient for any simple, ultimate law governing the universe." It sounds like that's still your view.

Very much, absolutely. I think, in fact, that you can understand and explain quantum mechanics very well if you assume the laws are only local laws. Let us say that what these particles do when they collide is determined by the exact spot they are in when they hit each other. That is, what happens at other spots in the universe, in principle, should not matter. And if it does matter, then you have

what we call nonlocality. But nonlocality would be a disaster for most solid scientific theories!

I don’t believe nonlocality is necessary. We don’t know exactly what to do when two particles collide because we don’t know whether particles look like grand pianos or like pure points. But then again, they can’t be pure points because pure points can’t do anything. There’s something in there, and we should be able to write down all the laws on what’s in there for these particles: How can they collide against each other? Why is it that they sometimes go this way and sometimes go that way? How can they exhibit spin?

We should be able to phrase such things as solid laws, and we are not even close to that. And this is why I think other breakthroughs should still be possible—many of them!—to help us get closer to this level of understanding that we simply don’t have for particles today, not even as something approximate.

In my talks with theoretical physicists, I’ve noticed that the greater and more accomplished the individual is, the more likely they are to say, “The real challenge is not in answering old questions but rather in finding new, better questions for whatever problem you’re addressing.” I think that’s because there’s this temptation for optimism about what can be known—this feeling that if we ask the “right” questions, meaningful answers must emerge. Do you really think the problem is that we’re not asking the right questions, or might it instead be that we’re asking the right ones, and their answers are, against our hopes, simply beyond our reach?

What you just said, that the questions are beyond our reach, is exactly what people said a decade and a century and a millennium ago. And of course, that was the wrong answer each time. We can answer these questions, but doing so requires lots and lots of science. Before Maxwell, nobody understood how exactly electric

and magnetic fields hang together, and they thought, “Oh, this is impossible to find out because it’s weird!” But then Maxwell said, no, you just need this one term, and then it all straightens out! And now we understand exactly what electric and magnetic interactions do. It’s simply not correct that you cannot answer such questions. You can, but you have to start from the beginning, like I said about quantum mechanics.

If you believe right from the beginning that quantum mechanics is a theory that gives you only statistical answers and never anything better than that, then I think you’re on the wrong track. And people refuse to drop the idea that quantum mechanics is some strange kind of supernatural feature of the particles that we will never understand. No! We will understand, but we need to step backward first, and that’s always my message in science in general: before you understand something, just take a few steps back. Maybe you have to make a big march back, all the way back to the beginning.

Just imagine: What would your basic laws possibly be if you didn’t have quantum mechanics? Answering that, of course, requires saying what quantum mechanics is.

Okay. So what is quantum mechanics?

Quantum mechanics is the possibility that you can consider superpositions of states. That’s really all there is to it. And I’d argue that superpositions of states are not real. If you look very carefully, things never superimpose. Erwin Schrödinger asked the right questions here—you know, take my cat; it can be dead, it can be alive. Can it be in a superposition? That’s nonsense!

And he was quite right. People shouldn’t continue to insist that a dead cat and a live cat superimpose. That’s complete nonsense—yet at that level, it seems to be the only correct answer to say exactly where the particle is, what its velocity is, what its spin is, and so on. There must, however, be different kinds of variables that

evolve in time, such as integer-valued variables or discretely moving variables, to name just two possibilities. These would be variables in terms of which you can't move a cat, you can't say whether it's dead or alive, unless you would make more nonlocal changes. There must be ways to describe all states for live cats and for dead cats, but these states will mix with states that don't describe cats at all.

Using superpositions, then, is just a trick that works at first but doesn't get at the states we want to understand. We have to make that step backward.

Walk me through this for a moment. If superpositions are illusory in that they are purely mathematical concepts that have no basis in physical reality, how does that square with the ongoing success of quantum information science and quantum computing, where it seems as if superposition is a real physical phenomenon that can be leveraged, for instance, to do things that can't be done classically?

I think quantum technology is just what you get if you assume the reality of superimposed systems. What do I mean by that? We know superposition in the macroscopic world is nonsense. That's clear. And I believe that in the microscopic world it's clearly nonsense, too, even though it may seem we have nothing besides superposition to use to understand atoms. What people in quantum technology probably don't realize is that they're doing the very converse of what they think they are doing. They think they're understanding quantum mechanics. I think what they should be doing instead is trying to remove the quantum mechanics from the description, trying to use more fundamental degrees of freedom, like those discrete states I mentioned.

They're not asking the right questions, and that failure makes things look more and more complicated—more and more quantum

mechanical—whereas in reality they shouldn't be interpreted that way.

Weren't we just discussing the tendency of eminent theorists to talk about not asking the right questions?

Let me say that, yes, they do the right experiments. Yes, they try to make the right things. And, yes, their quantum computers may be more powerful than anything else for certain applications because they understand "quantum mechanics." By that, I mean they understand how these microscopic systems actually act, in great detail, because this knowledge is something that actually came out of studying the quantum world. Yes, we know how small objects react and interact. But our problem is that at present we can only make statistical predictions. As soon as a quantum computer gives you statistical distributions instead of correct answers, well, that's the end of your "computer"; you can't use it for most applications anymore.

For most things, you want to use a computer in such a way that you avoid making superpositions—because you want to get a sharp answer. For instance, you want to decipher a secret code or something like that. You want to have the exact answer: "*This* is what it means, not *that*!" And let's not equate this answer to a superposition of those two possibilities—again, that's nonsense.

What I'm saying is we must unwind quantum mechanics, so to speak, to see what happens underneath. And until the quantum technologists start doing that, I believe they won't make really big progress. As an example, quantum computers always make errors, and their designers and operators try to correct them. To me, if you're trying to correct these errors, that means you want to go to more basic degrees of freedom that do not ever carry any error in them because they're exact—they're just classical. But to have this realization is apparently very difficult.

This is my feeling as to why we don't make breakthroughs. We should think about things in a different manner.

It seems you're saying we must live in a clockwork universe, one in which things must be purely deterministic at a very fundamental level, and thus there's very little room for any kind of quasi-mystical speculation. One consequence of that would seem to be the dissolution of mystery to some degree. And you mentioned the stubborn persistence of an almost religious approach to nondeterminism in quantum mechanics within the scientific community, not to mention in popular culture. Perhaps this attitude endures because, for so many people, it lets us preserve something ineffable about all that we experience in the world rather than assuming everything can be known if we fill in the right equations. So if you do believe in this kind of clockwork universe, I wonder what you'd say its most mysterious aspect is.

There are still many mysteries that make our problem very, very difficult. And this deterministic universe we discuss is something that could be fully understood only by someone with a much bigger mind, a much bigger brain, than I have because they'll have to consider all possibilities. And as soon as you make some wrong assumption, you again get this quantum-mechanical situation in which things get to superimpose one another.

A simpler question is: Can you formulate quantum mechanics without a superposition principle? And my answer is yes. In one of my last papers on arXiv.org, I wrote a little simple model—too simple to be useful in the real world. But the model is just a clock with a pendulum that moves in a very organized way, and that pendulum drives a wheel that shows the time, the hands that show the minutes and seconds. I call it my "grandfather's clock" model. From the pendulum, you can derive what time the hands should show. And these hands are deterministic. They are just showing a time with infinite precision, say. The pendulum is really a quantum

pendulum—it can be quantized; we can write quantum equations for it.

I found the connection to the mathematics of this pendulum and the mathematics of these hands that show the time. Keep in mind, the hands are completely classical, and the pendulum is completely quantum mechanical, but one is related to the other—it's one machine.

I got very few reactions to this model. I would have thought people would say, "Oh, yes, of course. Now we understand how to continue!" But instead they've said, "Okay, right, 't Hooft has another hot idea, another crazy idea. And he has many of those crazy ideas. Let him be happy with it; we're going to do our own thing." That's the most common reaction I've gotten.

I'd suspect the reasons for that reaction are, in some sense, not scientific and rather more "cultural," right? I'm thinking of this in terms of the signal-to-noise ratio that exists for anyone trying to drink from the firehose of new preprint papers on arXiv.org and elsewhere. It can be very tough to know what to pay attention to and how to evaluate whatever does get one's attention.

That leads me to one more question. I wonder how you feel about the cultural impacts of your scientific contributions, in particular the holographic principle, which you first proposed in the early 1990s.

Arguably because of this idea, there are people—mostly nonscientists, I'd imagine—who truly believe that the cosmos is in fact within a black hole or that it's all some simulation in a higher-dimensional computer. The idea for this "simulation hypothesis" is that perhaps nothing is "real" besides information itself, and everything else might be just a projection of patterns of 1s and 0s encoded on the outermost

boundary of the observable universe. So, you put forth a provocative theoretical insight more than 30 years ago, and it has somehow led to the world's richest man seriously suggesting on a popular podcast that "we are most likely" all just avatars in some cosmic-scale video game. I'm curious about your thoughts on this phenomenon.

I do have some reservations. Maybe I never should have talked about the holographic principle because, yes, some people are galloping away into nonsense, linking this idea with supernatural features and poorly defined dimensionality, all to sound very mysterious. I have a big problem with that. I think you shouldn't phrase the laws of nature in more complicated terms than strictly necessary. You should simplify as much as possible. Even Albert Einstein once said something like this—that you have to simplify things as much as possible but not beyond reality, not beyond the truth. We should try not to be supernatural; if we scientists leave only a wake of mysteries behind us, we're not doing the right thing.

I am a bit worried that the holographic principle has only invited people to be more mysterious; I want the extreme opposite. I want people to try to be super rational. For me, even quantum mechanics is already too far away from reason. And if you rephrase quantum mechanics to treat Hilbert space [a type of vector space that allows for infinite dimensions] as something used for practical purposes rather than its being a fundamental property of nature, you don't even need this type of holography anymore. I wish more people understood that. We have to try to phrase things more precisely to keep public misunderstandings from wreaking havoc on science.

Editor's Note (4/9/25): This article was edited after posting to better clarify some of Gerard 't Hooft's comments.

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https://www.scientificamerican.com/article/breakthrough-prize-winner-gerard-t-hooft-says-quantum-mechanics-is-nonsense

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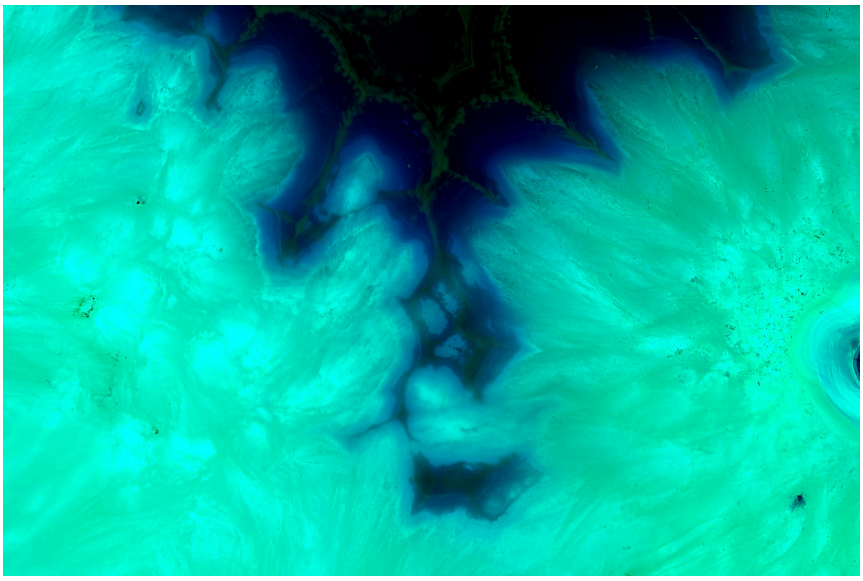
Vision

- **Researchers Discover New Color That’s Impossible to See without Lasering Your Retinas**
  Researchers discover a new color outside the range of human color vision, but you have to laser your retinas to see it

This Impossible New Color Is So Rare That Only Five People Have Seen It

Researchers discover a new color outside the range of human color vision, but you have to laser your retinas to see it

By Jacek Krywko edited by Allison Parshall & Sarah Lewin Frasier



Teal is as close as you can get to seeing the new color without having your eyes lasered.
Getty Images

The average human eye can see as many as 10 million variations in color, according to some estimates, from purest gray to laser green. Now scientists say they've broken out of that familiar range and into a new world of color. In a paper published in *Science Advances*, researchers detail how they used a precise laser setup to stimulate the retinas of five participants, making them the first humans to see an impossibly saturated bluish-green beyond our visual range.

Our retinas contain three types of light-detecting photoreceptors, or cone cells. S cones pick up relatively short wavelengths, which we see as blue. M cones react to medium wavelengths, which we see as green. And L cones are triggered by long wavelengths, which we

see as red. These red, green and blue signals travel to the brain, where they're combined into the full-color vision we experience.

But these three cone types handle overlapping ranges of light: the light that activates M cones will also activate either S cones or L cones. "There's no light in the world that can activate only the M cone cells because if they are being activated, for sure one or both other types get activated as well," says Ren Ng, a professor of electrical engineering and computer science at the University of California, Berkeley. Ng and his research team wanted to get around that fundamental limitation, so they developed a technicolor technique they call Oz.

"The name comes from *The Wizard of Oz*, where there's a journey to the Emerald City, where things look the most dazzling green you've ever seen," Ng explains. On their own expedition, the researchers used lasers to precisely deliver tiny doses of light to select cone cells in the human eye. First they mapped a part of the retina to identify each cone cell as an S, M or L cone. Then, using the laser, they delivered light only to M cone cells.

It wasn't exactly a comfortable setup. "This is not a consumer-oriented device, right? This was a basic visual science and neuroscience project," Ng says. In fact, the researchers experimented on themselves: three of the five participants were co-authors of the paper. The two others were colleagues from the University of Washington who were unaware of the study's purpose.

As one of the participants, Ng entered a darkened laboratory and sat at a table. "There were lasers, mirrors, deformable mirrors, modulators, light detectors," he says. Next he had to bite down hard on a bar to keep his head and eyes still. As the laser shone on his retina, he perceived a tiny square of light, roughly the size of a thumbnail viewed at arm's length. In that square, he glimpsed the Emerald City: a color the researchers have named olo.

The new color olo appears as a highly saturated version of this hue, represented by the hexadecimal code #00ffcc.

Ripley Cleghorn

What, exactly, does olo look like? Ng describes it as “blue-green with unprecedented saturation”—a perception his brain conjured up in response to a signal it had never before received from the eye. The closest thing to olo that can be displayed on a computer screen is a version of teal: the color represented by the hexadecimal code #00ffcc, Ng says. (This hexadecimal code is also sometimes referred to as sea green, aquamarine and bright turquoise.) If you want to try envisioning olo, take that color as the starting point and imagine that you are adjusting it on a computer. You keep the hue itself steady but gradually increase the saturation. At some point, you reach the limit of what your screen can show you, but you keep increasing the saturation past what you can find in the natural world until you reach the limit of saturation perceptible by humans, resulting in what you’d see from a laser pointer that emitted almost exclusively teal light. Olo lies beyond even that range.

To find out whether what the participants saw as olo really was a color beyond humans’ standard visual capabilities, the researchers conducted color-matching experiments in which participants could compare olo with a teal laser and adjust the color’s saturation by adding or subtracting white light. All participants found that if they added white light to olo, desaturating it, the new color matched the laser, confirming that olo lies beyond the normal human range of color vision.

“It’s a fascinating study, a truly groundbreaking advance in the ability to understand the photoreceptor mechanisms underlying color vision. The technical demands necessary to achieve this are enormous,” says Manuel Spitschan, who studies light’s effects on human behavior at the Max Planck Institute for Biological Cybernetics in Tübingen, Germany, and the Technical University of

Munich and was not involved in the new study. “An open question is how this advance can be used.”

Ng’s team dreams of one day building screens that can scan your retina to display perfect images and videos by delivering light to individual cones—enabling crisp, nonpixelated visuals in impossible colors. “That’s going to be extremely hard to do, but I don’t think it’s out of the realm of possibility,” Ng says. More immediately, he speculates, Oz could be used to let congenitally color-blind people experience colors such as green and red for the first time—although it wouldn’t be an actual treatment for the condition. “The Oz experience is transient,” Ng says. “It’s not permanent.”

“It’s a technical breakthrough, and I would love to have it in my lab,” says Maarten Kamermans, who studies vision and the retina at the Netherlands Institute for Neuroscience and was not involved in the new study. “Think of animal research. We could impose animal types of photoreceptors on human subjects to say, ‘Oh, this is really what a dog would see, what a mouse would see, what a goldfish would see,’” he says. “Now *this* would be interesting.”

Jacek Krywko is a freelance writer who covers space exploration, artificial intelligence, computer science and all sorts of engineering wizardry.

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https://www.scientificamerican.com/article/researchers-discover-new-color-thats-impossible-to-see-without-lasering-your