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# ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ FEBRUARY 10, 2024

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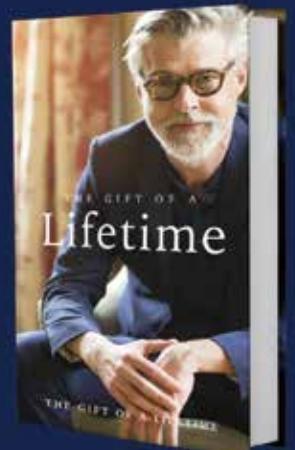
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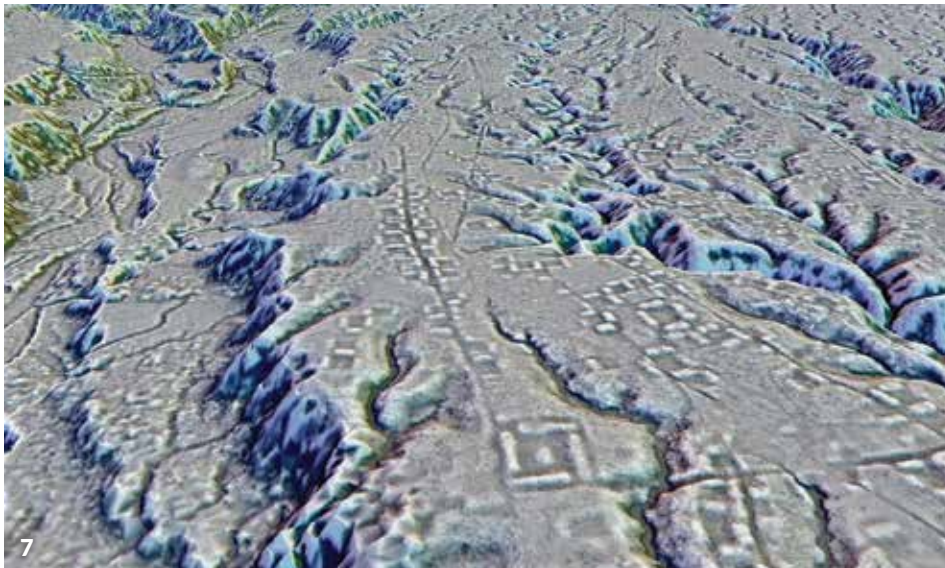


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FROM TOP: GLENN HARVEY; MARIA ZOTOVA/MOMENT/GETTY IMAGES; A. DORISON AND S. ROSTAIN





## Using public health research to save lives

More than 106,000 people died of drug overdoses in the United States in 2021. That's more than the number of people who died due to firearm-related injuries (48,830), falls (44,686) or motor vehicle crashes (42,939). These are all considered preventable causes of death, and as such, they are a public health problem. Reducing the toll requires research to identify risk factors and then the development of interventions that make the environment safer and discourage unsafe behavior.

Motor vehicle crashes make for a good case study. From 1972 to 2019, the death rate from crashes dropped by more than half in the United States, from 26.9 per 100,000 people to 11.9. It took multiple interventions to make that happen, including laws requiring seat belts and lower speed limits, graduated driver's licenses for teens, safer roads, new technologies like airbags and advocacy from groups like Mothers Against Drunk Driving.

Some simple interventions are remarkably effective. Just using a seat belt, for example, reduces the risk of death for people in the front seat of a car by 45 percent compared with those without seat belts. New technologies like forward collision avoidance may do more. Research by the AAA Foundation for Traffic Safety estimates that these technologies could potentially prevent more than 2.7 million crashes a year if they were on all cars and properly used by drivers.

In this issue, we explore one effort to prevent deaths from drug overdoses. In the 1990s, use of prescription opioids like Oxycontin fueled a rise in overdoses, according to the U.S. Centers for Disease Control and Prevention. Over the last decade, powerful synthetic opioids such as fentanyl have greatly increased the risk of overdose and death — so much so that annual deaths from opioid overdoses have more than doubled since 2015. Addiction is a disease; the goal here is keeping people alive so they can get treatment and rebuild their lives.

Access to naloxone, a medication that reverses an opioid overdose, is one tool. Another is overdose prevention centers, where people can use drugs in a supervised setting. As freelance science journalist Tara Haele reports, the United States lags behind some other countries in opening overdose prevention centers, despite data showing their effectiveness in saving lives (Page 16). Only two officially sanctioned overdose prevention centers currently exist in the United States, both in New York City. To see how well these centers might work across the country, researchers are gearing up to study the impacts of the New York sites, as well as one that is scheduled to open in Rhode Island later this year.

Current barriers to opening more overdose prevention centers include addressing legal obstacles and local concerns, Haele notes. But as the opioid crisis grinds on, some government officials and communities appear increasingly open to whatever tools that can save lives.

The work of confronting public health threats never ends. New risks emerge, whether it's the advent of synthetic opioids or the use of mobile phones while driving. Research helps gauge the effectiveness of new public safety approaches, as well as how best to implement interventions that save lives.

— Nancy Shute, Editor in Chief

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Excerpt from the February 16, 1974 issue of *Science News*

50 YEARS AGO

## Fossils show man walked

Anthropologist D. Carl Johanson... has discovered a skull fragment, shin and thigh bones of a 3-million-year-old man in Ethiopia.... The bones belonged to an ape man (hominid) of the genus *Australopithecus*.... “We have absolute, concrete evidence that our ancestors walked on two legs over 3 million years ago,” the 30-year-old scientist told a news conference.

**UPDATE:** Exactly when upright walking emerged in the evolutionary history of humans remains hotly debated. Fossil analyses suggest that several hominid species ambled around on two legs about 5 million to 7 million years ago. An upper leg bone of the oldest known, 7-million-year-old *Sahelanthropus tchadensis*, bears signs of upright walking including an inner projection near the hip joint, scientists reported in 2022 (*SN*: 9/24/22, p. 7). But not all paleoanthropologists are convinced those features prove a two-legged gait. And some scientists think the bone belonged to an ape that may have walked upright at times.

MYSTERY SOLVED

## How poison dart frogs hoard toxins in their skin

Toxins found in the skin of poison dart frogs may hitch a ride there via molecular taxicabs.

As a group, Dendrobatidae frogs host more than 500 poisonous compounds, all types of alkaloids, that the amphibians acquire from a steady diet of insects. But how these toxins, which help the frogs fend off predators, make it from the gut to the skin has been a mystery.

Now, scientists have pinpointed a protein that can give at least some toxins a ride. The protein, dubbed ABG, might pick up alkaloids from a frog’s blood or intestines and transport the toxins to the skin as a chemical defense, researchers report December 19 in *eLife*.

It’s the first time researchers have identified a protein that transports toxins around dart frogs’ bodies, says Roberto Márquez, an evolutionary geneticist at the University of Michigan in Ann Arbor who was not involved in the study.

Researchers have long thought that there must be a metabolic component to how “poison frogs exist just as a ball of toxins,” Márquez says. Proteins capable of binding to alkaloids were primary suspects, he says, because they would allow you to get toxins from your diet, “move them to your skin and not die trying.”

Stanford University biologist Aurora Alvarez-Buylla and colleagues managed to find one such alkaloid-binding protein by going fishing with molecular bait. In lab dishes, the team mixed a chemical lure similar to a well-studied poison frog alkaloid called pumiliotoxin with blood from Diablito poison dart frogs (*Oophaga sylvatica*). ABG emerged as the most common frog protein attached to the bait.

Genetic analyses of wild Diablito frogs collected in Ecuador suggest that ABG is made in the liver. Additional experiments that used fluorescent markers to locate ABG in tissues throughout the body suggest that the protein then makes its way from the liver to the intestines and skin.

ABG is a “biochemically promiscuous” protein, Alvarez-Buylla says. It also latched onto other poison dart frog toxins like epibatidine and decahydroquinoline. That’s surprising, she says, given that some proteins tend to be specific about the kinds of small molecules that they attach to. And there are still hundreds more toxins that the team didn’t test, so “there’s definitely more to explore there.”

With one case “very beautifully figured out,” Márquez is excited to understand how poison dart frogs handle all their myriad toxins. — *Erin Garcia de Jesús*



Diablito poison dart frogs seem to accumulate chemical defenses with help from a protein that transports toxins from food to the skin.



Some cats can play fetch. But the felines typically are the ones that decide when to start and stop, a survey of cat owners suggests.



FOR DAILY USE

## When do cats play fetch? When they feel like it

In news that probably won't surprise cat owners, cats that play fetch do it on their own terms.

Fetching felines tend to dictate when a fetching session begins and ends, a survey of over 900 cat owners suggests. The vast majority of the participants' cats seemed to pick up the behavior on their own, with no explicit training from their humans, researchers report December 14 in *Scientific Reports*.

"Ultimately, I think the cats are in control," says Jemma Forman, an animal behavior scientist at the University of Sussex in Brighton, England. The study

adds a new facet to scientists' understanding of cat behavior, which has been less studied than that of dogs.

Previous studies have found that cats can fetch, but there's not much research on why or how the animals do it, or whether the behavior requires training. The inspiration for the new study came in the form of a sleek Sphynx named Bear. "He surprised me one day by bringing a toy to me," says Elizabeth Renner, a psychologist at Northumbria University in Newcastle upon Tyne, England.

So she teamed up with Forman and University of Sussex psychologist David

Leavens to learn more about fetching cats by using social media to survey people who have (or had) them.

The scientists were interested in the animals' agency. Whose idea was it to play fetch in the first place? More often than not, the answer was the cat. Of 1,154 cats tallied, owners reported that over 94 percent hadn't been trained to fetch. The survey also revealed other tidbits, such as favorite things to fetch: toys, crumpled paper and hair ties.

Owners may have unwittingly trained their cats to fetch, says Dennis Turner, a cat behavior expert based in Zurich. Even just tossing a toy left at your feet rewards your cat with attention. That reinforces fetching behavior, he says. "Cats learn very quickly — if they want to."

Cats may also train their humans. One cat owner in the study figured out that her pet would fetch only pom-poms of a certain size, rejecting a larger one that the owner bought. In human-cat relationships, "there's a lot of learning going on back and forth," Turner says.

The results offer plenty for scientists to sink their claws into. For instance, the team is now recruiting cat owners for a study to find out whether fetching is a type of social interaction between humans and cats. — *Meghan Rosen*

THE EVERYDAY EXPLAINED

## The acoustics of pouring water

The sound of someone pouring a cool drink of water might make you feel thirsty. Or, if you're a scientist, you might feel curious. Mechanical engineer Mouad Boudina of Seoul National University in South Korea wanted to understand the conditions that affect the volume of that enticing sound. The key, Boudina and colleagues found, is how bumpy a stream becomes as it falls. Streams start smooth and form bumps before breaking up into droplets. When the stream hits the surface of water in a glass, those bumps form vibrating air bubbles that produce sound. In lab tests, water poured from a tube close to the surface of a water vessel was inaudible. The stream hadn't fallen far enough to form bumps. Streams poured from a greater height became bumpy and loud, the team reports in the December *Physical Review Fluids*. Thin streams were louder than thick ones: As they fall, thin streams become bumpy more quickly. Once streams broke up, droplet size determined volume. Droplets in thick streams were louder than droplets in thin ones. — *Emily Conover*



Water poured from a teapot into a glass will form a bumpy stream before breaking up into droplets (three examples shown). A stream's bumpiness, which depends on pouring height, and thickness affect the loudness of the stream hitting the water in the glass, a study shows.

# AI helped create a new type of battery

Predicting a solid electrolyte took days instead of decades



A researcher tests a new type of battery based on a material discovered with assistance from AI.

## BY EMILY CONOVER

In the hunt for new materials, scientists have traditionally relied on tinkering in the lab, guided by intuition, with a hefty serving of trial and error.

But now researchers have discovered a new battery material by combining two computing superpowers: artificial intelligence and supercomputing. The discovery highlights the growing potential for using computers to help scientists discover materials suited to specific needs, from batteries to carbon capture technologies to catalysts.

Calculations winnowed down more than 32 million candidate materials to 23 promising options, researchers from Microsoft and Pacific Northwest National Laboratory, or PNNL, report in a paper submitted January 8 to arXiv.org. The team synthesized and tested one of those materials to create a working battery prototype.

Scientists have used AI to predict materials' properties before, but previous studies typically haven't seen that process through to producing the new material. The new study "goes all the way from start to finish," says computational materials scientist Shyue Ping Ong of the University of California, San Diego.

The researchers targeted a coveted type

of battery material: a solid electrolyte. An electrolyte transfers ions — electrically charged atoms — back and forth between a battery's electrodes. In most lithium-ion batteries, the electrolyte is a liquid. But that comes with hazards, like batteries leaking or causing fires. Developing batteries with solid electrolytes is a major aim of materials scientists.

The candidates were computer-generated via a game of mix and match, substituting different elements in crystal structures of known materials. Sorting through 32 million contenders with traditional calculations would have taken decades, says Microsoft computational chemist Nathan Baker. But with machine learning techniques, which can make quick predictions based on patterns learned from known materials, the calculation produced results in just 80 hours.

First, the team used AI to filter materials based on stability, namely, whether they could exist in the real world. That pared down the list to less than 600,000 candidates. Further AI analysis selected those likely to have electrical and chemical properties necessary for batteries. Because AI models are approximate, the team filtered this smaller list using computationally intensive methods based on physics.

Filtering left the team with 23 candidates, five of which were already known. Researchers at PNNL picked a material that looked promising — it was related to other materials that the researchers knew how to make in the lab, and it had suitable stability and conductivity. Then they set to work synthesizing it, eventually fashioning it into a prototype battery. And it worked.

"That's when we got very excited," says materials scientist Vijay Murugesan of PNNL in Richland, Wash. Going from the synthesis stage to the functional battery took about six months. "That is superfast."

The new electrolyte is similar to a known material containing lithium, yttrium and chlorine, but swaps some lithium for sodium — an advantage as lithium is in high demand.

Combining lithium and sodium is unconventional. Typically, ions of one element or the other serve as a conductor. The two types of ions might be expected to compete with one another, resulting in worse performance. The unorthodox material highlights one hope for AI in research, says materials scientist Yan Zeng of Florida State University in Tallahassee. "AI can sort of step out of the box."

In the new work, researchers created AI models that could predict properties of a material based on training data from known materials. The AI architecture is known as a graph neural network, in which a system is represented as a graph, a mathematical structure composed of "edges" and "nodes." This type of model is well suited for describing materials, as the nodes can represent atoms, and the edges can represent bonds.

The study is one of many efforts to use AI to discover new materials. Scientists at Google DeepMind used graph neural networks to predict the existence of hundreds of thousands of stable materials, the team reported in the Dec. 7 *Nature*. And in the same issue, Zeng's team reported developing a robotic, AI-operated lab designed to produce new materials autonomously. ■



ARCHAEOLOGY

# Lasers reveal lost cities' complexities

Roads, crop fields and more dot ancient Ecuadorian sites

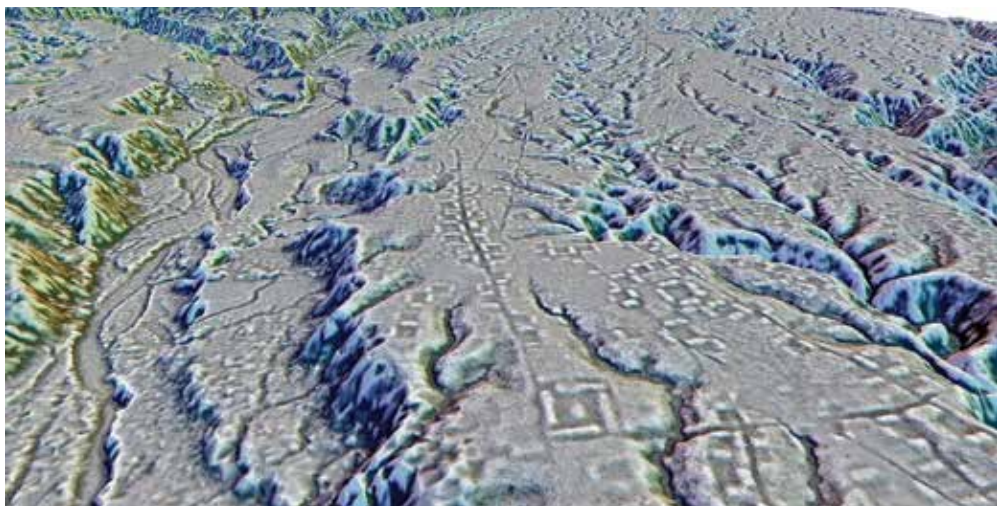
BY AMANDA HEIDT

Scientists have mapped the Amazon's earliest and largest example of farm-based citylike settlements high in the foothills of the Ecuadorian Andes.

The thousands of mounds, plazas, terraces, roads and agricultural fields—revealed in their fullest extent for the first time, by airborne laser scans—necessitate a rethinking of just how complex ancient Amazonian civilizations may have been, researchers report in the Jan. 12 *Science*.

Over the last decade or so, the use of light detection and ranging, or lidar, in archaeology has led to significant discoveries in tropical climates, where dense jungle often obscures ancient settlements (SN: 12/2/23, p. 24). Scans of Maya sites in Guatemala, Olmec ruins in Mexico and Casarabe sites in the Bolivian Amazon have revealed that all were metropolitan settlements with complex infrastructure.

“It’s a gold rush scenario, especially for the Americas and the Amazon,” says Christopher Fisher, an archaeologist at Colorado State University in Fort Collins



Laser scans at several ancient sites (one shown) in the Upano Valley in Ecuador revealed the remains of buildings arranged around plazas and distributed along wide streets.

who was not involved in the research. “Scientists are demonstrating conclusively that there were a lot more people in these areas, and that they significantly modified the landscape,” he says. “This is a paradigm shift in our thinking about how extensively people occupied these areas.”

For decades, archaeologists have visited the Upano Valley at the foot of a volcano in the eastern foothills of the Andes to excavate hundreds of human-made mounds left by pre-Hispanic peoples. But, until 2015, Upano had not yet been systematically imaged like similarly sized Mesoamerican settlements to the north.

Then, the Ecuadorian government

commissioned scans of a 600-square-kilometer swath of the valley. Based on his own expeditions in the valley over many years, archaeologist Stéphen Rostain of CNRS in Paris expected to see extensive infrastructure in the scans. But he was still surprised by the scale of what once existed when he and colleagues analyzed a 300-square-kilometer portion of the data.

Beneath the tree canopy is a massive network of roughly 6,000 platforms—once homes and community spaces—clustered into 15 settlements and connected by an intricate road system. The lidar data also revealed that open spaces between settlements were agricultural fields that had been drained to grow crops such as maize, beans and sweet potatoes. Within the settlements, there were tiered gardens that would have kept some food closer at hand.

Put together, the data show that the valley wasn’t simply a series of small villages linked by roads, but a vast human-engineered landscape built by skilled urban planners, Rostain says. Dating from several sites suggests the area was inhabited for a total of about 2,000 years, beginning around 500 B.C., by at least five cultural groups.

Lidar “helps us understand what the variety of urbanism was in the past,” says anthropological archaeologist Anna Cohen of Utah State University in Logan. “It shows that you need to look at these green spaces in addition to the buildings.” ■



Archaeologists had studied human-made mounds (some shown) in the Upano Valley for decades, but lidar scans offered an unprecedented view of the landscape.

FROM TOP: A. DORISON AND S. ROSTAIN; S. ROSTAIN

## HEALTH &amp; MEDICINE

# Teen brains and THC don't mix well

Potent cannabis products may up risks of addiction and psychosis

BY AIMEE CUNNINGHAM

Ask thousands of teens whether frequent use of certain substances brings a high risk of harm, and they mostly nail it: a majority say yes for cigarettes, alcohol, cocaine and heroin. But there's one substance that many skip over — cannabis.

Only 35 percent of 12- to 17-year-olds perceive a “great risk of harm” from smoking marijuana once or twice a week, according to the 2021 National Survey on Drug Use and Health.

It's a sentiment that some of their parents may share. Parents often don't understand that the products today “are not what they knew when they were in high school,” says Kelly Young-Wolff, a clinical psychologist and research scientist at Kaiser Permanente Northern California Division of Research in Oakland. If their children are using cannabis, parents may think, “it's not that bad, at least they're not using this other drug that's worse.”

The cannabis products available now are leaps and bounds more potent than in the past, which may increase risks for addiction and psychosis. Marijuana plants have been bred to contain more THC, the main psychoactive chemical. In 1995, the total percent of THC by weight of marijuana plant material was around 4 percent; now marijuana with a THC potency of 20 percent or more is available. Trousing that are concentrated cannabis products, including wax, budder and shatter, which can have a THC potency as high as 95 percent.

Cannabis is legal for adults to use recreationally in 24 states and Washington, D.C., and is allowed for medical use in 38 states and Washington. The availability of cannabis “promotes the idea that it's safe,” says pediatrician Beth Ebel of the University of Washington School of Medicine in Seattle. But that is an incorrect assumption. THC can impact the brain in ways the user didn't intend, Ebel says. “Some of the worst effects can have lifelong health consequences, especially for a young person.”

Concentrated cannabis products can be so extremely potent, and so different from what's been known as cannabis, that “we need to start calling them something else,” says neuroscientist Yasmin Hurd of the Icahn School of Medicine at Mount Sinai in New York City. “These are new drugs.”

## How THC shapes young brains

Adolescence is an especially risky time to use cannabis. “The adolescent brain is still developing into early adulthood,” Hurd says. During this period, connections within the brain are forming, getting reinforced or being pruned. “Your brain is trying to figure out, ‘what is important that I need to learn, and what is important that I need to retain,’” Ebel says, and this process is “negatively affected by THC.”

THC binds to a receptor, called CB1, of the endocannabinoid system. This complex system influences many functions in the body. In the brain, it helps regulate anxiety, pain, memory, motivation and more. It also contributes to structural changes that occur as teen brains mature. But THC can interfere with the system's signaling during this key time and leave an imprint on the brain's structure.

Studies in lab animals have found that exposure to THC in adolescence can reduce CB1 receptors and lead to problems with memory and learning. One of the areas THC alters is the prefrontal cortex, which matures during adolescence and is integral to problem-solving and emotional regulation. In rats given THC, nerve cell protrusions that connect with other nerve cells were prematurely pruned, disrupting the circuitry of the prefrontal cortex, Hurd and colleagues reported in *Molecular Psychiatry* in 2019.

There's also evidence in people that THC changes teens' brains. Scientists analyzed nearly 1,600 magnetic resonance images of the brains of nearly 800 adolescents, taken at 14 and 19 years of age. Cannabis use over the five years was associated with accelerated thinning of the prefrontal cortex, researchers reported in *JAMA Psychiatry* in 2021. Cortical thinning is expected in adolescence and is probably tied to the pruning of underused connections. Accelerated thinning means that process isn't following the normal developmental plan. The team hypothesizes that accelerated thinning might be connected to the premature loss of nerve cell protrusions that was described in the rat study.

## Mental health harms

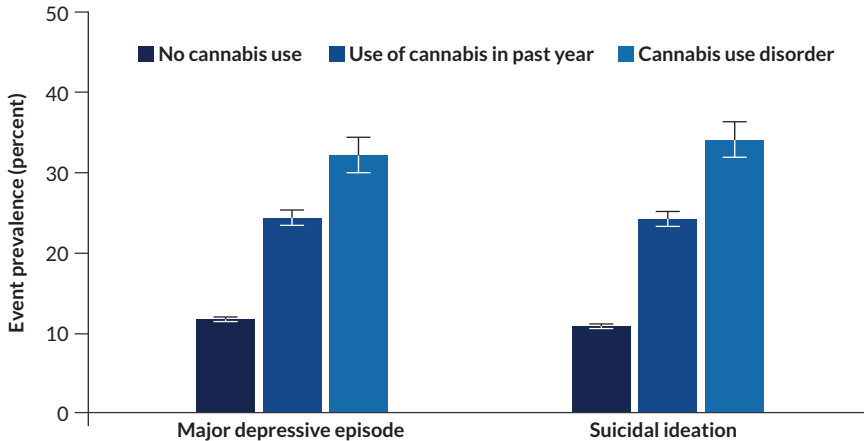
Using cannabis, even recreationally, may also puts teens' mental health at risk. In a

Concentrated cannabis products, produced by extracting cannabinoids from the marijuana plant, can have a THC potency as high as 95 percent.





Prevalence of mental health events in adolescents by cannabis use



**Cannabis and mental health** Adolescents who met the diagnosis for cannabis use disorder or who used the drug recreationally had a higher prevalence of depression and suicidal ideation than those who didn't use cannabis. SOURCE: R.S. SULTAN ET AL/JAMA NETWORK OPEN 2023

study of over 68,000 adolescents, kids ages 12 to 17 whose cannabis use did not meet the threshold for a substance use disorder were about twice as likely to develop depression or have suicidal ideation as those who didn't use cannabis, researchers reported in May in *JAMA Network Open*.

The risks increase for those with cannabis use disorder, in which someone's use interferes with daily life but they aren't able to stop using. Adolescents with cannabis use disorder were 2.5 times as likely to have depression and three times as likely to have suicidal ideation as those who didn't use cannabis, the study found.

Beginning cannabis use as a teen is more likely to lead to dependence than starting as an adult, just like alcohol, cocaine and nicotine. Compared with young adults, adolescents are more susceptible to dependence within a year of taking up marijuana. Eleven percent of those ages 12 to 17 progressed to cannabis use disorder by 12 months, but only 6 percent of those ages 18 to 25 did, researchers reported in 2021 in *JAMA Pediatrics*. After three years, the prevalence was 20 percent of adolescents versus 11 percent of young adults.

Yet many teens are turning to marijuana as a coping mechanism. A study of what motivated U.S. high school seniors to use cannabis found that reasons related to coping — such as to escape problems, relieve tension or deal with anger — about doubled in prevalence during the last

four decades, researchers reported in 2019 in the *Journal of Studies on Alcohol and Drugs*. For a project on how cannabis legalization for adults in California has impacted adolescent health, Young-Wolff has talked to clinicians who care for adolescents. They've told her that many of their patients who use cannabis are doing so to self-medicate, trying to relieve symptoms of depression or anxiety.

Ebel has seen this too. But as the drug wears off, users are more anxious than they were before, she says. "It drives a cycle that drives increased use."

When marijuana is a part of a teen's everyday life, it may change their future trajectory. A study of young people in Australia and New Zealand compared the frequency of cannabis use before age 17 with how participants had fared by age 30. Those who used cannabis daily were more likely to become dependent on it, use other drugs and attempt suicide, and less likely to finish high school, compared with teens who had never used, scientists reported in 2014 in *Lancet Psychiatry*.

Cannabis addiction is also tied to the development of schizophrenia. Among nearly 7 million Danish people ages 16 to 49, the link between cannabis use disorder and new cases of schizophrenia was stronger for males, especially at the ages of 16 to 25, scientists reported in May in *Psychological Medicine*. The team estimates that in 2021, without cannabis use

disorder, about 15 percent of new cases in males and 4 percent in females would not have occurred.

### The risks of concentrated cannabis

Although smoking the marijuana plant is still the most common way teens use cannabis, vaping cannabis concentrates is on the rise. A study of high school seniors reported that from 2015 to 2018, among past-year cannabis users, smoking decreased from 95 percent to 90 percent, while vaping increased from 26 percent to 34 percent. Daily use was also more common among those who vaped versus those who smoked, researchers reported in *JAMA Pediatrics* in 2020.

Using high-potency products may also be associated with an increased risk of psychosis, a symptom of schizophrenia. In a study of adults, daily use of cannabis products with THC concentrations of 10 percent or higher led to nearly five times the risk of psychosis compared with people who didn't use cannabis, scientists reported in 2019 in *Lancet Psychiatry*.

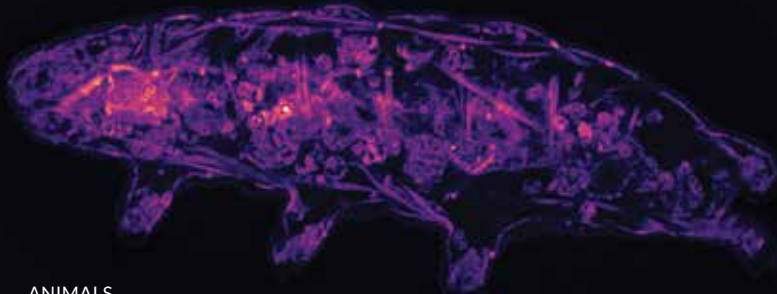
There are also reports of a rise in cannabis hyperemesis syndrome, a complication of using high-potency cannabis that leads to abdominal pain, nausea and repeated vomiting. A Canadian study found that emergency department visits for the syndrome increased by a factor of 13, from 0.26 visits per 100,000 people in 2014 to 3.4 visits per 100,000 people in 2021.

Concentrated cannabis products are largely unstudied and "pose new and alarming health risks," Ebel says. Users of high-potency products are essentially test subjects, Hurd says.

Public health officials recommend that parents talk with their kids about the risks of cannabis use. It's also important for parents to consider the messages they send about marijuana. Some clinicians have noticed that parents are using cannabis more, Young-Wolff says, and that they've become more permissive about teen cannabis use. "That can really make it hard to get this message to the kids to not use."

For adults who participate in the new legality of marijuana, she says, "if you are going to use cannabis, don't use in front of your children." ■

Tardigrades, like this one shown under a microscope and stained with a dye to highlight its internal organs, can survive all sorts of extreme conditions when dormant.



ANIMALS

## Here's the key to tardigrade survival

### Scientists pinpoint the trigger for suspended animation

BY TINA HESMAN SAEY

Researchers have discovered a molecular sensor that tells tardigrades it's time to toughen up.

The microscopic eight-legged animals, also called water bears, are nearly invincible when dormant. They pull in their legs, jettison water, turn their insides to glass and slow their metabolism to imperceptible levels. In this curled-up state known as a tun, they can withstand trips to space, X-rays and other extreme insults.

"Tardigrades aren't extremophiles, they're extemo-tolerant," says Derrick Kolling, a chemist at Marshall University in Huntington, W.Va.

Oxidation of the amino acid cysteine triggers the tun state, Kolling and colleagues report January 17 in *PLOS ONE*. Reversing the process revives tardigrades.

Knowing that cysteine oxidation is the key is inspirational, says comparative physiologist Hans Ramløv of Roskilde University in Denmark. But he also calls it irritating. "I have always claimed that the transformation was passive, and now I can see that it is definitely not passive."

The finding helps explain some aspects of water bear biology, and perhaps that of other organisms that go into suspended animation, when metabolism drops to nothing and the animals are essentially dead, Ramløv says. For instance, tardigrades have very high metabolism when emerging from dormancy. That may be because they are actively reversing cysteine oxidation and repairing damage

caused by it, he says. But a fundamental question remains, he adds: "how you can stop metabolism and die and restart metabolism and live."

As *Hypsibius exemplaris* tardigrades enter the tun state, superoxide levels shoot up, Kolling's team observed. Superoxides are oxygen molecules with an extra electron, leaving one electron unpaired and ready to react. The unstable chemicals, or free radicals, can damage cells.

But superoxides can also be a signal, says chemist Leslie Hicks of the University of North Carolina at Chapel Hill. Her lab teamed with Kolling's to decipher what was happening. One of the first steps was exposing tardigrades to a type of stress they wouldn't normally encounter: hydrogen peroxide, a powerful oxidizing chemical. Sure enough, tardigrades went into tun mode. Removing hydrogen peroxide woke them up. That suggests oxidation is an important signal for entering and leaving dormancy.

The researchers further examined oxidation of cysteine, one of the amino acids that make up proteins. Blocking cysteine oxidation prevented tardigrades from forming tuns triggered by exposure to high levels of salt or sugar, the researchers found. Blocking cysteine oxidation also wiped out the ability to survive freezing. Since tardigrades don't form tuns when frozen, that finding suggests cysteine oxidation may be important in all of water bears' survival mechanisms, Hicks says. ■

ANIMALS

## Numbats can't stand more heat

Why climate change is extra risky for these marsupials

BY JAKE BUEHLER

Numbats are curious creatures. To save energy, these marsupials, the only ones that are active solely during the day, hoard body heat. But that trick may put the endangered animals at further risk as the climate warms, a new study suggests.

Even brief sun exposure on days over 23° Celsius (73° Fahrenheit) can severely limit the time these squirrel-sized animals can spend foraging, researchers report January 11 in the *Journal of Experimental Biology*. So at relatively reasonable temperatures, numbats might rapidly overheat in the sun, the team finds.

"Climate change means that numbat habitats are becoming hotter and drier, with more extreme heat wave events," says Christine Cooper, an environmental physiologist at Curtin University in Perth, Australia. She and physiologist Philip Withers of the University of Western Australia in Perth wanted to know how higher temperatures might impact numbats and what that might mean for their conservation.

Though they once ranged across much of the southern half of Australia, wild numbats (*Myrmecobius fasciatus*) are limited to a handful of small populations in the western part of the country. Habitat loss coupled with introduced predators, cats and red foxes, have endangered this species.

Add in climate change, and the marsupials may be increasingly caught between a rock and a hot place: They exclusively eat termites and can forage only during the day when their prey is active. Termites make for a low-cal diet, so numbats are adapted to maximize heat gain to save energy they'll need in cooler temperatures, Cooper says.

To measure how numbat bodies heat up in varied environmental conditions, the researchers slowly drove around two nature reserves not far from Perth,



recording numbat surface temperature using a thermal-imaging camera fitted with a telephoto lens. Over 2020 and 2021, the team recorded 50 numbats. Sixty-two percent of numbat sightings occurred in the sunshine. The surface temperature of some body regions rose to 35° C or more, suggesting the animals rapidly heat up in the sun.

Using environmental and body temperature data from the thermal images, the researchers then calculated how much, and how fast, a numbat might heat up. When temperatures exceed 23° C, numbats may brave the sun in only short stints, maybe about 10 minutes, before reaching a core body temperature of 40° C, the maximum body temperature ever recorded for an active numbat, Cooper says.

Ducking into the shade isn't a perfect solution. Based on the team's calculations, only about 18 percent of the heat numbats absorbed came directly from the sun itself. Heat from the hot air and radiating from the ground also warmed the animals. In increasingly hot conditions caused by



Numbats forage during the heat of the day when termites come out.

climate change, even the shade might become too hot for numbats to properly function. It's not yet clear how much these animals might be able to adapt to rising temperatures.

Numbats might be able to forage earlier and later in the day. But "if temperatures become too extreme, numbats might not have sufficient time to forage during daylight, and it is unlikely that they can survive when foraging at night," Cooper says. Once night falls, termites retreat

deeper underground and out of reach, and the numbats face additional exposure to predators.

Next, scientists should assess how a loss of termite hunting ability from extreme heat impacts numbat survival or reproduction, says Eric Riddell, a global change biologist at the University of North Carolina at Chapel Hill. In doing so, "we can actually draw more direct associations between how hot the animal gets and its ability to survive." ■

## ANIMALS

# Honeybees steal bumblebee pollen

New observations shed light on what drives the theft

BY DARREN INCORVAIA

Honeybees dine on protein-packed plant pollen. And some are even willing to steal from other bees to get it.

Researchers in Italy have observed honeybees snatching pollen off the backs of bumblebees. The observations, published in the February issue of *Apidologie*, are among the most extensive documentation of bee-on-bee larceny to date.

On a 2019 trip to Mount Antola in northern Italy, independent naturalists Tiziano Londei and Giuliana Marzi, both based in Milan, recorded video of what they thought were honeybees (*Apis mellifera*) trying to push bumblebees off the flower of a woolly thistle. A closer look at the video, however, revealed that

this wasn't a case of competitive harassment; it was full-blown robbery.

As red-tailed bumblebees (*Bombus lapidarius*) scrounged around the flowers for nectar and pollen, some pollen grains stuck to their hairy bodies. Londei and Marzi witnessed honeybees snagging this pollen. The thieves tended to target male bumblebees slightly more than females, as the males appeared less bothered by the pilfering, though even females didn't react aggressively.

"Honeybees are well-known as pollen pigs," says Avery Russell, a biologist at Missouri State University in Springfield. So stealing pollen from the bodies of bumblebees, he says, "doesn't seem like a far stretch."

To see how common the criminality is, Londei and Marzi went back to the scene twice in the following three years and observed bees at two other sites too. Honeybees at the other sites were not seen stealing from bumblebees, but bees at the first site continued their larcenous ways. For instance, honeybees

collected pollen from only three of the 31 flowers the researchers observed in 2021, but stole from 28 of the available 66 bumblebees.

Scrutinizing the differences between these sites, the researchers suspect honeybees resort to theft where pollen is hard for them to get from flowers (the honeybees struggled to collect pollen from the woolly thistle), and where there are plenty of other bees around.

Pollen stealing by honeybees has previously been observed only in North America, first in Kansas and then later in California and Indiana. Discovering the behavior in Italy suggests this may be a global crime spree.

Next, it would be nice to learn whether pollen theft negatively impacts bumblebees or the flowers they pollinate, Russell says. He's also curious if other bee species ever steal pollen too.

"We do notice that in the hive, bumblebees will nibble on each other's pollen baskets," the part of the leg where pollen is stored, he says. ■

## PSYCHOLOGY

# Self-control is distinct from willpower

Knowing the difference may help people keep their resolutions

BY SUJATA GUPTA

A scientific squabble over how to define self-control draws from an unlikely source: a story from Greek mythology.

Sailing home to Ithaca after the Trojan War, Odysseus longed to hear the Sirens' legendary song. But he knew that was a bad idea. The Sirens, the goddess Circe had warned, lured passing sailors to their island where the men would almost certainly meet their demise. So Circe helped the hero king form a plan. As his boat approached the Sirens' island, Odysseus had crew members plug their ears with wax, and he ordered the men to tie him firmly to the boat's mast. He told the crew to tie him tighter if he begged and pleaded to heed the Sirens' call. His plan in place, Odysseus was able to both hear the Sirens and live to tell the tale.

The science is increasingly clear. Proverbially tying oneself to the mast—or crafting strategies in advance to thwart temptation—is the optimal way to meet one's goals. But not all agree that such preemptive strategies constitute self-control.

Social psychologists say Odysseus utilized exemplary self-control. That's because they tend to distinguish between strategic self-control—the Odysseus

approach—and willpower. Willpower would be akin to Odysseus resisting the Sirens' call in the moment without rope and muscular crewmen.

Some social scientists, though, have started to push back against that linguistic split. Most laypeople use both willpower and self-control to refer to resisting temptation in the moment, says Chandra Sripada, a psychiatric neuroscientist and philosopher at the University of Michigan in Ann Arbor. As such, most people would view Odysseus' decision to tie himself to the mast not as an act of self-control but an admission that he lacked it.

"The Odysseus case is a vivid example of how precommitment, preplanning and things like that aren't called by ordinary people self-control," Sripada says.

Ivory tower infighting over what does, and does not, constitute self-control might seem like a battle with low stakes. Experts largely agree that preemptive planning is the best way to achieve one's goals. So who cares if that route to success reflects self-control or something else? All roads, after all, lead to Ithaca.

The issue does matter, Sripada insists. Consider the start of a new year. Social

scientists often appear in the media as experts who can help people achieve their New Year's resolutions. But if those experts speak a different language than their audience, their message may not sink in.

And people do seem terrible at meeting their resolutions. One survey found that roughly 40 percent of people in the United States make resolutions, but less than half complete them by year's end. Roughly a third of resolution-setters don't make it past the three-month mark. Another survey showed that most adult Americans think they'll fail at their resolutions due to, you guessed it, a lack of willpower.

Think of it this way, Sripada says: If he told his patients to exercise self-control to avoid sweets, they would think he meant resisting the immediate craving to eat a freshly baked cookie. They would not think he meant taking the long route home to avoid driving past the bakery.

"You have to communicate with people using a familiar vocabulary," Sripada says.

## Defining self-control

Terms commonly used in psychology have long infiltrated everyday speech, but therapy speak in the real world is becoming increasingly common, recent media reports suggest. In the process, words like *gaslighting*, *triggered*, *narcissistic*, *toxic*, *traumatized* and *flourishing* have become diluted and imprecise (SN: 1/28/23, p. 14).

The term self-control shows that similar mistranslations also occur in reverse. The idea of self-control emerged thousands of years ago. For instance, in *The Laws*, a book about political philosophy, ethics, theology and psychology, Plato asserted that self-control compensated for a lack of strategic planning, researchers contended in 2023 in *Review of Philosophy and Psychology*.

By comparison, scientists entered the self-control discourse relatively recently. Other concepts, such as attention, memory, motivation and desire, have followed a similar trajectory from lay discourse to scientific jargon, says study coauthor Juan Pablo Bermúdez, a philosopher and cognitive scientist at the Universidad Externado de Colombia in Bogotá. "Once [these words] come into the science, they change. Sometimes they change for



Greek mythological hero Odysseus tied himself to his ship's mast to resist the Sirens' alluring yet fatal song, as depicted in this 19th century painting by John William Waterhouse. Odysseus' foresight, social psychologists say, was a powerful act of self-control.



the better. Sometimes they get muddier. [Self-control] seems to be a case of the latter,” Bermúdez says.

To be clear, scientists’ hearts are in the right place. In the early aughts, it was known that people reporting high levels of inner self-control — as measured by responses to statements such as, “I am good at resisting temptations” or “I get carried away by my feelings” — tended to report higher levels of well-being and academic achievement and more stable relationships than those reporting lower levels of self-control. Scientists assumed that people strong in self-control were better than others at muscling through temptation. How, scientists wanted to know, could others strengthen that muscle?

But then research began to emerge that challenged that framework. In one study, scientists analyzed the results of about 100 self-control studies of almost 33,000 participants. People who scored high in self-control weren’t necessarily great at resisting temptation in the moment. Instead, they seemed to have established habits or routines that removed the need to resist in the moment, researchers reported in 2012 in *Personality and Social Psychology Review*.

In another 2012 study, scientists pinged over 200 people on beepers several times a day to measure their desires in real time. People who scored high in self-control reported experiencing less temptation and weaker desires than those with lower scores, the team reported in the *Journal of Personality and Social Psychology*.

Those studies led to a seismic shift in the field of self-control, says social psychologist Malte Friese of Saarland University in Saarbrücken, Germany. “Apparently the people who are good in self-control... don’t inhibit all day long. They do something different.”

Thus began the willpower/self-control split. Scientists began exploring the tools that could help people do those different

things while sticking to the moniker “self-control.” Some research focused on strategies people could call on in the moment to move beyond simple willpower to resist temptation, says Kentaro Fujita, a social psychologist at the Ohio State University in Columbus. For instance, research has shown that distracting oneself or focusing on the negative aspects of a temptation can help people overcome immediate desires.

But with evidence mounting that preplanning a la Odysseus may be the key to lasting success, that’s where scientists focused their attention, says Fujita, who outlined those strategies in 2020 in *Policy Insights from the Behavioral and Brain Sciences*. Some tips include linking goal failure to a self-imposed punishment, such as donating money to a loathed organization. Another tip involves bundling a disliked

action — say, running — with a desirable one, such as listening to a favorite podcast.

“This article challenges a common belief: that successful self-control requires willpower,” Fujita and colleagues wrote.

### Commoners missed the memo

But Sripada’s research shows that people who don’t regularly design or participate in studies don’t disentangle the terms willpower and self-control. He and colleagues tested how people think about self-control in a study published in 2022 in *Cognition*.

In one experiment, the team sought to replicate the Odysseus story through a different tale, this one about a man named Mo and his desire to eat less cheese. The researchers directed 86 online participants to read one of several vignettes. In one scenario — a counterpart to the “tying himself to the mast” story — Mo gives his cheddar to a roommate so that he won’t eat it later. Despite begging and pleading for his cheese the next day, the roommate denies his request.

In an alternate scenario, Mo doesn’t preemptively hand off the cheese. Instead, when the roommate asks if she can use his

cheddar to make a sandwich, Mo gives it to her despite wanting it for himself, thus overriding his strong craving. That is, he resists the cheese’s Siren call.

The team then asked participants: “How much self-control did Mo exercise in order to not eat cheese?” Respondents could answer from 1 for “none” to 7 for “a lot.” Participants rated Mo high in self-control when he gave his roommate the cheese in the moment, the team found. They rated him low in self-control when he “begged and pleaded” for the cheese the next day. In other words, laypeople have not received social psychologists’ memo that strategic planning constitutes self-control — and not just any self-control but the best kind.

These findings show that researchers who study self-control have not done enough to investigate laypeople’s understanding of the concept, says Friese. “We have our own terminology and we are doing research based on that terminology, but it’s not really aligned with what laypeople may think.”

That mismatch makes it hard for scientists to communicate the power of preemptive strategies to the public. But expanding the meaning of self-control might also be making it hard for scientists to communicate with each other. “There is no [scientific] consensus on what self-control is and what it is not,” Fujita says. “Depending on who you talk to and depending on their theoretical vantage point, they might be using the same word to mean very different things.”

Psychologists’ expansion of the term self-control runs counter to thousands of years of language use, Sripada says. Researchers, and the public they hope to reach, would be better off finding another term to describe the superior, preemptive, tie-yourself-to-the-mast strategies. And they can stick to the original idea of self-control as equivalent to resisting temptation in the moment, or willpower.

With that in mind, Sripada suggests an alternate phrasing when communicating to people about how to achieve their resolutions: “Do you want to keep your New Year’s resolutions? Then don’t rely on self-control. That is a sucker’s game.” ■

“We have our own terminology and we are doing research based on that terminology, but it’s not really aligned with what laypeople may think.”

MALTE FRIESE

## GENETICS

# How herders shaped Europeans' genes

## Yamnaya ancestry makes some people prone to multiple sclerosis

BY BRUCE BOWER

Ancient herders who rode horses west out of their grassy homelands in southwest Asia erased a DNA divide between far-flung farmers and hunter-gatherers in Europe around 5,000 years ago.

The molecular legacy of these ancient herders, known as the Yamnaya people, reshaped Eurasians' genetic profile, impacting everything from their descendants' height to their susceptibility to some diseases (SN: 11/25/17, p. 16). International teams of researchers describe these findings, based on analyses of DNA from over 1,600 ancient individuals, as well as new hints about the origins of the Yamnaya, in four studies in the Jan. 11 *Nature*.

The new DNA evidence reveals that the Yamnaya mated with members of a distinctive eastern European culture—named the Globular Amphora Culture for its large, globe-shaped vessels—before expanding into northern Europe, says evolutionary biologist Morten Allentoft of Curtin University in Perth, Australia. That hybrid population formed a dominant culture that archaeologists call the Corded Ware Culture, he and colleagues hypothesize.

Allentoft's group combined new DNA data from 317 Europeans and western Asians with previous genetic data from over 1,300 Eurasians. Most individuals lived between 11,000 and 3,000 years ago.

The new evidence traces a large portion of Yamnaya herders' genetic origins to hunter-gatherers who lived near western Russia. Remains of those hunter-gatherers, from an ancient graveyard called Golubaya Krinitsa, date to around 7,300 years ago.

Archaeological finds place the origin of Yamnaya culture at around 5,400 years ago, so evidence of their genetic ancestry emerging two millennia earlier "is quite a surprise," says Volker Heyd, an archaeologist at the University of Helsinki who was not involved in the work. He suspects that hunter-gatherers whose more than 7,000-year-old remains and artifacts have been found across much of southwestern

Asia, not just at the Russian graveyard, contributed to Yamnaya genetic origins.

The ancient advance of herders into Europe produced a serious genetic downside, say computational biologist William Barrie of the University of Cambridge and colleagues. Yamnaya people endowed northern Europeans today with a heightened genetic risk for multiple sclerosis, a disease in which the body's immune cells attack the brain and spinal cord.

Today, MS affects more than 2.5 million people globally. Precisely how genes, viruses and environmental factors produce MS is unknown. Among northwestern Europeans, MS rates reach as high as 303 per 100,000 people—about twice the rates for most southern Europeans.

Barrie and colleagues compared ancient Eurasian DNA with modern DNA from some 400,000 white British individuals. Gene changes linked to a risk for developing MS emerged in Yamnaya herders about 5,000 years ago, the team found. Yamnaya migrations brought those variants to northern Europe where they persist at a high rate.

"Our analyses indicate that MS gene variants helped people survive in the past," Barrie said January 9 at a news conference in Copenhagen. Gene changes linked to MS may have boosted the Yamnaya's immune defenses against diseases transmitted from their horses, cattle, sheep and goats.

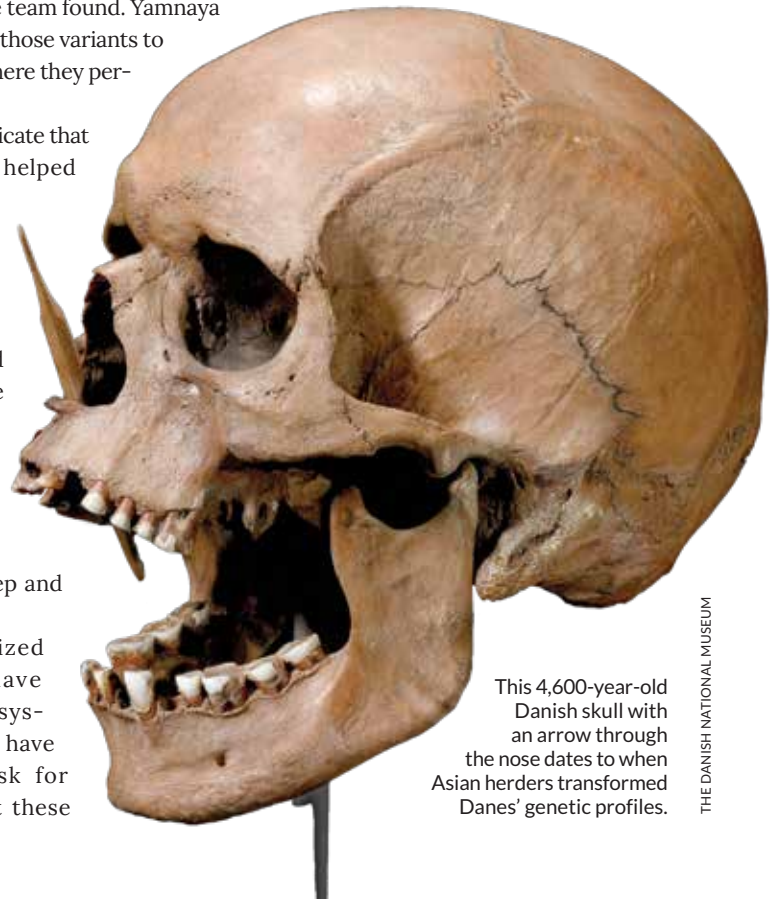
Modern, sanitized environments have altered immune systems in ways that have increased MS risk for those who inherit these

genes that were once advantageous for herders, Barrie's group speculates.

Other inherited disease risks also emerged. Eastern Europeans—who display considerable ancestry from ancient hunter-gatherers in that region—inherited a gene variant from those groups that is associated with Alzheimer's disease. Past benefits of this variant are unclear.

In a separate analysis, a group led by University of Copenhagen geneticist Evan Irving-Pease uncovered a link between Yamnaya ancestry and taller heights and lighter skin tones in northern Europeans relative to their southern counterparts.

Tall, light-skinned Yamnaya people or their direct descendants served as the ancestors of modern Danes after reaching Denmark about 4,850 years ago, Allentoft's group reports in another paper. Yamnaya descendants replaced farmers who had displaced hunter-gatherers a millennia earlier. Archaeologists often assume Danes descended from hunter-gatherers who occupied Denmark about 15,000 years ago as the last ice age waned, the team says. ■



This 4,600-year-old Danish skull with an arrow through the nose dates to when Asian herders transformed Danes' genetic profiles.

THE DANISH NATIONAL MUSEUM



## ASTRONOMY

**A new black hole portrait unveiled**

Heads up space fans: There's a new picture of the supermassive black hole lurking in the galaxy M87.

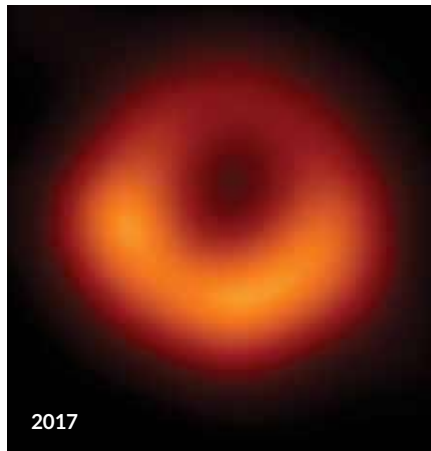
The image looks a lot like the initial shot, revealed in 2019. The main difference is that the brightest spot around the black hole has shifted counterclockwise by about 30 degrees, researchers report January 18 in *Astronomy & Astrophysics*. This is probably a result of material sloshing around in the black hole's accretion disk while being consumed.

But other aspects have not changed. A bright ring and the black hole's shadow appear almost exactly the same size as before. This helps confirm that M87's black hole is the type predicted by Einstein's general theory of relativity and not some more exotic or unexpected variety, says astrophysicist Lia Medeiros of Princeton University.

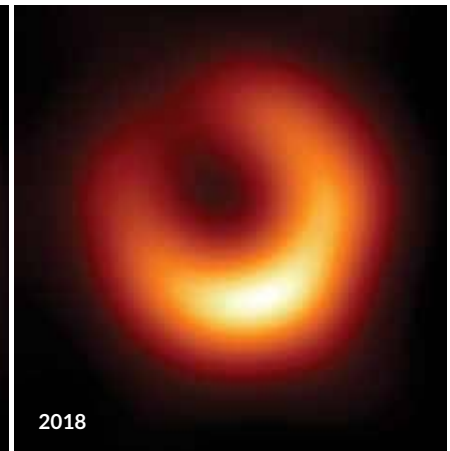
Medeiros is part of a collaboration called the Event Horizon Telescope, or EHT, which used a global network of radio telescopes to zoom in on M87's heart, about 55 million light-years from Earth. The original image of M87's black hole used data collected in 2017. The new pic uses observations from 2018.

Those observations include data collected by a telescope added to the EHT network since the original observations: the Greenland Telescope. Thanks to the additional telescope, the new image contains previously inaccessible details, which the team will dig into later.

Future images will help physicists learn more about the complex interactions between the black hole's magnetic field and the plasma spinning around it. — *Adam Mann*



The black hole at the center of the galaxy M87 was first imaged with data collected in 2017 (left). The latest view (right), based on data from 2018, looks very similar. But one change is the position of the brightest spot in the ring, which rotated about 30 degrees around the black hole.



dense cluster of stars 40,000 light years from Earth. These pulsars are a type of fast-spinning neutron star that rotates in fractions of a second while sending out powerful beams of radiation like a cosmic lighthouse.

For some pulsars, their beams flash past our planet with a regularity that rivals an atomic clock. By hunting for tiny variations in a beam's arrival on Earth, researchers can deduce the existence of anything perturbing the pulsar's motion.

The ticks of one particular pulsar, known as PSR J0514–4002E, revealed that it has an invisible companion weighing between about 2.1 and 2.7 times the mass of the sun, researchers report in the Jan. 19 *Science*. That potentially makes it too heavy to be a neutron star, astronomer Ewan Barr of the Max Planck Institute for Radio Astronomy in Bonn, Germany, and colleagues say. Neutron stars are thought to collapse into black holes once they reach around two to three times the sun's mass. But because nobody knows exactly where that dividing line rests, nor precisely what happens once this limit is reached, the researchers can't definitively say what this object is.

Researchers have discovered a handful of similar entities before. Barr and colleagues speculate that this new object formed when two lighter neutron stars crashed together. By studying the pulsar ticks more closely, the researchers hope

to determine the hidden entity's true nature and use it to probe matter in similarly extreme objects. — *Adam Mann*

## ASTRONOMY

**Radio burst hails from galaxy pileup**

**NEW ORLEANS** — A mind-bogglingly strong spurt of electromagnetic energy known as a fast radio burst has for the first time been traced back to a compact group of galaxies.

FRBs last fractions of a second but can release as much energy as the sun does in a month. They have been traced to all sorts of environments, including lone galaxies and globular clusters, but their cause remains unclear. "We think that they likely are caused by some flavor of magnetar — a highly magnetic neutron star," astronomer Alexa Gordon of Northwestern University in Evanston, Ill., said January 9 during a news conference at a meeting of the American Astronomical Society.

Gordon and colleagues used the Hubble Space Telescope to link FRB 20220610A, the most powerful and distant FRB yet found, to seven merging galaxies about 11 billion light-years from Earth. Such a chaotic environment can lead to galaxies swapping gas, dust and other material, triggering the birth of stars. If a massive star formed under these conditions, its death could have left behind a magnetar, perhaps explaining the FRB. — *Adam Mann*

## ASTRONOMY

**Pulsar companion puzzles scientists**

Circling around a pulsar in our galaxy is a mysterious entity that is either a very heavy neutron star, one of the lightest black holes ever discovered or a never-before-seen quasistellar object.

The finding comes from the MeerKAT radio telescope in South Africa, which discovered 13 millisecond pulsars in a



# Saving Lives with Safe Injection

A study will assess how well overdose prevention centers might work in the United States **By Tara Haelle**

OnPoint NYC opened two overdose prevention centers in 2021, where people can use drugs with supervision from trained staff who can help treat and reverse overdoses.

It's June 2023 and Victor has been spending most of his days at what he calls his "second home," on East 126th Street, between Park and Lexington avenues, in East Harlem. A dozen or so men congregate outside, some sifting through belongings in a plastic bag or texting on their phone, others sitting on folding chairs or stools, playing cards, smoking, talking or just watching passersby. As an unhoused person in New York City, Victor says OnPoint NYC, a nonprofit organization that opened two overdose prevention centers in November 2021, provides him

a "sense of community" he can't get elsewhere.

Inside, Victor, who provided only his first name when I talked to him last June, will go through reception and into a back room. He'll fill out a form that provides the information OnPoint needs to make sure he doesn't die. The form asks for his name and time of arrival, what drug he'll be consuming and how he'll consume it. From a list that includes meth, marijuana, cocaine, crack, benzos, fentanyl, speedball and many more, he checks heroin, which he'll inject. At the bottom, the form



asks: “If you weren’t using here now, where would you have gone to use?” Options include the street, sidewalk, between cars, under a bridge, a park, a public restroom, a subway station, your own place (Victor doesn’t have one), a friend’s place or “other.” And it asks if he’d be using alone.

“Yes” is a common answer to that last question. That’s why OnPoint NYC exists. Its two locations, the one in East Harlem and one in the Washington Heights neighborhood, are the only officially sanctioned overdose prevention centers, or OPCs, operating in the United States. People bring drugs they’ve obtained elsewhere and use them under the supervision of trained staff who can provide sterile supplies for drug use and can respond to overdoses.

The approach remains highly controversial in the United States, with critics pointing out that the sites are sanctioning, if not encouraging, illegal drug use. What’s more, critics are concerned that OPCs increase crime, local drug use and public nuisance in the area. This opposition is just one of the challenges alongside many legal, social, financial and logistical barriers for an OPC trying to open and remain open.

“I understand what it sounds like, right? You’re gonna allow people to use drugs on your site,” says Sam Rivera, executive director of OnPoint NYC. “When people question whether it’s good or it gets people well, showing them is what gives them the answer. The answer is yes, of course it does.”

The United States had more than 106,000 drug overdose deaths in 2021, the most recent year for which complete data are available. That’s more per capita than other high-income countries with available data. The vast majority of those deaths involve opioids, including prescription opioid medications and heroin, but predominantly synthetic opioids such as fentanyl. Annual deaths from opioid overdoses have more than doubled since 2015.

“We obviously need to figure out what alternative interventions we can provide to people to prevent them from dying,” says Nora Volkow, director of the National Institute on Drug Abuse in Bethesda, Md. “It’s crucial.”

After Congress directed that institute along with the Centers for Disease Control and Prevention to conduct a report in 2021 on the potential public health impact of OPCs, the agencies’ findings noted “the consistent observation that initial objections to OPCs from local stakeholders tend to disappear following their implementation.”

OPCs have existed around the world for decades. Research has shown that they meet many of their primary goals: reducing overdose deaths, health care costs, the use of emergency services,



OnPoint NYC’s two overdose prevention centers are in East Harlem and Washington Heights (shown). They are the only officially sanctioned OPCs in the United States.

emergency room visits, hospital stays, public drug use, infectious disease from nonsterile needles, and drug-related litter, such as used syringes. The sites also let people test their drugs to find out what they actually include. Many sites provide additional services aimed at improving overall health — infectious disease screening or testing, wound care, substance use treatment referrals and other programs that meet health care or social needs.

There’s been growing interest in the United States as well. A 2017 study estimated that an OPC in Baltimore that would cost \$1.8 million a year to run would save the city \$7.8 million a year in health care costs, but Maryland’s legislature has yet to authorize one. A center operated in San Francisco for nearly 11 months in 2022 before shutting down due to political backlash. Last year, the state of Minnesota and the city council of Somerville, Mass., each set aside money for OPCs. Additional sites have been proposed or are under consideration in Seattle, Denver, Philadelphia and elsewhere.

OnPoint has become a model for proposed sites across the United States. Researchers are analyzing its data, alongside data from other countries, to assess how OPCs might fare in a country without universal access to health care, with limited social safety nets, and with more drug use and overdose deaths.

In April 2023, the National Institutes of Health awarded the first portion of a grant, expected to total more than \$5 million over four years, to researchers who will assess the effectiveness and costs of OPCs based on data from OnPoint and another site approved by the Rhode Island

legislature and slated to open this year. That data could help shape how future centers operate and what services they offer, as well as how the nation approaches drug use more generally.

For Victor, the benefits of OnPoint go far beyond the immediate services provided. “It’s them treating you and looking at you as a person, because most people, most places you go, once you tell them you’re doing drugs, they have an idea of who you are already, a stigma,” he says.

Fostering community can be key to recovery, Volkow says: “That building of trust and a sense of acceptance and belonging is really the first step that can make a person want to go to treatment.”

For Rivera, the experience at the center is, “for lack of a better term, a lovefest.” Though he says his staff never initiates conversations about detox, treatment, rehab or recovery, they nevertheless have those conversation every day with people who come to the center.

### A short history of harm reduction

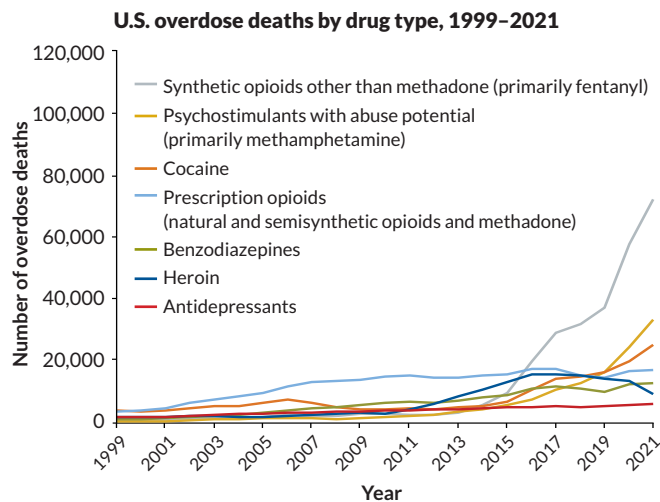
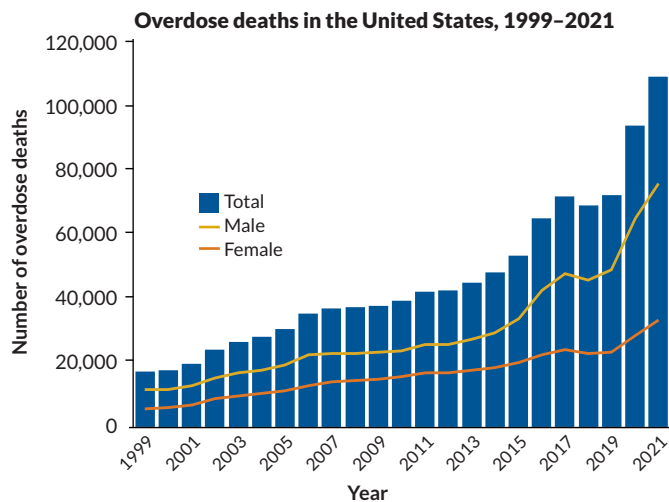
The first OPC opened in Bern, Switzerland, in 1986, and today there are more than 140 legally-sanctioned OPCs in more than a dozen countries, including Australia, Canada, Mexico and across Europe. Since Canada opened North America’s first OPC, Insite, in Vancouver in 2003, it’s added dozens more sites around the country, plus more “pop-up” mobile spots run out of tents or campers. OPCs are also known by other names, such as supervised injection sites, drug consumption facilities and safe consumption sites. But regardless of what you call them, the philosophy is the same: harm reduction.

Harm reduction “focuses on improving the health

and reducing the negative health outcomes for individuals,” says Elizabeth Samuels, an epidemiologist and emergency medicine physician at UCLA. “At its most basic level, it’s treating people with respect, dignity and autonomy,” and giving them info and tools “to keep themselves and their loved ones safe.” Laws requiring seat belt use in cars are harm reduction tactics. So are adding filters on cigarettes and distributing condoms to prevent pregnancy and the spread of sexually transmitted infections.

Samuels says there’s plenty of evidence that harm reduction strategies work to reduce drug-related problems. Yet in the United States, such interventions – providing safe, sterile drug consumption equipment, for example – are often stigmatized or criminalized. The current approach of punishing people who use drugs is a carry-over from the failed “war on drugs,” she says, “but it remains pervasive in the American psyche and in some portions of the general population.” We know addiction is a disease, not a moral issue, she says. “Pushing people underground and making them feel shame,” she adds, increases risky drug-related behaviors, such as sharing needles, which can transmit blood-borne diseases like HIV and hepatitis C.

Barriers to OPCs in the United States are financial (for example, who is going to fund them?), logistical (where will they be located?) and social (will communities accept them?). But the biggest hurdle has been legal. In a section often called the “crack house statute,” the Anti-Drug Abuse Act of 1986 makes it a felony to “knowingly open, lease, rent, use or maintain any place, whether permanently or temporarily, for the purpose of manufacturing, distributing or using any controlled substance.” Crack, a form of cocaine



**A continuing crisis** Overdose deaths in the United States have more than doubled since 2015, reaching more than 106,000 in 2021 – the last year for which complete data are available (left chart). Most of those overdose deaths involve opioids (right chart). SOURCE: NIH, CDC



that is nearly always smoked, has come with harsher penalties than other forms of the drug. Cocaine in crack form has historically been perceived as more prevalent in Black communities, which has contributed to racial injustices.

A nonprofit called Safehouse tested this law in 2019, attempting to open an OPC in Philadelphia. The effort kicked off a court battle, and in 2021, the Third Circuit Court of Appeals ruled that the proposed OPC would violate the statute. Safehouse continues to explore its legal options.

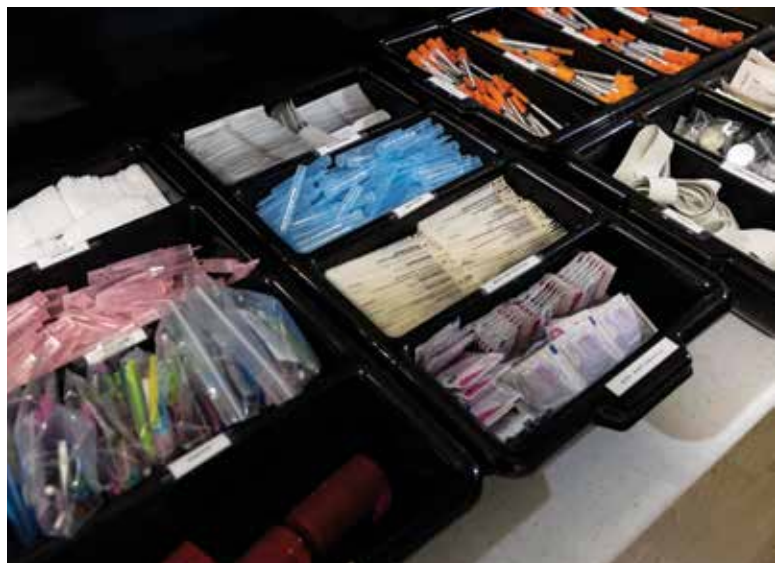
Meanwhile, harm reduction advocates in New York were growing desperate as people died from overdoses — more than 2,000 in New York City during 2020 alone. New York Harm Reduction Educators in East Harlem and the Washington Heights Corner Project, both harm reduction social services organizations, had been running syringe exchange programs and offering related services in the city since the early 1990s. Representatives from these groups had done the logistical groundwork to open an OPC and had the support of city hall. A 2018 feasibility study conducted by the city's health department and funded by the New York City Council suggested that opening four OPCs in New York City could prevent up to 130 deaths a year and save \$7 million annually in public health care costs.

In the early days of 2021, the New York groups had a choice to make. The Safehouse ruling, from a different federal appellate court than the one overseeing New York, showed the potential legal risks of opening an OPC. But after President Joe Biden took office and listed “enhancing evidence-based harm reduction efforts” as a drug policy priority, the groups decided to move forward, merged into OnPoint NYC and opened two new sites.

“Our people are dying, and we know we have the medicine, the apparatus, everything we need to keep people alive, and they don't have to die,” says Rivera, who was named as one of *Time* magazine's most influential people of 2023.

While most of OnPoint's extra services receive funding through city and federal grants, the overdose prevention and drug supplies services are funded through private dollars, a mixture of individuals, nonprofit organizations and foundations.

So far, OnPoint hasn't been challenged in court, but the Anti-Drug Abuse Act statute remains a major deterrent to building more centers, Samuels says. Lack of public funding and community resistance are also barriers. The vast number of people dying has changed the climate somewhat, she says. More people are seeking all the “evidence-based tools in our toolbox to prevent any further loss of life.”



Painted in blue letters at OnPoint in East Harlem are the words, “This site saves lives,” in English and Spanish (top). The site provides not only sterile needles, other drug use and wound care supplies (middle), naloxone, drug testing and drug consumption booths (bottom), but also services aimed at improving overall health.

TOP: ONPOINT NYC; BOTTOM TWO: YUKI IWAMURA/AFP GETTY IMAGES

### What the research shows

Along the top of the back wall in the safe consumption area at OnPoint in East Harlem, where Victor uses his heroin, blue painted letters announce: “THIS SITE SAVES LIVES.” And below it in Spanish, “ESTE SITIO SALVA VIDAS.” Below are two defibrillators, each with plushies on top, including a Pokémon Psyduck, a gray puppy and even one shaped like a grinning bottle of naloxone, a medication used to reverse opioid overdoses. Two crash carts are ready to go if the staff notice someone slumped over, becoming discolored or otherwise showing potential signs of an overdose, which happens about three to five times a week, says Alsane Mezon, a harm reduction specialist at OnPoint.

Existing research on OPCs, which comes primarily from Insite in Vancouver and the Uniting Medically Supervised Injection Centre in Sydney, suggests the sites do save lives. The first major systematic review, published in 2014 in *Drug and Alcohol Dependence*, included a study looking at overdose deaths in Vancouver before and after Insite opened in September 2003. Nearly 90 overdose deaths occurred within 500 meters of the site in the period from January 1, 2001 to December 31, 2005, with the fatal overdose rate declining by 35 percent after the opening. That’s compared with a 9 percent reduction over the same time period in the rest of Vancouver.

In a study of the area around the OPC in Sydney, the average monthly number of ambulance calls for opioid-related overdoses in the hours the center was open, which numbered in the hundreds, decreased by 80 percent after its opening. The decrease was more dramatic than what was seen in the rest of the state of New South Wales. None of the studies included in the 2014 review or a more recent one from 2021 documented any death from overdose inside an OPC.

Despite concerns from critics, the reviews also found no increase in crime, drug trafficking or drug use-related public nuisance associated with the OPCs but did document reductions in syringe litter and public drug use. And when it comes to concerns about the sites encouraging drug use, one study from the Vancouver site showed no increase in relapse rates or the overall number of people in the area who used drugs, nor a drop in those starting methadone therapy.

Neither review linked OPCs to a decline in the number of people who injected drugs, but four

studies of the Vancouver site and one of the Sydney site suggested an association between visiting OPCs and the likelihood of being referred to addiction treatment or entering a detox program. The 2021 review, published in the *American Journal of Preventive Medicine*, found frequent use of OPCs increased the rate of accessing treatment by 1.4 to 1.7 times compared with those who used drugs but visited OPCs less frequently or not at all.

A study of the Vancouver site calculated that, after accounting for the cost of running the site, it saved 14 million Canadian dollars in medical costs over a decade, including prevention of 1,191 new HIV and 54 new hepatitis C infections.

Early results from OnPoint appear consistent with previous findings. OnPoint staff and NYC health department employees reported in *JAMA Network Open* that during OnPoint’s first two months of operation, 613 people used services a total of nearly

6,000 times across both sites, most often for injecting heroin or fentanyl. As seen in Vancouver and Sydney, most visitors were male, and just over a third were unhoused. Center staff responded 125 times to an overdose or near-overdose, with EMS being called five times and three people transported to the emergency department. OnPoint has not recorded any overdose deaths within its walls since it opened.

Three-quarters of people who went to OnPoint said they would

have used drugs in a public place. About half of those who went accessed other services there: picking up naloxone to have on hand, going to counseling, receiving medical care or a holistic service such as acupuncture.

Until OnPoint opened, the only peer-reviewed research on OPCs in the United States came from an underground site that opened in 2014 in an unnamed location. In a research letter reported in 2020 in the *New England Journal of Medicine*, Alex Kral, a behavioral health epidemiologist based in the San Francisco Bay Area with the nonprofit research institute RTI International, and colleagues evaluated the site’s first five years of operation. Out of 10,514 drug injections, 33 opioid-related overdoses occurred on-site and all were reversed with naloxone, with no deaths or transfers to medical facilities.

A separate study by Kral and colleagues, reported in *Drug and Alcohol Dependence* in 2021, looked at police reports of incidents in the area around the underground site and at two

“Health care provided at an OPC might be the first time someone is experiencing compassionate, low-threshold and free health care.”

BRANDON MARSHALL



comparison sites without OPCs for five years before and five years after the site's opening. Drug incidents had been declining around the OPC before opening and continued to decline afterward, suggesting the site had no negative impact. The analysis also found a decrease, rather than an increase, in crime around the OPC site.

Kral, who is not aware of other underground sites in the United States, also studied the OPC that opened in San Francisco in January 2022 and remained open through December of that year. In addition to safe consumption booths, the site offered on-site buprenorphine treatment (to treat opioid use disorder), legal services and even recreational activities such as karaoke competitions. That site reversed 333 opioid overdoses, about one per day it was open. Kral's team analyzed data on general nuisance and drug-related nuisance within a 500-meter radius around the OPC and around a similar comparison area elsewhere in San Francisco. The analysis suggested, contrary to claims often made by critics, a reduction in nuisance overall, and no increase in drug-related nuisance or homelessness.

Similarly, a separate group of researchers, unaffiliated with OnPoint NYC, recently reported data showing no significant change in violent or property crimes, 911 calls for crime or medical incidents or 311 calls related to drug use in the immediate six-block areas around the OnPoint OPCs.

The small amount of U.S. research has already started to inform policy, Kral says, pointing to the Rhode Island and Minnesota legislatures' decisions to authorize the opening of OPCs. "We are seeing politicians take what can be a political risk to do this, and I think our data is part of the reason for that," he says.

## A major U.S. study

Still, the existing research isn't without limitations. All of the studies are observational, meaning they can show correlations but cannot attribute benefits directly to the OPCs. Many other factors might play a role in local crime rates, medical service utilization, homelessness, infectious disease spread and so on.

OPCs are also far from homogenous. Though the systematic reviews found that OPCs reduce overdose deaths locally and do not come with increases in local drug use or crime, the 2021 review noted that not much research exists in "resource-poor and politically diverse settings." Drug use and structural factors, such as law enforcement practices and stigma around drug use, differ across different regions. Assessments of the value of the



Sam Rivera, executive director of OnPoint NYC, oversees both of the overdose prevention centers. According to a recent report, in their first year of operation, the sites were used more than 48,000 times by more than 2,800 people, with OnPoint staff intervening 636 times to prevent overdoses from becoming fatal.

OPC-linked social services, which themselves vary widely, are also limited.

All this leaves a big question open: Can OPCs dramatically reduce harm in the United States, a country with a lot of drug use and among the highest overdose mortality rates in the world?

The new study funded by the National Institutes of Health through the National Institute on Drug Abuse could help answer that question by studying two OPCs over five years. Researchers from New York University will look at both OnPoint sites, and Brown University researchers will focus on the OPC that is set to open in Providence later this year.

That Providence site, in the process of hiring a medical director and finalizing the location, will be funded by \$3.25 million allocated from lawsuit settlements between the state and opioid manufacturers, distributors and pharmacies, as well as with money from private foundations and donors, says Annajane Yolken, director of strategy at Project Weber/RENEW, a nonprofit that is helping establish the site. None of the NIH research money will go toward the center's operating expenses.

The study, part of the NIH harm reduction research network, will look at four outcome types: the impact on people who use the facilities, based on surveys and health records; effects on neighborhoods, including crime, public attitudes and economics; qualitative findings from interviews with OPC staff and clients; and the costs, of running the site versus health care savings, for example.

"We are first and foremost scientists—we're not advocates—so our task is to bring the highest level



Alsane Mezon, a harm reduction specialist at OnPoint, stands with crash carts used to respond to overdoses some three to five times a week. The carts include naloxone, a life-saving medication that can reverse an opioid overdose.

“No one service solves all problems, and they don’t necessarily replace or supplant other important things.”

JONATHAN GIFTOS

of scientific rigor to these questions, and we’re hoping that the science can inform policy,” says Magdalena Cerda, the NYU epidemiologist leading the OnPoint portion of the study.

“There are some unique aspects of the U.S. context that justify the need for this kind of study,” says Brandon Marshall, the Brown University epidemiologist leading the Providence portion. Most countries with OPCs have universal health care, and OPCs are funded through that system. The United States doesn’t have that structure, which often means Americans engage with health care differently than people in other countries. “Here, health care provided at an OPC might be the first time someone is experiencing compassionate, low-threshold and free health care,” Marshall says.

Barriers to health care, particularly for chronic pain or mental health conditions, are likely one reason drug use is worse in the United States than in other countries, Kral says. Volkow also points to the “tremendous social disparities” in the United States.

Social inequities and the lack of a social safety net in the United States may influence how big a difference OPCs can make in reducing overdose deaths, Samuels adds. There’s also the punitive treatment of drug use, including its criminalization, and an aversion to harm reduction strategies compared with other countries with OPCs, Marshall says. He adds that addressing these issues is additionally challenging because of the racist roots of many U.S. drug policies.

What works in Canada and Australia may turn out not to work in the United States, and success may vary across U.S. locations too. One key strength of the two-site study is how much New York City and Providence differ from each other.

“One of the real values of our study is the fact that it leverages two very different contexts, a very urban, dense context of New York City and then the less urban, more suburban Providence,” Cerda says. “Being able to compare those contexts will hopefully give us some more generalizable insights.”

Another big difference will be the services provided. “If you’re going to open an overdose prevention center, then you have to think about all of these wraparound services,” Rivera says. Once people are there, they can have a decent meal, take a nap, meet with a case manager and more.

Cerda refers to OnPoint as the “Cadillac” of OPCs, because it offers so many wraparound services. The plan for the Providence site does not include as many of those services, but the site will be located alongside a treatment program. That could be a benefit for access to treatment, or it might make people more uncomfortable going there.

“We know that the more people use an OPC, the more likely they are to enter into some kind of addiction treatment program broadly,” Marshall says, “but we don’t really know at a more granular level what that looks like.”

### Pairing data with stories

When I met Rivera at his office at OnPoint in June, he was wearing torn gray jeans and a plain gray T-shirt that said in bold white letters: “HEALTH JUSTICE FOR ALL.” He’s a physically large presence, and with his thick, tattooed arms and hands adorned with silver and turquoise jewelry, he might seem intimidating if not for his kind eyes and inviting demeanor.

Hanging on the wall behind the desk in his office, cluttered with knickknacks both practical and decorative, is a plastic plaque commemorating the documentary *Clean Needles Save Lives*. The 1991 film tells the story of the illegal needle exchange program, run by the activist group AIDS Coalition to Unleash Power, or ACT UP, that was established in response to the AIDS epidemic.

Rivera defines “health justice for all” as access to health care without barriers — “an opportunity for someone who’s actively using drugs to use safely and have supplies that are clean and healthy. That’s health care,” he says. “Quite frankly, many drug users don’t have access to health care in the way they need it and deserve it.”



No one expects OPCs to solve the entire drug problem in the United States. For example, sites typically do not allow pregnant individuals or those under 18 to use their services, and women may not feel as welcome at many sites given that the people using OPCs are predominantly male, many with a history of incarceration.

Even for those who do visit the sites, there are barriers. Some people have difficulty injecting themselves, but most sites do not allow someone to help another person inject. Another potential barrier is a lack of smoke rooms — OnPoint has these but many OPCs do not — which is an equity issue because it excludes people who use drugs in this way.

Despite the limitations, Samuels says, OPCs have shown they help people and they save lives. “That’s meaningful in itself,” she says, “and part of a comprehensive, multimodal strategy to address the overdose crisis.”

Jonathan Giftos, an addiction medicine physician and the former assistant commissioner of the NYC Bureau of Alcohol and Drug Use Prevention, Care and Treatment, similarly regards OPCs as one piece of a bigger picture. While the city does not provide funding for OnPoint’s OPC services, the bureau where Giftos worked serves as the city’s liaison with the center, which does receive city funds for some of its extra services.

“No one service solves all problems, and they don’t necessarily replace or supplant other important things, like prevention or treatment or recovery spaces,” says Giftos, now chief of ambulatory care at NYC Health + Hospitals/Woodhull. “As we evaluate their impact, it’s important that we interpret the results through that lens and not think that because they didn’t solve every single problem facing a community, that they’re not effective.”

In his qualitative research from the underground site, Kral regularly heard that people using the site didn’t have friends and felt disconnected from the community. OPCs allow vulnerable people who have been stigmatized by society and burdened by shame to “actually be themselves for a moment” and to develop relationships that encourage them to make decisions “about the kinds of things they want to change in their life,” he says. These centers offer possibilities that can’t be measured in overdose or infectious disease rates.

“The way I have been able to really help people is with empathy, respect and love,” says Mezon, the OnPoint harm reduction specialist. She is a medical assistant, but she says her personal interactions with people at the center are just as

important as her clinical tasks. “When I come in, I tell them, ‘First you’re human. We’re going to show you respect,’ and that really changes the narrative.” Mezon says people come to the OPC from as far away as Long Island, Rochester, N.Y., and New Jersey not only because they can get a shower and test their drugs for fentanyl and other substances, but also because they know they will be treated with compassion.

She speaks about her work as a calling. “I have to walk this dark forest every day to find these beautiful flowers that get lost,” she says. “I’m just really grateful to have all walks of life here. This situation does not discriminate, so I’m here to help.... All the things that they’re not getting out there, we’re trying to give them in here.”

Marshall says a lot of work needs to be done to destigmatize addiction and emphasize the humanity of people affected by the overdose crisis. He believes that data and scientific research need to be paired “with the human perspective.”

Edward Krumpotich agrees. A drug policy consultant based in Grand Rapids, Minn., Krumpotich spent a lifetime battling addiction himself and lost his brother to a heroin overdose. He has also helped write half a dozen harm reduction bills in three states, including the 2023 legislation in Minnesota that authorized funding for an OPC.

“Many times, we get stuck in certain statistics. That doesn’t tell the whole tale of how this crisis is happening,” he says. “I think what it’s going to take is when community members realize that their next-door neighbor or their family member is somebody who suffers with this disease. I think when people realize that people like myself, who have been to 30-plus treatments, now write nation-leading law, it can happen to anybody.”

Marshall says personal narratives can change people’s hearts and minds. “Some of the strongest voices are people with lived experience who can really humanize this issue and explain how the crisis has personally affected them,” he says, “and how things like harm reduction enabled them to live happy, healthy lives.” ■

## Explore more

- For more information on the U.S. overdose prevention strategy from the Department of Health & Human Services, check out [www.hhs.gov/overdose-prevention](http://www.hhs.gov/overdose-prevention)

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*Tara Haelle is a science journalist based in Dallas who reports regularly on infectious disease, medical research and health care disparities.*

## Getting help

If you or someone you know faces an addiction, resources are available to help:

The U.S. Substance Abuse and Mental Health Services Administration has a **national helpline** that is available 24 hours a day and 365 days a year. Call 1-800-662-HELP (4357).

For family of people living with substance use disorders, the Substance Abuse and Mental Health Services Administration offers a free brochure titled “**What is substance abuse treatment?**” Find it at [bit.ly/SAMHSAbrochure](http://bit.ly/SAMHSAbrochure)

The National Harm Reduction Coalition has resources for finding **access to sterile syringes and naloxone**. Visit [harmreduction.org/resource-center/](http://harmreduction.org/resource-center/)

To find out how to **test drugs for fentanyl** using test strips, check out a video and a brochure in several languages from the NYC health department at [on.nyc.gov/3Ubt4Hp](http://on.nyc.gov/3Ubt4Hp)



# NOW STREAMING ON MARS

Future Red Planet explorers will need to connect with each other — and us **By Payal Dhar**

GLENN HARVEY

When astronauts land on Mars, a couple of decades from now, perhaps, they'll need to find a way to communicate — with each other, with equipment on and around the planet, and with mission control back on Earth. Despite living so far from home, they'll no doubt want to connect with loved ones, keep their playlists up-to-date or stream the latest episodes of their favorite shows.

But setting up a Wi-Fi connection to Earth's internet won't be an option. Earth is simply too far away — around 55 million to 400 million kilometers, depending on where the planets are in their orbits. Spacefarers will need another strategy.

Establishing a good communications infrastructure is essential for human missions to Mars, says Claire Parfitt, a systems engineer with the European Space Agency, or ESA, who is based in Noordwijk, Netherlands. "At the moment, we're in the early stages of working out what that means."

Researchers are testing ways to upgrade existing networks, along with some far-out alternatives. For example, NASA's Psyche mission, which lifted off in October with the job of exploring an asteroid between Mars and Jupiter, will also test interplanetary communication using lasers. Lasers could carry far more data than the radio waves that have been used from the earliest days of space travel.

No known strategies can get rid of the time lag in communications between Earth and Mars; a message moving at the speed of light takes anywhere between four and 24 minutes for a one-way trip. In other words, a quick ping to mission control is out of the question, not to mention a WhatsApp call home.

There's also the issue of solar conjunction, says Parfitt, when the sun comes between Earth and Mars. This happens for a couple of weeks every two years or so, cutting off communications between the planets. The last one took place in November.

But new approaches could open possibilities that make communications on Mars more akin to what we experience here on Earth. At least one research team has wondered: What if Mars had its own internet?

## How communication works today

Several space agencies have landers, rovers and satellites already at Mars that have to communicate with Earth.

Consider NASA's Perseverance rover. It sends and receives two kinds of information. One is command and telemetry, where operators on Earth send instructions, receive information and make decisions on what to do next. Percy

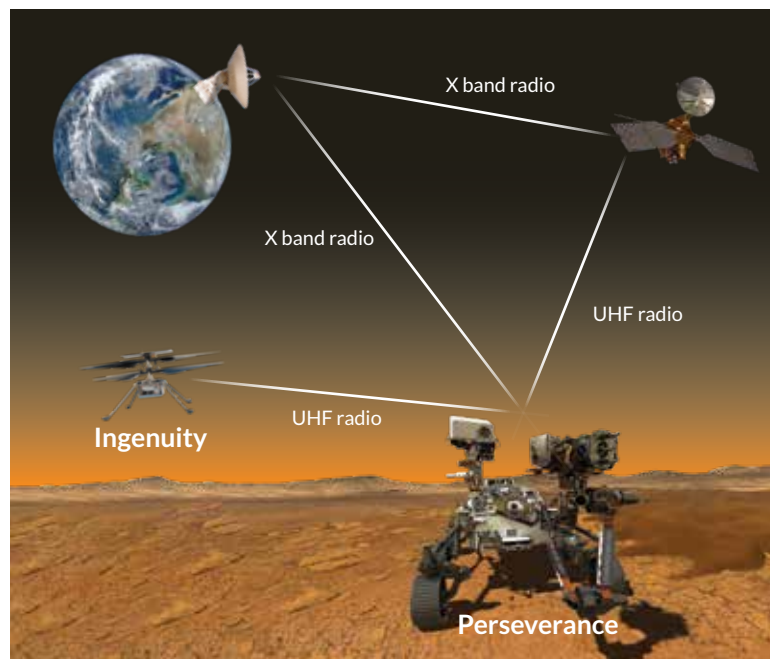
typically receives over 1,000 commands from Earth every day. The second is the science data — pictures of Martian rocks, for example — that Percy collects. The helicopter Ingenuity also regularly pings the rover, which serves as a base station to relay data and commands between Ingenuity and Earth. Orbiters circling the planet, including NASA's Mars Odyssey and Mars Reconnaissance Orbiter, or MRO, and ESA's Trace Gas Orbiter, or TGO, similarly send science data back home.

A lot of the communication with Mars is routed through the Mars Relay Network in what NASA describes as "a tightly choreographed dance." This network of five orbiters around Mars — MRO, TGO, MAVEN, Mars Odyssey and Mars Express — transmits information via antennas pointed toward Earth.

A rover that needs to send its latest observations back to Earth first passes the data along to one of the orbiters using ultrahigh-frequency radio transmissions. If that orbiter doesn't have a line of sight to Earth, it can hold on to the information until it does. The data are then relayed toward Earth, where powerful radio antennas distributed across the globe are always listening for pings from deep space.

Once a human crew lands on Mars, this system will not be good enough. Vincent Chan, a researcher in fiber-optic and satellite communications at MIT, doesn't foresee local, on-the-ground

**Calling home** Perseverance and other Mars rovers get most commands directly from Earth via X band radio waves. Though Percy can send small amounts of data directly, it often uses ultrahigh-frequency, or UHF, radio waves to transmit data to one of the orbiters in the Mars Relay Network, which have big antennas for sending data to Earth. Percy is also a base station for communication with the helicopter Ingenuity.





communication as a challenge. A Martian crew can interact using radio frequency and existing wireless technologies, he says. Two mini cell towers would be enough when the astronauts are close together, and a relay of some kind could be used when the astronauts are far enough apart that messages have to be sent over the horizon. People living in remote regions of Earth communicate in a similar way all the time. “Those services are already in play,” Chan says, and “very economical.”

A big antenna on the crew’s landing vehicle, pointed toward Earth, would probably be the very first infrastructure Martian explorers would set up, Chan says, but then things could get more challenging. When that ground-based antenna doesn’t have a direct line of sight, astronauts could use orbital relays akin to the Mars Relay Network to communicate with Earth. Several orbiters would have to be available for round-the-clock coverage, and they’d need to be optimized for heavy data transfer.

ESA is currently looking at making today’s relay network more robust. It is in the early stages of considering a concept called the Mars Communication and Navigation Infrastructure, or MARCONI. If it moves forward, the project will develop a set of communication- and navigation-related payloads that could piggyback on any mission headed to Mars.

Once deployed into orbit, these payloads would act as nodes to provide radio communication on and with Mars, Parfitt explains. They could then stick around for use on future missions. “The more mass you land, the more expensive it is, so you wouldn’t

necessarily want to land massive communication systems on Mars every time,” she says.

Though traditional radio frequencies would suffice for low data rates, using a laser link could carry 10 to 100 times as much data in the same time frame. Because of the higher frequencies of optical waves, hundreds of thousands of times those of radio waves, much more information can be packed in. Thus, this type of optical signal is just where space communication may be headed.

### Learning from the moon — and Psyche

The Psyche spacecraft, launched last October, will test the feasibility of long-distance laser communications as it heads toward Psyche, the metal-rich asteroid it’s going to explore. The spacecraft carries NASA’s Deep Space Optical Communications, or DSOC, technology.

Using lasers for space communication isn’t new, but they have never been tested from distances farther than the moon. In mid-November, Psyche beamed data to Earth from a distance of 16 million kilometers — 40 times farther than the moon. In December, it sent a video of a cat named Taters from 31 million kilometers away.

ESA is also exploring long-distance optical communication. One program called ScyLight, short for Secure and Laser Communication Technology and pronounced *skylight*, is supporting the research and development of optical and quantum technologies for secure and fast data communication from space.

Despite the benefits, optical communication requires ultraprecision in aiming the signal. Unlike radio communications, optical signals are sent in a narrow beam that has to point exactly at the receiver. What’s more, cloud cover and atmospheric effects also interfere with lasers.

Any shift toward optical communications would mean some upgrades to the existing radio antennas that listen for messages from deep space — called the Deep Space Network — or new infrastructure.

Though it’s closer than Mars, the moon offers learning opportunities for future connectivity. As part of the Artemis program, which aims to return humans to the moon (SN: 12/3/22, p. 14), NASA has contracted private companies to set up a lunar 4G network for telecommunications. Such networks are based on radio waves and would include installing antennas and base stations that can withstand the harsh lunar landscape.

An ESA program called Moonlight invites private space companies to set up a constellation of communication satellites around the moon, including for regions that don’t have direct visibility to Earth. The

NASA’s Deep Space Optical Communications technology, attached to the Psyche spacecraft, is currently testing laser communication beyond the moon. In this image of Psyche inside a clean room before launch, the transceiver is located (though not visible) to the right of DSOC’s tubelike sunshade.



first phase of the program includes the launch of the Lunar Pathfinder orbiter, currently planned for 2026.

“Everything that is being done for the moon, it’s got the objective of taking humans and missions to Mars,” says Tomas Navarro, who is based in London and is a future projects engineer with ESA.

## A thought experiment

Those Martian explorers, not to mention future inhabitants, will no doubt want to do more than send messages back and forth. They’ll want a setup akin to Earth’s internet, which we use for everything from sharing photos to accessing massive databases. In June 2023, Tobias Pfandzelter and David Bermbach of Technische Universität Berlin proposed that a fleet of satellites orbiting Mars could provide the Red Planet with its own offshoot internet.

Most of us here on Earth access the internet through our phones using radio-frequency radiation on either wireless 4G or 5G networks or through Wi-Fi routers. These connections are linked via fiber-optic cables around the world. The proposed Mars network would instead be similar to Starlink, a constellation of satellites in low Earth orbit operated by SpaceX (SN: 3/28/20, p. 24). On Earth, broadband internet and mobile phone coverage via satellite is expensive, but on Mars, such a system might be cheaper and easier to build than an expansive and robust network on the ground.

Pfandzelter and Bermbach are both experts in cloud computing—the delivery of computing services over the internet. For their proposed Martian internet, they extrapolated concepts from edge computing, in which information is processed close to where it is collected.

Pfandzelter and Bermbach are both experts in cloud computing—the delivery of computing services over the internet. For their proposed Martian internet, they extrapolated concepts from edge computing, in which information is processed close to where it is collected.

Michael Clegg, a general manager at the technology company Supermicro, based in San Jose, Calif., has explained edge computing using the analogy of a popular pizza restaurant “that opens smaller branches in more neighborhoods, since a pie baked at the main location would get cold on its way to a distant customer.” Edge computing generally relies on base stations on the ground to store and relay the data, but low Earth orbit satellites are now being seen as an alternative.

Pfandzelter and Bermbach concluded that a constellation of 81 low-orbit satellites around Mars would be good enough for planetwide coverage. They would provide a local communications system that would be an extension of Earth’s internet.

Consider an astronaut on Mars trying to catch up on a Netflix show. “If you were to stream it from Earth, you would have to first wait 10, 15 or even 40 minutes,” Pfandzelter says, and that’s just to

connect. It would be a frustrating stop-and-start affair. And if another astronaut on Mars wanted to watch the same movie, they have to go through the same process all over again.

Instead, a cloud data storage system on Mars could make movies easy to access. “You could just have the same experience that you have on Earth, because all your data is locally copied,” he says. Meanwhile, other uploads and downloads to and from Earth, such as science data, could continue in the background.

Putting internet satellites into orbit around Mars would also be economical because it wouldn’t require landing infrastructure on the surface; landing equipment can make up a big chunk of a mission’s budget. “It would be much cheaper to just send a bunch of networking satellites to Mars, and just keep them in orbit,” says Pfandzelter.

It’s similar to a scaled-up version of the MARCONI concept (and could use radio or optical waves, depending on the state of those technologies).

Even if arrival on Mars is decades away, Parfitt says, it’s not too soon to start planning. Live video-chatting between planets is out of the realm of scientific possibility. Unless there is a major upheaval in the laws of physics, messages won’t ever be able to travel faster than the speed of light. “It’s not a problem to be solved. It’s just a problem.”

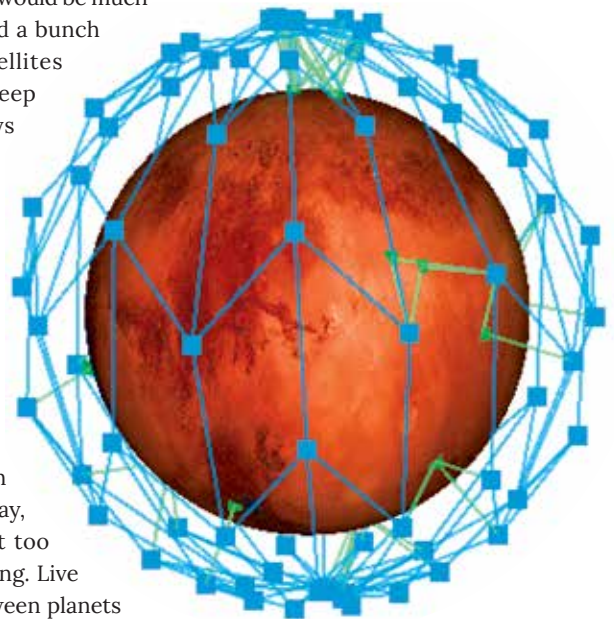
But other limitations can be overcome. Tackling those challenges may not only benefit future astronauts on Mars but may also help get them there sooner.

“When you put in an infrastructure like that,” Parfitt says, “you see many, many more missions being proposed.” ■

## Explore more

- For more on the DSOX experiment, visit [go.nasa.gov/3UoX4jx](https://go.nasa.gov/3UoX4jx)

*Payal Dhar is a freelance journalist and author based in Bangalore, India.*



A team of researchers suggests that a network of 81 satellites in orbit around Mars, depicted here in blue, could offer planetwide internet coverage. Green points show Mars landing sites as of 2018.

## BOOKSHELF

## An ode to the moon

Science journalist Rebecca Boyle has an intergenerational connection with the moon. Her grandfather Pfc. John J. Corcoran was involved in the 1943 Battle of Tarawa on the namesake atoll in the Pacific Ocean during World War II. The United States' narrow victory against Japan came at heavy human cost. One reason: A weak high tide forced American soldiers to wade through the ocean into Japanese gunfire rather than sail their boats to meet their enemies.

Historians blame the moon for the massive casualties — the battle occurred during a time of month when the sun's and moon's gravitational tugs partially cancel each other out, contributing to the lower-than-usual high tide.

Boyle, however, recognizes that the moon's impact on humankind is far more vast and multifaceted. After all, the moon helped shape Earth into the home we know, she writes in her new book, *Our Moon*. At the outset, Boyle promises to convince readers of the moon's extensive influences, both biological and spiritual. Over nearly 300 pages, she delivers.

Naturally, the book touches on well-known subjects, including the Apollo missions that brought humans to the lunar surface. Still, the book is guaranteed to surprise, filled with factoid gold that will enthrall geologists, moon nerds and casual readers alike. For instance, Boyle incorporates new research on how the moon formed 4.5 billion years ago, pointing to geologic evidence that may still be entombed deep within Earth's mantle. And contrary to what Apollo photos suggest, the moon's surface sparkles with technicolor hues, astronauts reported. "The Moon was not gray, but a landscape flecked with color,"



**Our Moon**  
Rebecca Boyle  
RANDOM HOUSE,  
\$28.99

Boyle writes.

"Analysis of the

Moon rocks has since found volcanic glass in every color of the spectrum."

And then there are the ways the moon has influenced life on Earth. The tides pulled our ocean-confined ancestors out of the water. Extremes between high and low tides in the distant past kept beaching marine life; those that could breathe in air or developed limbs for walking became the earliest landlubbers. Acting as a mini counterweight to the Earth's own heft, the moon has kept our planet's axis from lurching all over the place, thereby preventing extreme climate swings over millennia. The moon also inspired the first religions, and its study spawned the first science.

Boyle packs in an impressive amount of information.

But instead of throwing details at the reader, she packages them into imagined experiences of a lunar visitor. The result is a rich travelogue that makes the moon's sensations visceral, down to its acrid smell and the hay fever you'd get from exposure to pesky lunar dust. Early humans brought the distant moon down to Earth through patient observation and art. Now, Boyle brings readers up there.

With much ground to cover, she divides the book into three sections: the moon's making, its cultural footprint and how modern society recast the moon in a new light. Rather than adhering to a strict chronology, Boyle roams under these three broad umbrellas. Her discussions within each section come in palatable bite sizes and swing between the ancient and modern, culture and science.

That masterful weaving is on display when Boyle recounts the moon's role in keeping track of time. "Time confers power to whoever commands it," she writes, and it remains "the simplest and

Various societies have used the phases of the moon to track time.

most predictable way to seize that command." Stone Age Scots, Mesopotamians and Native Americans understood the power of the lunar cycles, and they erected monuments to track the moon's trek across the sky. But around 45 B.C., Julius Caesar designed a calendar that banished the moon from its timekeeping duties. Now, society mostly looks to the sun as our daily metronome.

Today, we're at another juncture where the moon might further drop from its standing of reverence and communion. Soon, astronauts will return there, with the United States, China and other countries scoping out landing sites. Instead of being endeavors for the benefit of all humankind, these explorations will probably be a nationalistic race for scientific real estate, Boyle warns. Our heavenly neighbor is also being eyed as a mining outpost, a junkyard, a waystation for deep space travel or a settlement destination. The moon, she worries, may fall into the ravenous maw of capitalism.

Still, the moon is more than just another target for humankind's material ambitions. *Our Moon* reminds us that our "silvery sister" has given us our habitable climate, sciences and cultures. These gifts are more than enough; they are priceless.

— *Shi En Kim*

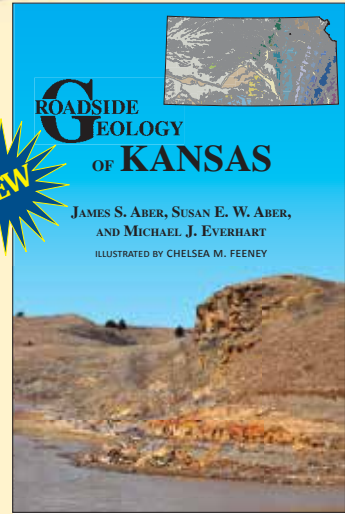


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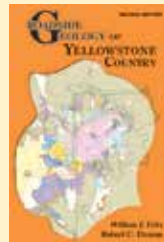
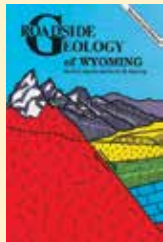
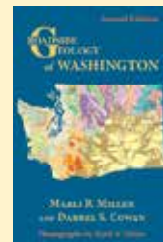
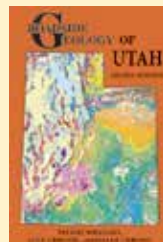
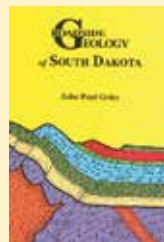
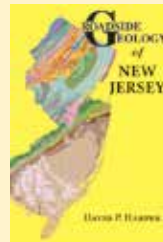
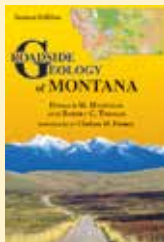
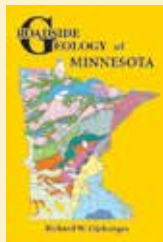
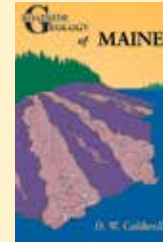
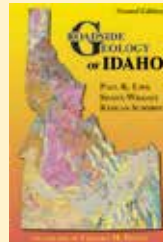
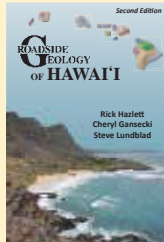
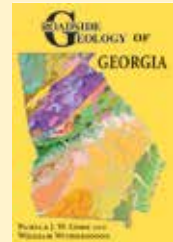
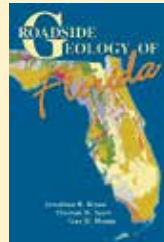
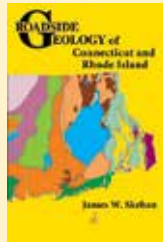
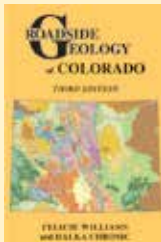
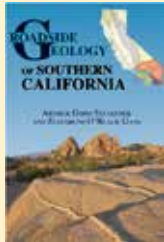
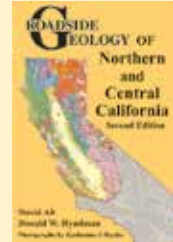
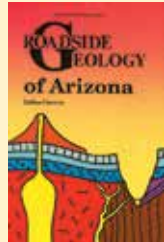


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# GRAVITY: KEY TO STORING GREEN ENERGY?

Engineers are working on a new type of “battery” that is nothing like those that power remote controls and MP3 players or run electric cars. Built underground, these enormous new batteries are infinitely rechargeable and run on gravity.

These new batteries could help address a looming problem: storing solar and wind energy to generate power when the sun doesn’t shine or the wind doesn’t blow. The battery is created by raising something big and heavy—from a lump of concrete to metal blocks—and then lowering

them to release their kinetic energy, which runs a turbine to produce electricity.

This story, along with an explainer on potential and kinetic energy, appears online and in the February print issue of Science News Explores, our award-winning magazine for young people. It is the ninth story in our climate change solutions series, Action for Earth. While paging through that issue, be sure to also check out our top 10 tips for how Gen Z’ers can get their best online experiences.



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### Conservation considerations

The online mapping tool *Landscape Explorer* uses historical and modern aerial images to show how the American West's landscapes have changed over the last 70 years, **Brianna Randall** wrote in “*Landscape Explorer transports you back to a more wild West*” (SN: 12/2/23, p. 32). **Randall** wrote that *Landscape Explorer* has helped conservationists in Montana prioritize where to remove invasive trees that have taken root in grasslands, which threaten local biodiversity and increase the risk of catastrophic wildfires. Given the climate crisis, reader **Mark Granville** wondered why conservationists would cut down trees that help remove carbon dioxide from the atmosphere. Is grass better at trapping the greenhouse gas?

Though mitigating carbon emissions is key in combating the climate crisis, other ecosystem benefits like biodiversity, water storage, and people’s cultural and spiritual values remain important, says **Kelsey Molloy**, a rangeland ecologist at the Nature Conservancy, which is a member of the partnership that led the Montana efforts. That said, the role of grasslands and other rangelands in storing carbon is often overlooked, **Molloy** says. “Grasses store carbon deep in the soil, and that carbon is not lost from fires the way [it is] in treed landscapes.”

It’s a common misconception that planting more trees everywhere will decrease global warming, says **Scott Morford**, an applied spatial ecologist at the University of Montana in Missoula who led the development of *Landscape Explorer*. “In places like the Amazon, maintaining and increasing tree cover is critical for global climate regulation. In snow-dominated grasslands and shrublands, however, there is no clear evidence that increasing tree cover contributes to climate cooling,” he says.

Planting trees in historically treeless grasslands can also increase warming by altering the way the land surface reflects light back into space, **Morford** says. “In the northern Great Plains of the United States, tree cover would need to surpass 95 percent to achieve even a small net cooling effect.”

Previous simulations have even suggested that removing vast swaths of forests in the Northern Hemisphere and replacing them with grasslands may help cool the planet due to changes in the land surface’s reflectivity, **Morford** says. Of course, “no reasonable conservationist who values grassland protection would suggest cutting down North America’s northern forests to benefit the climate,” he says. “We are instead dedicated to safeguarding what little remains of the planet’s most endangered terrestrial biome and averting the collapse of its unique and essential biodiversity.”

As we seek solutions to the climate crisis, it’s important not to pit ecosystems and environmental challenges against one another, **Morford** says. “Rather, let’s unite to address the intertwined challenges of climate change and biodiversity loss in a way that preserves all the natural systems we cherish.”

### Bird acrobatics

*High-speed cameras reveal that Anna’s hummingbirds turn sideways to slip through gaps narrower than their wingspan*, **Erin Garcia de Jesús** reported in “*Hummingbirds show off a flight trick*” (SN: 12/16/23 & 12/30/23, p. 14).

The story unlocked a memory for reader **Blair Campbell**: “Years ago, in my parents’ backyard, [which was] partially enclosed by a chain link fence installed to pen the little dog, I was fascinated to see a ruby-throated hummingbird take a weaving flight back and forth through the links.”

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## The oldest known fossilized skin shows how life adapted to land

A dark sliver of rock pulled from an Oklahoma limestone quarry is the world's oldest fossil of skin ever found.

The fossil is nearly 290 million years old, researchers report in the Jan. 22 *Current Biology*, and once dressed a species of amniote, a group of four-legged vertebrates that evolved from amphibians and includes all reptiles, birds and mammals. It's 21 million years older than the only other reported fossilized skin from the Paleozoic Era, spanning 541 million to 252 million years ago, during which animals moved onshore and diversified.

"This is definitively the oldest [known] piece of mummified skin," says paleontologist Ethan Mooney of the University of Toronto Mississauga. It fits "into a broader story of how the first animals left the water and went onto land."

Fossil collectors Bill and Julie May found the fossil (the two pieces left of the bottom right piece above), along with exquisitely preserved skin impressions (also shown), at an Oklahoma quarry in an ancient limestone cave system known as Richards Spur, a huge trove of amniote and amphibian fossils.

There, a special concoction of cave conditions contributed to the skin fossils' superb preservation. Corpses were buried in fine sediments, which excluded oxygen and slowed decay, and were exposed to groundwater rich in iron, an element that helps preserve tissues. Also, the site was an ancient oil seep. Petroleum and tar permeated the remains, sealing them off from decaying conditions while also staining them black.

The skin samples all have nonoverlapping scales, though the scale sizes, distributions and abundances vary. The specimens probably come from different places on the amniote body, Mooney's team suggests, and possibly different animals too.

Cross sections of the cast revealed a thickened outer skin layer, or epidermis. The development of a robust epidermis would have protected the early amniotes from the elements while also helping them retain water.

Eventually, the scaly, beefed-up epidermis led to bird feathers and mammalian hair follicles. Tough and bumpy amniote skin, Mooney says, was "the first stage." — *Nikk Ogasa*



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