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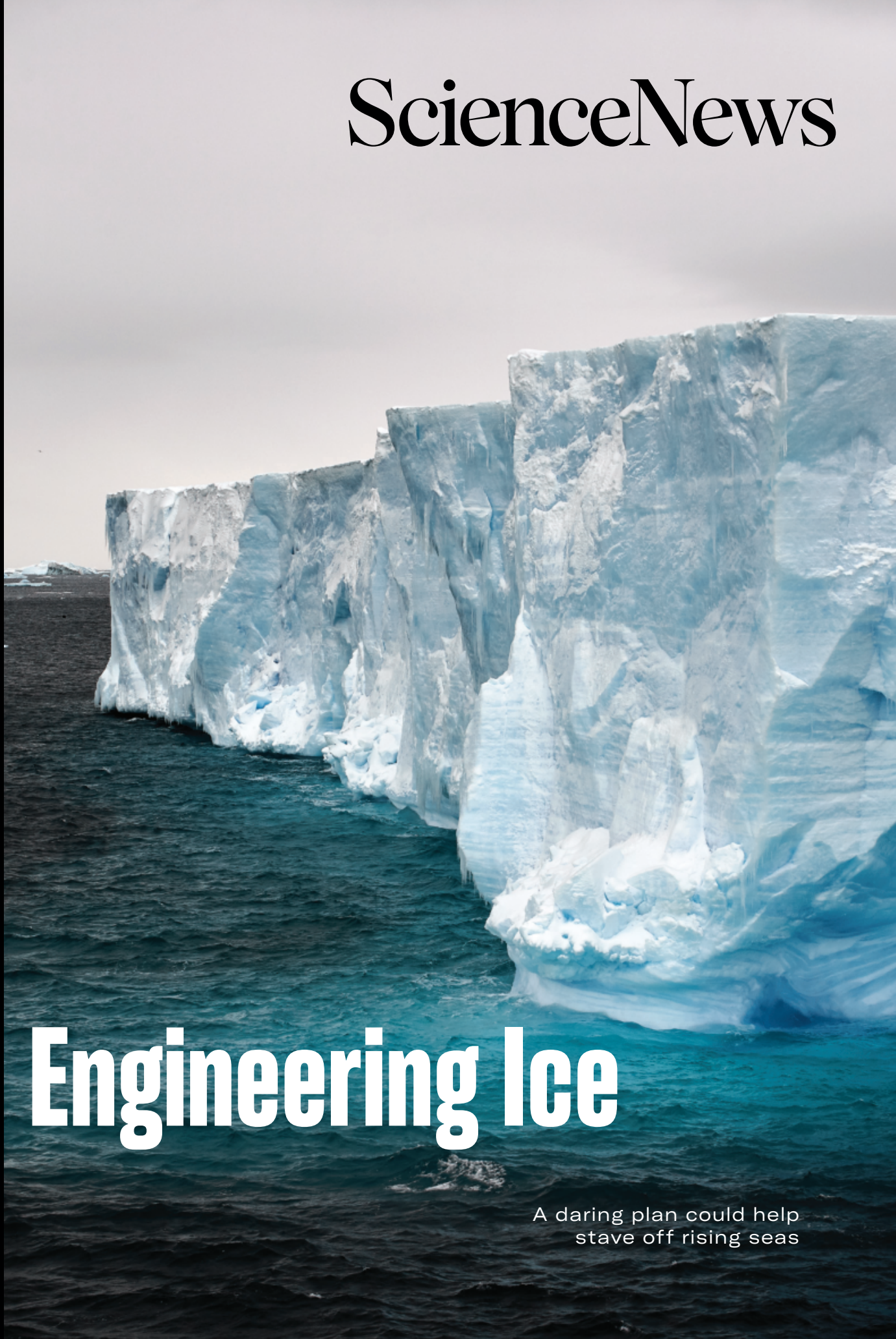

Engineering Ice

A daring plan could help stave off rising seas

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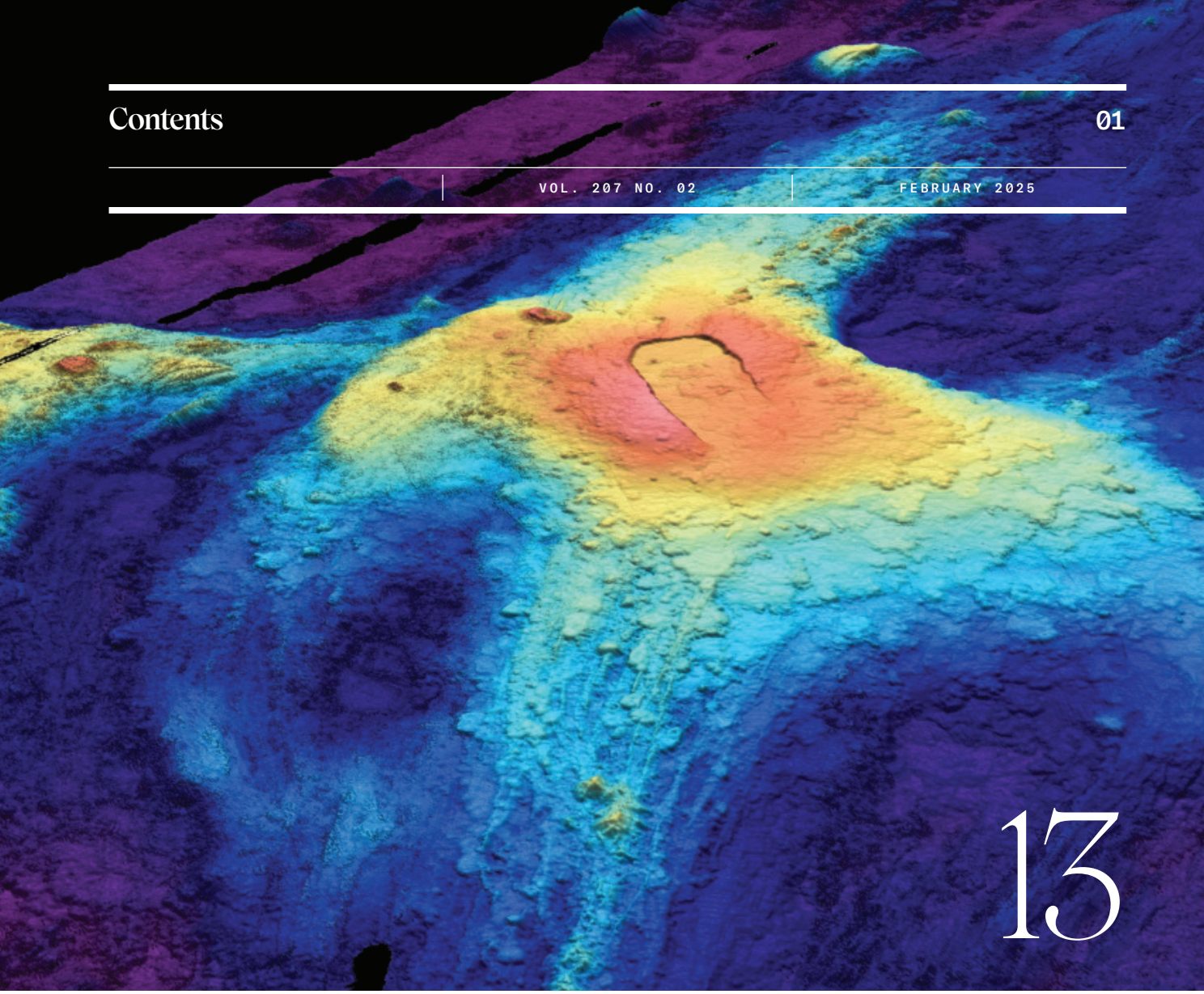

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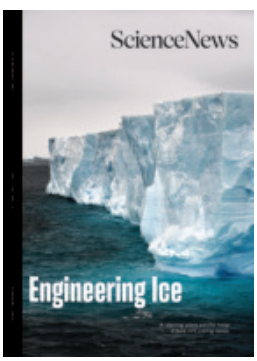

On the Cover

Photograph by Jonathan Pozniak

SUSAN MERLE/OREGON STATE UNIV.

Circle keeping ... has been an effective approach to fostering connectivity and learning about each other through shared stories, instead of plunging headlong into accomplishing goals. It has also been important for flattening established hierarchies by holding an equal space for every voice regardless of whether it is from a rookie or an established investigator."

–Ruma Banerjee, Vincent Massey Collegiate Professor of Biological Chemistry, University of Michigan Medical School, Co-Director, ASBMB MOSAIC program

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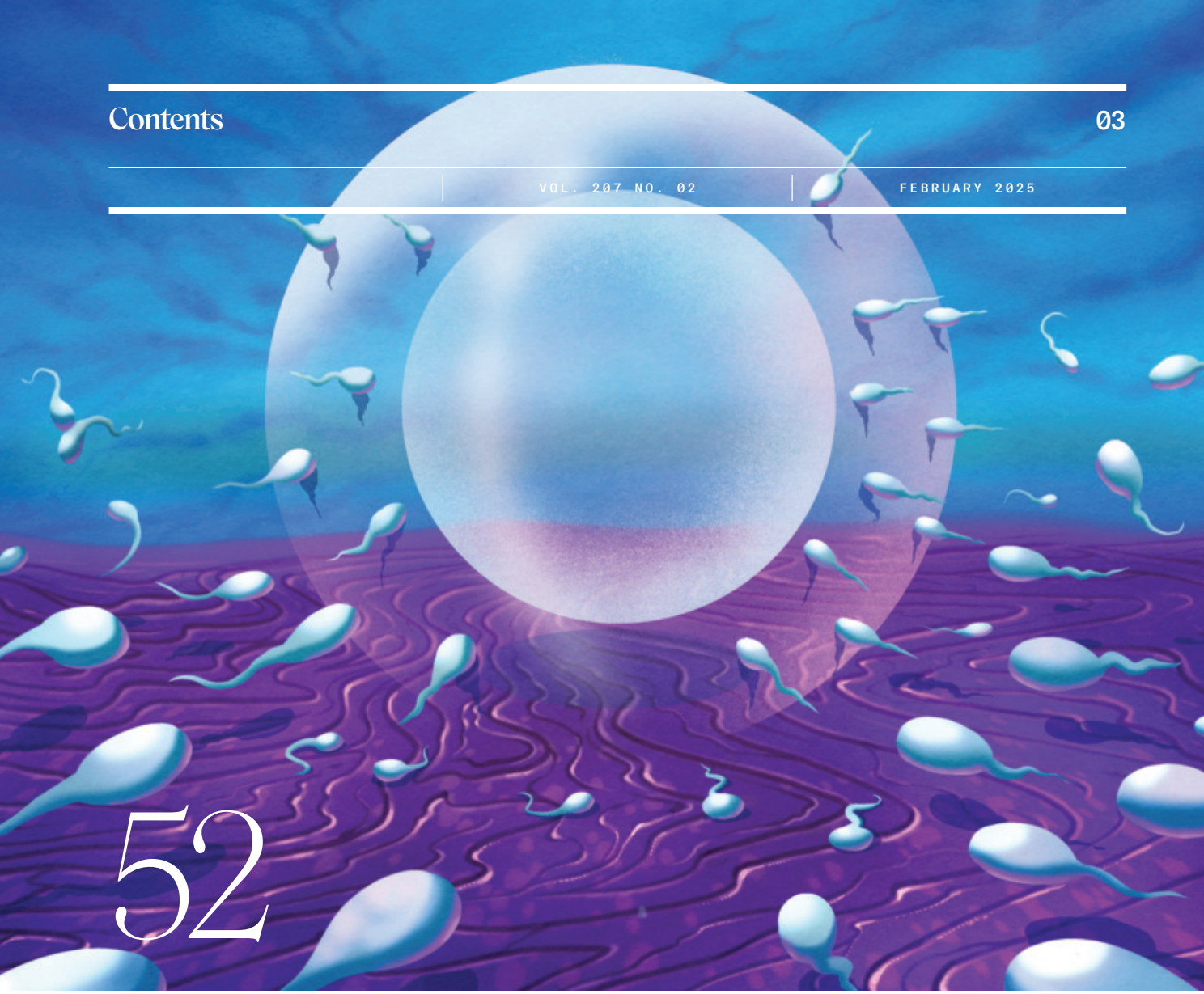

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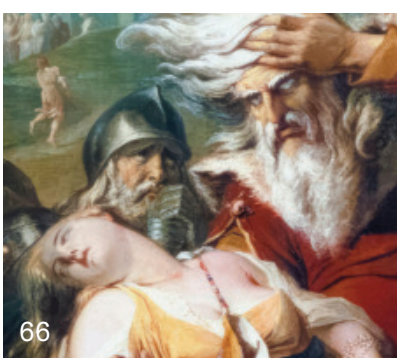

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FROM TOP: ARIK ROPER; ALBUM/ALAMY STOCK PHOTO

A daring plan to hold back the sea

Canute, king of England in the 11th century, achieved legendary status by ordering that his throne be carried to the shore, whereupon he ordered the tide to stop rising. When the ocean did not comply, he proclaimed it as proof that even kings have limits to their powers. Some historians interpret this as an act of piety; only God can rule the sea. But the tale is also sometimes misread as an example of human folly.

Today, there are good reasons to wish the sea to yield. Sea levels are rising worldwide, with low-lying Pacific islands and cities including Bangkok, Amsterdam, Shanghai and Miami increasingly at risk of inundation. The vast glaciers at the North and South poles are among the biggest threats. In the last few years, scientists have become so worried about the catastrophe that melting ice could cause that they are urging humankind to seriously consider tackling what would be the biggest engineering projects ever, including building underwater curtains to hold back warm seawater and prevent glacial melting.

It sounds like a folly only a megalomaniac would put forth. But freelance journalist and frequent *Science News* contributor Douglas Fox explains why this and other audacious ideas are getting serious consideration (Page 34). Fox is well equipped for the assignment, having previously traveled to Antarctica to report on the continent's massive glaciers.

This month we also debut math puzzles (Page 68). The logic, reasoning and problem-solving used in mathematics are fertile ground for puzzles and games. When we decided to include puzzles in the magazine's redesign, we knew math puzzles had to be in the mix. I'm delighted that Ben Orlin, author of multiple books including *Math for English Majors*, has created our first math puzzle. Going forward, we'll alternate science-themed crosswords and math puzzles in the magazine, and we welcome your feedback.

In addition, *Science News* is launching its first podcast. *The Deep End* is based on our award-winning multimedia project Electricity Saved My Brain, which chronicled the experiences of people with severe depression who received experimental brain implants. *Science News* neuroscience senior writer Laura Sanders hosts. The show debuts February 10 and is made possible thanks to our partnership with public media organization PRX. Listen at bit.ly/SN_TheDeepEnd. I hope you'll find it as fascinating and deeply moving as I did.

Nancy Shute
Editor in Chief
nshute@sciencenews.org

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DOUGLAS FOX

FREELANCE JOURNALIST

● IN OUR COVER STORY, Douglas Fox tackles a looming consequence of climate change: sea level rise caused by melting Antarctic ice. Some scientists are so alarmed that they are exploring plans to slow or even stop the melt by drilling holes into glaciers to help freeze them to their beds or setting up giant curtains to keep warm water away (Page 34). Fox became aware of these glacial engineering efforts when glaciologist Slawek Tulaczyk mentioned an ice-loss interventions workshop in 2023. "I found it striking that this person whom I'd long seen as cautious and conservative had been quietly thinking about climate interventions that might otherwise seem extreme," Fox says. "It caused me to take more notice than I otherwise might have."

Amber Dance
For freelance science journalist Amber Dance, reporting on some museums' efforts to retool science dioramas hit close to home (Page 44). "I visited the Carnegie Museum of Natural History a lot when I was small — my mom was a docent there before I was born," Dance says. "It was fun to return there with an eye towards diorama development." The story also allowed her to delve into history, which, she says, "is not something I often get to report on when writing news."

Fred Schwaller
Men have limited options for birth control, primarily condoms and vasectomies. But that could soon change. Science writer and editor Fred Schwaller reports from Berlin on two new types of male contraceptives that have shown promise in clinical trials and others that are coming down the pipeline (Page 52). If these contraceptives can overcome regulatory hurdles, "their benefits on family planning and social equity will be huge," Schwaller says.

Bethany Brookshire
Tragic love stories and Valentine's Day compelled freelance journalist Bethany Brookshire to cover broken heart syndrome in this issue's Technically Fiction (Page 66). "We know so little about how to treat it successfully," says Brookshire, who previously was a staff writer for *Science News Explores*. "As a former physiologist, I know that we know far less than we think about the human body, but it's always wild to me to come across yet another instance where we just don't know what to do!"

Ben Orlin
Put on your thinking cap for *Science News*' inaugural math puzzle, which asks readers to imagine a world without zero (Page 68). The puzzle's maker, Ben Orlin, is an author and part-time math teacher. He credits the book *Reckonings* by anthropologist Stephen Chrisomalis for introducing him to the idea of zeroless numerals. "I feel lucky to get to share fun ideas with readers," Orlin says, "and I hope they share their ideas right back."

CLOCKWISE FROM TOP LEFT: J.T. THOMAS; KATIE WITT; FRANZISKA POTHOU; LANCER PHOTOGRAPHY; RAYLEEN TRITT

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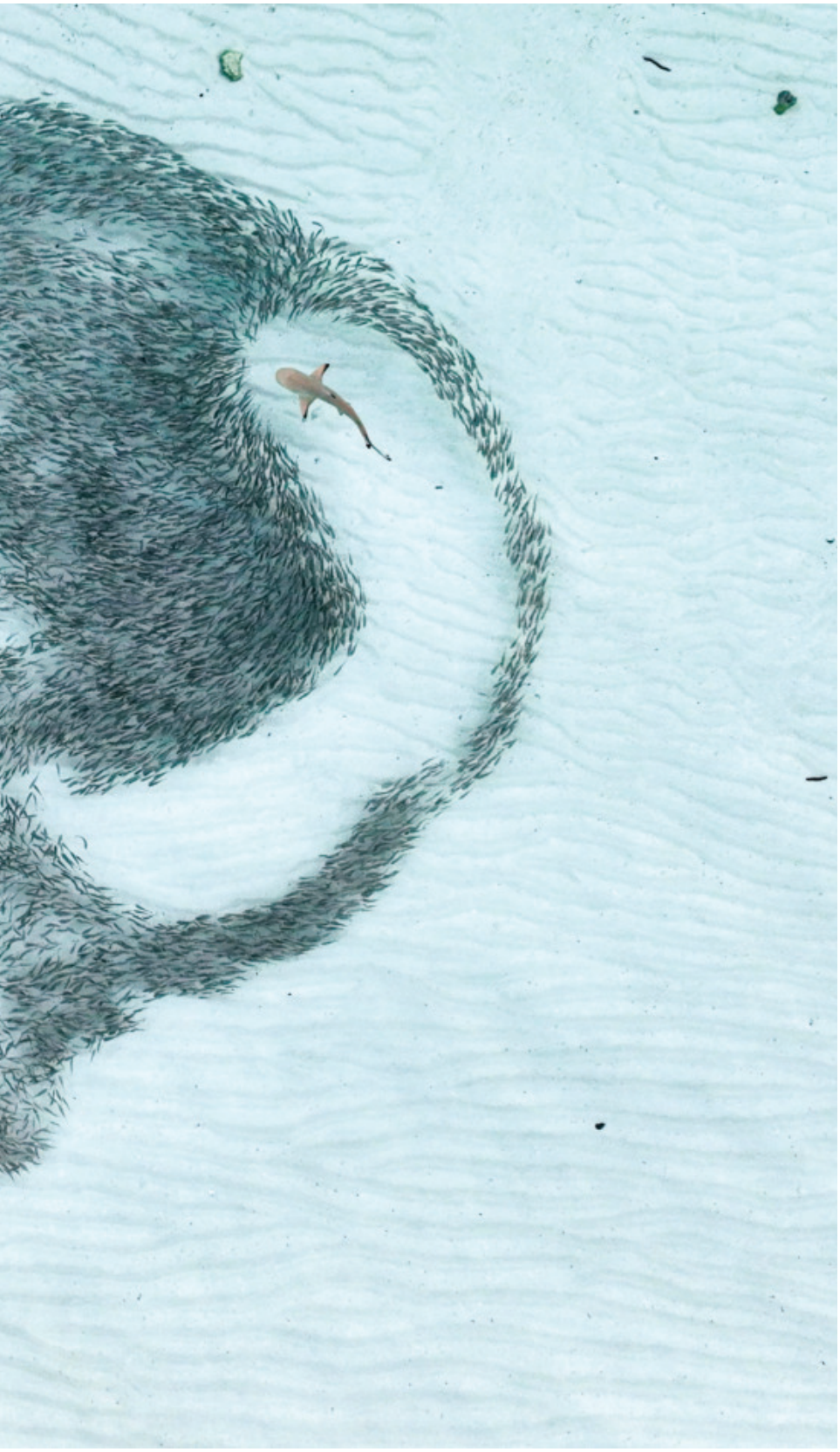

ANIMALS

A BIRD'S-EYE VIEW OF A SHARK HUNT

By Tina Hesman Saey

● **A school of hardyhead** silverside fish (*Atherinomorus lacunosus*) flees from four blacktip reef sharks near the shore of the Maldives in this aerial photo. Behavioral biologists Angela Albi and August Paula of the Max Planck Institute of Animal Behavior in Konstanz, Germany, captured the image, a still frame from drone footage, during a study of how sharks interact with each other and their prey. Blacktip reef sharks (*Carcharhinus melanopterus*) are social animals, and juveniles, such as these four, often gather and circle within schools of fish. Albi is trying to determine whether the sharks coordinate their attacks. The snapshot won the 2024 Royal Society Publishing Photography Competition. Scientists from around the world submitted images from their research in five categories.

PHOTO BY A. ALBI AND A. PAULA

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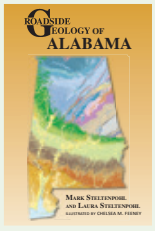

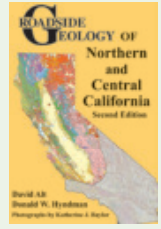

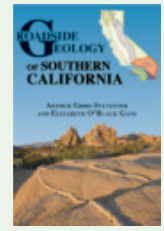

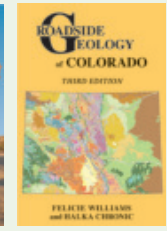

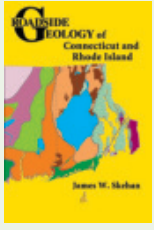

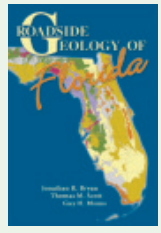

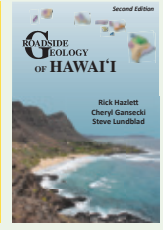

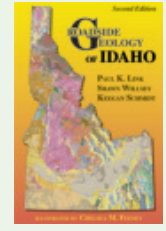

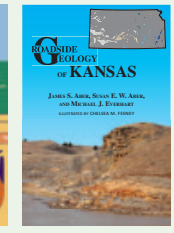

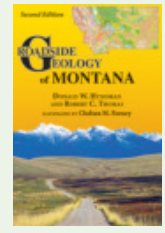

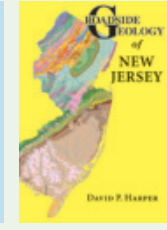

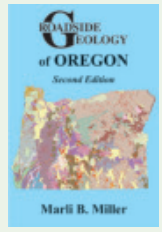

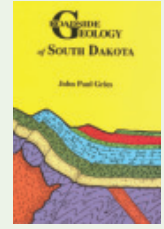

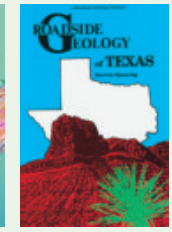

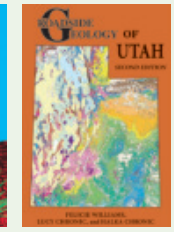

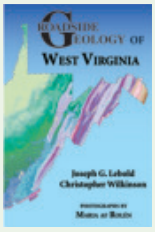

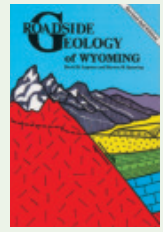

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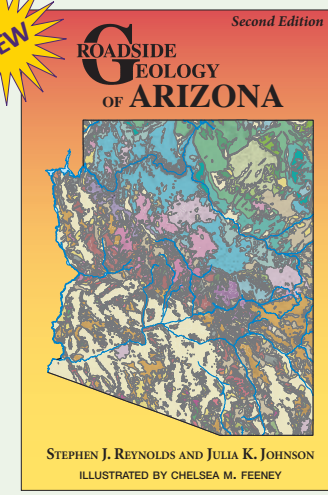

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News

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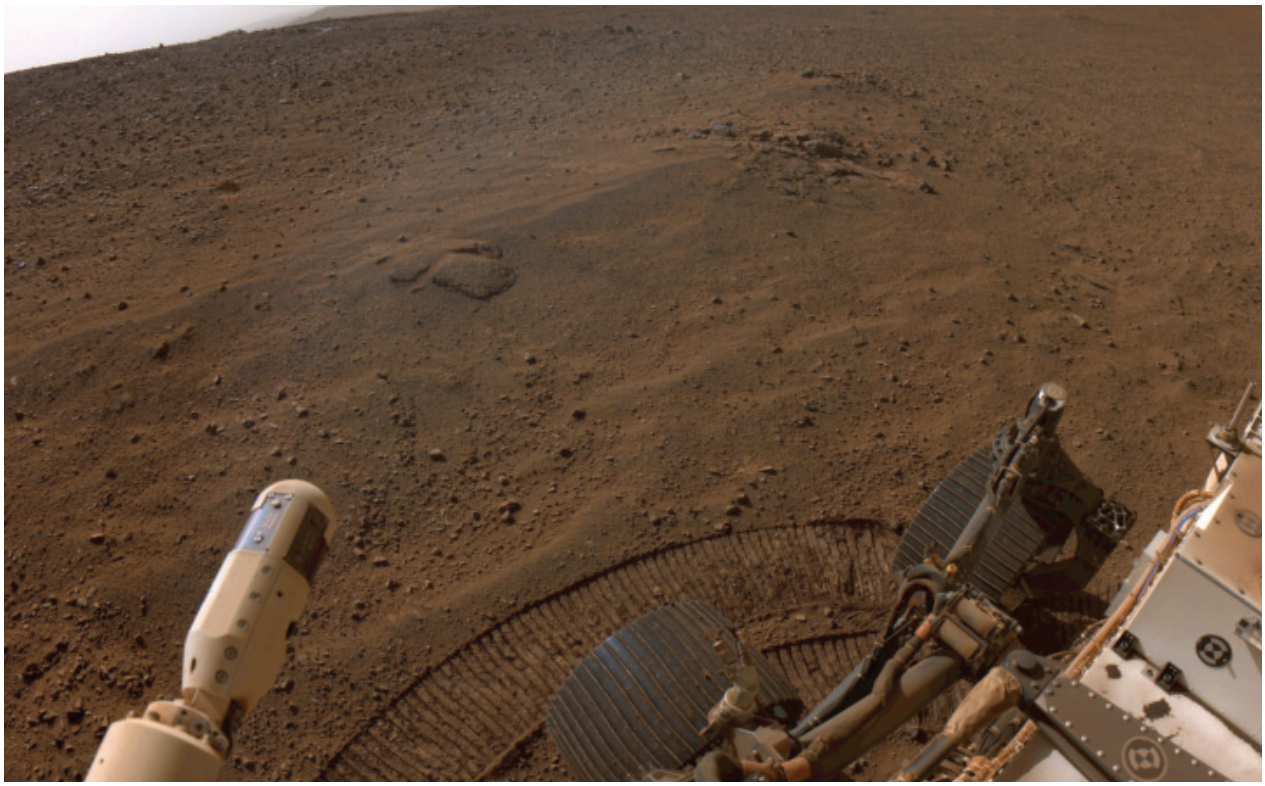
ECOSYSTEMS

ETHIOPIAN WOLVES STOP AND LICK THE FLOWERS

● Some carnivores have a taste for dessert. *Canis simensis* wolves in Ethiopia's highlands dine almost exclusively on rodents. But the predators also have a sweet tooth, sometimes slurping nectar from Ethiopian red hot pokers (*Kniphofia foliosa*). This newly documented behavior hints at an unexpected role for the wolves: pollinator. As a wolf licks nectar from the cone-shaped flowers, its snout can become covered in pollen that may get passed to other blooms. The wolves are the first large carnivorous predators known to feed on flowers. — *Erin Garcia de Jesús*



PLANETARY SCIENCE

Rover finds a potential setting for Martian life

By Nikk Ogasa

● **The Perseverance Rover on Mars** may have stumbled upon the oldest rocks humans have ever seen and, possibly, evidence of a new setting that ancient Martian organisms could have inhabited, if they ever existed.

"This is really one of the most exciting things that this mission is going to do, is to be looking at rocks that were formed so early in the history of the solar system," Caltech geochemist Kenneth Farley said during a news briefing at a meeting of the American Geophysical Union that was held in Washington, D.C. "Almost the dawn of the solar system."

For most of its mission, Perseverance has been poking around Jezero crater, probing and sampling rocks that are probably about 3.7 billion years old. The rocks at the rim, however, are probably much older, having been uplifted by the impact that created the crater.

In December — following a 500-meter climb from Jezero's floor — the robot surmounted the crater rim after weeks of studying the area's geology. And all that exploration appears to have paid off.

The rocks are likely older than 4 billion years, Farley said. "These are among the oldest rocks in the solar system, and they're older than any rocks that exist on Earth."

At the top of the crater, the rover traveled through an area known as the Pico Turquino Hills and took images of numerous outcrops. The rocks there "are extremely diverse, and it appears that each one of the hills ... has a distinct assemblage of largely igneous minerals, with some alteration by water," Farley said. "These are likely pieces of the earliest crust."

↑ The rover Perseverance took this photo looking out over the rim of Mars' Jezero crater in December.

JPL-CALTECH/NASA

Since instruments aboard the rover can't precisely date the rocks, researchers are basing these age estimates on their current understanding of the crater's formation and Mars' history. "This is one of the reasons why we want to do sample return," Farley said. NASA is currently reviewing new plans for its Mars sample return mission after an independent review concluded the initial plan was too costly and slow.

If the newly encountered Martian rocks are really that old, they could contain information about how rocky planets like Mars and Earth evolved in their infancy.

Ancient rocks weren't all that Perseverance found. The rover also came across evidence of a completely new setting that could have been habitable for possible Martian life: a field of white, cantaloupe-sized stones. "The instruments aboard the rover confirm that these cobbles are pure quartz," Farley said. "This has never been seen before" on Mars.

Quartz forms in places where hot fluids circulate through rocks, and sometimes at temperatures that are habitable. These Martian rocks may have formed in a setting akin to a hot spring, which can support life on Earth. The goal is to now search for and sample quartz embedded in the Red Planet's surface.

Perseverance will spend the next several months away from the crater exploring Witch Hazel Hill. Rocks there should be more representative of the broader region's geology, Candice Bedford, a planetary scientist at Purdue University in West Lafayette, Ind., said at the news briefing.

NASA has already ID'd outcroppings of layered rocks at the site. Looking through the layers, Bedford said, would be "like turning a [page in the book] of Martian history." ✖

EARTH

AN UNDERSEA VOLCANO MAY SOON ERUPT NEAR OREGON

BY RACHEL BERKOWITZ

An undersea volcano is likely to erupt sometime in 2025. This much advance notice is a big deal, because forecasting eruptions more than hours ahead is "pretty unique," says geophysicist William Chadwick. About 470 kilometers off the Oregon coast and over a kilometer beneath the waves, a volcano known as Axial Seamount ticks all the boxes that hint at imminent activity, Chadwick and colleagues reported at a meeting of the American Geophysical Union that was held in Washington, D.C.

For the last decade, a suite of devices have been monitoring Axial's every action — rumbling, shaking, swelling, tilting — and delivering real-time data via a seafloor cable. It's "the most well-instrumented submarine volcano on the planet," says Mark Zumberge, a geophysicist at Scripps Institution of Oceanography in La Jolla, Calif., who was not involved in the work.

In November, a particular milestone caught Chadwick's eye: Axial's surface had ballooned to nearly the same height as it had before the volcano last erupted in 2015. Ballooning is a sign that magma has accumulated underground and is building pressure.

The 2015 swelling allowed his team to predict that year's eruption — "our best forecasting success," says Chadwick, of Oregon State University's Hatfield Marine Science Center in Newport. The recent swelling, along with increased seismic activity that indicates moving magma, has led the researchers to narrow in on the next one.

Axial scientists also have a new tool for estimating the day-of magma burst that will set things off. And other researchers recently used artificial intelligence to analyze data from earthquakes that preceded the 2015 eruption to identify exactly what patterns they should see hours ahead of the next one.

If this precursory earthquake detection works, it will be a field day for volcanologists such as Rebecca Carey. Detecting early warning signals offers the "exciting opportunity to deploy remotely operated vehicles to catch the eruption occurring," says Carey, of the University of CONT. ON PAGE 14

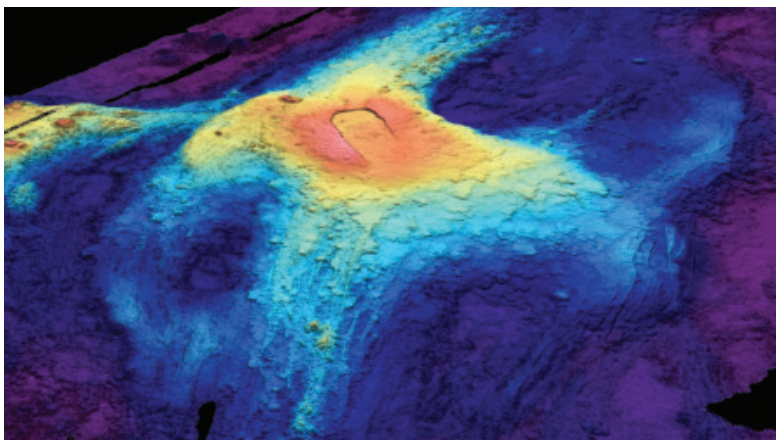
CONT. FROM PAGE 13 Tasmania in Sandy Bay, Australia. That could offer a glimpse into an eruption's effects on nearby hydrothermal systems and biological communities.

For humans, volcanoes on land generally pose a bigger hazard than ones underwater do. But that's not always the case. The 2022 Hunga Tonga eruption in the South Pacific Ocean triggered a tsunami that caused at least $90 million in damages. Generally, "forecasting is difficult," Chadwick says. One disincentive for experimental forecasting on land is the risk of false alarms, which could cause unnecessary evacuations and future distrust. At Axial, he says, "we don't have to worry about that."

Forecasting is only possible thanks to extensive monitoring data and knowledge of how a specific volcano behaves. "There's no crystal ball," says Valerio Acocella, a volcanologist at Roma Tre University in Rome. Rather, predictions are based on the expectation that when a volcano's activity reaches some threshold that it reached before, it may erupt.

Geophysicist Michael Poland of the U.S. Geological Survey's Cascades Volcano Observatory in Vancouver, Wash., agrees. Because most of today's efforts rely on recognizing patterns, he says, "there's always the risk that a volcano will follow a pattern that we haven't seen before and do something unexpected." Both Poland and Acocella hope that forecasts will evolve to be based on the physics and chemistry of the magma systems that underlie a volcano.

Until then, scientists will learn what they can from any successes. And Axial is a good place to try, Acocella says. It has relatively frequent eruptions, and each one is an opportunity to test ideas. That regular behavior makes Axial "a very promising volcano," he says. "We need these ideal cases to understand how volcanoes work." ✖



↓ This 2014 map of Axial Seamount shows the underwater volcano's elevation above the seafloor. Red indicates higher elevation while dark blue indicates lower elevation.

SUSAN MERLE/OREGON STATE UNIV.

HEALTH & MEDICINE

AI could design lifesaving antivenoms

By Meghan Rosen

● **Artificial intelligence** could take the bite out of snake venom.

Using AI, scientists have designed proteins that say not so fassst to toxins wielded by cobras and other venomous snakes. It's a proof-of-concept approach that could one day offer a new much-needed treatment for snakebites. In lab tests, the custom proteins saved the lives of mice given an otherwise lethal dose of toxins, scientists report in *Nature*.

These proteins "are really doing their job," says Michael Hust, an antibody researcher at the Technical University of Braunschweig in Germany who wasn't involved in the research. "The mice are surviving. This is what we all want."

The study is the latest application of work on protein structure and design that earned three scientists the 2024 Nobel Prize in chemistry. About a year ago, medical biotechnologist Timothy Jenkins spotted a study from the lab of David Baker, a biochemist at the University of Washington School of Medicine in Seattle and one of the Nobel awardees. This study, which had yet to undergo peer-review, described AI-designed proteins that stick like superglue to specific molecules.

That sparked an idea: Could the AI think up a design that clamps onto and neutralizes snake venom toxins?

Jenkins, of the Technical University of Denmark in Lyngby, has spent years trying to develop new snakebite therapies. Worldwide, snakebites kill some 100,000 people each year. Venomous snakes can deliver a blizzard of toxins via their bite. Some of the most dangerous include three-finger toxins, which can stop people's hearts and the ability to breathe. Antivenoms exist, but the technology is outdated, Jenkins says.

Current antivenom producers milk snakes to extract their venom, which is "like handling a live hand grenade," Jenkins says. The producers inject a small dose of that venom into a horse or other large animal and later harvest antibodies.

When given to a snakebite victim, those antibodies bind to venom toxins, shutting them down. But manufacturing antivenom in this way is costly and time-consuming, so scientists have been searching for other methods. One option that's seen recent success is scanning a vast collection of lab-made antibodies to identify those that target particular toxins.

With AI, scientists can quickly build toxin-targeting proteins from scratch. Jenkins and Baker created custom proteins using a generative AI model called RFdiffusion. It's a free protein-design tool that shares some similarity with AIs that generate images. Instead of conjuring up a picture of the pope in a puffer jacket, RFdiffusion can concoct protein designs that match a molecule scientists want to target.

Baker's team had trained the AI on all known protein structures and their amino acid sequences, the string of molecular building blocks that fold up into a protein's 3-D shape. Then, the team computationally disassembled those shapes. That taught the AI how to put together a complete protein from its components, like learning how to build a car engine by taking it apart.

Baker and Jenkins asked the AI to design proteins that would glom on to venom toxins. Then they manufactured the proteins in the lab. Like a magnetic cap covering the tip of a key, the synthesized proteins prevented the toxin from docking onto cells.

The team injected 20 mice with the custom proteins 15 minutes after a lethal dose of cobra toxins. Every mouse survived. "We were very, very excited about this," Jenkins says.

The team wants to develop the proteins into a product that could be tested in humans. But scientists will need to ensure the custom proteins are safe, Hust says. Jenkins agrees. The study is a first step to defanging venoms' harms. ✖

100 percent

The survival rate of mice given AI-designed antivenoms and a lethal dose of snake toxins

NEIL WEBB

ANTHROPOLOGY

HUMANS HAVE LINKED EMOTIONS TO THE BODY FOR MILLENNIA

By Jason Bittel

● Have you ever felt like there was a pit in your stomach? What about a flutter in your heart? It turns out that anatomical connections we make with certain emotions may go back at least 3,000 years, researchers report in *iScience*.

Cognitive neuroscientist Juha Lahnakoski and colleagues cataloged words for body parts and emotions used by people who lived in Mesopotamia between 934 and 612 B.C. The team compared those ideas, which were etched on clay tablets and other artifacts, to modern-day links between emotions and body parts.

Certain body areas are still used in similar contexts in modern times, says Lahnakoski, of LVR Clinic Düsseldorf in Germany. "The heart was often mentioned together with positive emotions such as love, pride and happiness, as we might still say 'my heart swelled' with joy or pride." These ancient people, who lived during the Neo-Assyrian Empire, also associated the stomach with feelings of sadness and distress.

Not every connection has stood the test of time. For instance, Neo-Assyrians linked anger with the legs and happiness with the liver.

Parsing where such links originated or how they bled from one population into another is difficult. But by looking to the past, Lahnakoski says, scientists can evaluate which links are deeply rooted and which have gone by the wayside. ✖

PALEONTOLOGY

NEW CLUES EMERGE IN KANGAROO WHODUNIT

By Carolyn Gramling

● The prime suspects behind the demise of most of Australia's kangaroo species by 40,000 years ago are thought to be the arrival of human hunters and rapid changes in the climate, which may have restricted kangaroos' dietary options. But the marsupials had weathered climate shifts before, diversifying into new species with varied diets as Australia, once a lush rainforest, dried out over millions of years.

Paleontologist Samuel Arman of the Museum and Art Gallery of Northern Territory in Alice Springs, Australia, and colleagues analyzed wear on the teeth of 937 kangaroos representing 12 ancient species (including *Simosthenurus occidentalis*, illustrated) and 16 modern ones. The wear patterns point to what the creatures ate.

The analyses reveal the ancient marsupials weren't picky eaters as once thought, the team reports in *Science*. So when it came to climate-driven changes in food availability, the animals might have rolled with the punches.

Modern kangaroos tend to graze on soft grasses, or have a mixed diet of grasses and tougher plants. Previous cranial analyses suggested many ancient species were pickier, but the new study calls that into question, lending support to the hypothesis that hunting, not dietary restrictions, was the main culprit behind their demise. ✖

ENVIRONMENT

The 'Blob' killed millions of seabirds

By Jake Buehler

● **The tall, stony coastlines along the northeast Pacific Ocean** are much quieter than they were just a decade ago. Following a punishing marine heat wave in the region, the raucous seabird colonies that once crowded the sea cliffs are now greatly thinned, to a quarter of their former size in some places.

This abrupt loss of millions of birds may be the largest wildlife mortality event recorded in modern times, researchers report in *Science*.

"We knew [the population decline] was big, but the numbers are a gut punch," says Heather Renner, a wildlife biologist with U.S. Fish and Wildlife Service at the Alaska

FROM TOP: SARAH SCHOEN/USGS; NOBU TAMURA/WIKIMEDIA COMMONS (CC BY 3.0)

Maritime National Wildlife Refuge in Homer.

The story begins in late 2014, when a brutal marine heat wave nicknamed the Blob parked itself over the northeast Pacific, raising ocean temperatures far above normal for almost two years. The colossal cauldron cooked up an ecological chain reaction, slashing phytoplankton populations and in turn the fish that seabirds like common murres (*Uria aalge*) eat. In 2015 and 2016, the birds starved to death en masse. Renner runs a monitoring program spanning the region's coastline that has been collecting data on seabirds for the last 50 years. The scale of the toll was immediately obvious.

"We knew right away that it was a big catastrophe," Renner says. "There were 62,000 carcasses that washed up on the beaches, all over the Gulf of Alaska, all the way down to California. It was clearly a big deal, but we couldn't really quantify the size of the mortality very well."

To get a better idea of the full impact on the murre population, the team used colony count data from 1995 to 2022, gathered across 13 colonies along the coast and on islands in the Bering Sea and the Gulf of Alaska. After getting bird counts before and after the heat wave, the team then extrapolated those results to the entire Alaskan murre population.

↖ A group of common murres gather in a colony in Alaska. The species suffered catastrophic losses in 2015 and 2016 following a marine heat wave.

Renner and colleagues estimate that the heat wave killed 4 million murres in the Gulf of Alaska and Eastern Bering Sea. About half of Alaska's murres died in a single winter. "It was just so much worse than we thought," Renner says.

The loss is the largest die-off of wildlife, specifically nonfish vertebrates, yet reported in the modern era, the team suggests. In another heat wave a few years later, some 10 billion snow crabs in the Bering Sea died from starvation.

The sheer scale and speed of the common murre population collapse is shocking, says ecologist Simon Tye of the University of Arkansas in Fayetteville. "The before and after pictures [of the colonies] are pretty heartbreaking."

The fact that the birds hadn't rebounded even seven years later helps reject a hypothesis that the birds were just temporarily delaying breeding to wait out the hostile conditions. The stubbornly sparse colonies may mean that something fundamental has changed in the ecosystem, and it can't support a return to past murre numbers.

Renner doesn't think climatic impacts spurring such a dramatic, swift shift have been previously documented. The findings show such intense changes can occur on the scale of years.

Tye and Renner both point out that with continued climate warming, heat waves like the Blob are expected to occur more frequently. This could imperil already vulnerable populations of many animals that have yet to recover from the previous heat wave. ✖

HEALTH & MEDICINE

WHAT SCIENCE SAYS ABOUT ALCOHOL'S LINK TO CANCER

BY AIMEE CUNNINGHAM

In January, the U.S. surgeon general released a report on the link between drinking alcohol and developing cancer. It may have surprised many people.

Although evidence for this link has been growing for some time, less than half of Americans are aware of the association, according to a 2019 survey. That's in contrast to tobacco, which 89 percent of the survey respondents identified as a cancer risk.

The report puts the link between drinking alcohol and developing seven different types of cancer — including esophagus, breast, liver and colorectal — in the spotlight to increase awareness. The report also calls for adding information about cancer risk to warning labels on alcohol. And it recommends health professionals discuss the risk, which generally increases the more one drinks, with patients and the public. That way, people can take the risk into account in choosing whether or how much to drink.

Here's an overview of what scientists know about the association between alcohol and cancer, and what they still need to learn.

The World Health Organization's International Agency for Research on Cancer first classified alcoholic beverages as carcinogenic in 1988. That designation is based on studies finding an association between drinking alcohol and seven types of cancer: mouth, throat, voice box, esophagus, breast, liver and colorectal.

Researchers have identified the association through observational studies, which compare groups of people in the real world, rather than in a controlled setting. Generally, the observational studies compare different groups of people over time in terms of the amount they drink and their health. Such studies need to account for other factors that can contribute to cancer risk, such as smoking and age. The association persists for drinking alcohol even after considering those factors and other health behaviors, says Elisa Bandera, a cancer epidemiologist at the Rutgers Cancer Institute in New Brunswick, N.J.

One challenge with these types of studies is getting accurate information about drinking patterns, including binge drinking, and lifetime consumption of alcohol, Bandera says. The studies tend to rely on self-reporting. "Because alcohol may be perceived as an unhealthy behavior by some, there is potential for underreporting the actual amount consumed, leading to potential inaccuracies in the data," she says.

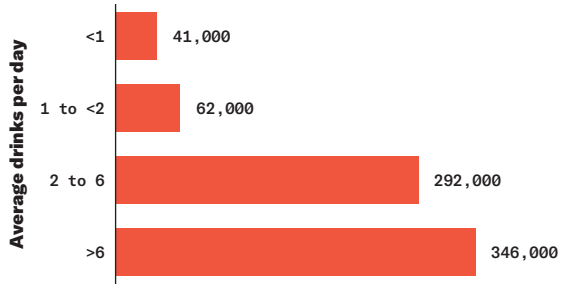
Some analyses combine data from multiple studies to report estimates of how many cases of cancer are tied to drinking alcohol. For example, alcohol contributed to an estimated 54,000 cancer cases in women and 42,000 in men in the United States in 2019, researchers reported in *CA: A Cancer Journal for Clinicians* in 2024.

An estimated 741,000 — that's about 4 percent — of all new cancer cases worldwide were attributable to alcohol in 2020, some of the same researchers reported in *Lancet Oncology* in 2021. Most of those cases were cancers of the esophagus, liver and breast. The vast majority of the total of new cancer cases were tied to drinking the equivalent of two or more drinks per day.

Another analysis that combined 572 studies and more than 486,000 cases of cancer looked at the relative risk of developing cancer.

ESTIMATED GLOBAL CANCER CASES ATTRIBUTABLE TO ALCOHOL, 2020

Drinking alcohol contributed to about 4 percent of all new cancer cases in 2020, researchers report. Of the more than 700,000 cases linked to alcohol, most were tied to consuming two or more drinks per day on average.



DATA: H. RUMGAY *ET AL/LANCET ONCOLOGY* 2021; GRAPH: B. PRICE

"Any alcohol consumption increases cancer risk to some extent."

—Jo Freudenheim

Overall, the risk increased with heavier drinking. Developing cancer in the esophagus, for example, is about 1.3 times as likely with light drinking, which the study defined as less than one drink per day, on average, than with not drinking. That grows to nearly five times as likely with heavy drinking, defined as more than four drinks per day, compared with not drinking.

Esophagus cancer is at the high end of the relative risk spectrum. For female breast cancer, the risk was slightly elevated with light drinking and about 1.6 times as likely for heavy drinking compared with not drinking, researchers reported in the *British Journal of Cancer* in 2014.

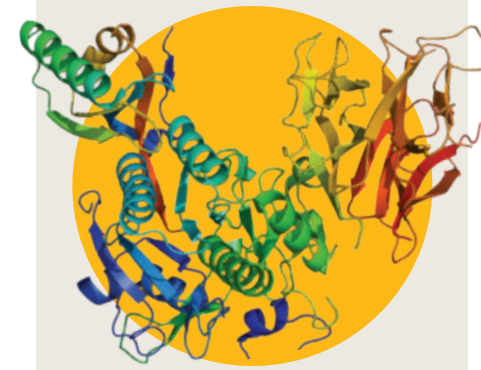
Scientists are still working out how alcohol can contribute to cancer risk. They have a few theories. With the help of enzymes, the body breaks down alcohol into acetaldehyde. This chemical can damage DNA, which may lead to unchecked cell growth. The process of breaking down alcohol can also lead to the formation of molecules called reactive oxygen species, which can increase inflammation and harm DNA.

Some research has suggested that drinking alcohol is associated with increased levels of estrogen, which could help explain the link between alcohol and breast cancer risk.

More research is needed on how alcohol contributes to cancer development, says Jo Freudenheim, a cancer epidemiologist at the University at Buffalo in New York. That's especially true for the effect of light to moderate drinking, she says.

Studies on the association between drinking and cancer risk tend to discuss the risk in terms of the amount of alcohol per day on average. So an average of seven drinks per week could mean one drink per day or three to four drinks on each of two days. The second pattern probably has a different biological impact than the first, Freudenheim says, "but we need more information about that."

Overall, the data suggest that "any alcohol consumption increases cancer risk to some extent," Freudenheim says. "I think it's important for people to know what their risks are." That means they can look at the data and decide, "I am willing to take on this amount of risk," she says. Freudenheim finds *Canada's Guidance on Alcohol and Health* useful in that regard. It discusses the risk of cancer and other health harms based on the number of drinks a person has per week. ✖



HEALTH & MEDICINE

BREAST CANCER'S SPREAD MAY BE INHERITED

By Tina Hesman Saey

● A gene involved in setting cholesterol levels may also determine whether breast cancer spreads to other parts of the body. A variant of the *PCSK9* gene drives the spread of breast cancer, but a lab-made antibody already approved to treat high cholesterol may help stop the proliferation, researchers report in *Cell*.

In a large study in Sweden, people who inherited two copies of a particular variant of *PCSK9* had a 22 percent risk of developing metastasis (cancer spread) within 15 years of their original diagnosis, the researchers found. That compares with a 2 percent risk of spread among people who inherited one or no copies of the variant.

Protein made by the pathogenic version of *PCSK9* removes a brake on two genes that spur cancer spread, mouse experiments revealed (the structure of normal PCSK9 protein, shown above). An antibody against PCSK9 that treats high cholesterol prevents the protein from removing the brake.

In mice, "we see that we get a reduction in breast cancer metastasis," says cancer biologist Sohail Tavazoie of the Rockefeller University in New York City. "It's not a cure, it's a reduction." Using the antibody earlier, perhaps even before cancer onset, may produce better results for people with two copies of the variant, Tavazoie hopes. ✖

NEUROSCIENCE

ELECTRONIC 'TATTOOS' MONITOR THE BRAIN

By Laura Sanders

● It's an unusual aesthetic, but it works: Spray-on tattoos that dot the head can collect brain activity without the consternation caused by typical methods. The electronic tattoos, described in *Cell Biomaterials*, go on with a microjet printer, last for hours and wipe off with soapy water.

Electroencephalography, or EEG, is a common test that can help diagnose epilepsy, brain injuries and sleep disorders. The test relies on electrodes glued to the scalp, where they pick up signals generated within the brain. But pitfalls abound: Hair can stymie electrode contact, wet gels can dry out, and wires and caps can form a Medusa-esque snarl, making it hard to stay comfortable.

Electrodes that are sprayed directly onto the scalp may get around a lot of these problems, engineer Nanshu Lu of the University of Texas at Austin and colleagues report. To apply these e-tattoos, a printer sprays ink made of polymers that can carry electrical signals onto precise spots on a person's head. The liquid oozes around hair to settle on the scalp before drying.

In tests, the team printed "wires" that carried signals down volunteers' heads to the top of their necks, where they were then hooked into standard wires (shown). Dry tattoos picked up the brain's electrical activity about as well as standard electrodes, the scientists report. ✖

N. LU

ASTRONOMY

PROBES GET UP CLOSE AND PERSONAL WITH THE SUN

BY LISA GROSSMAN

A pair of spacecraft that will create hundreds of artificial solar eclipses in orbit is primed to begin its cosmic tango.

The European Space Agency mission, called Proba-3, will allow scientists "to see an eclipse on demand," as one satellite blocks the other's view of the sun, says mission scientist and solar physicist Andrei Zhukov of the Royal Observatory of Belgium in Brussels.

That, in turn, will allow researchers to readily study a part of the sun observable only during an eclipse: the middle part of the corona, the uppermost region of the sun's atmosphere. Scientists suspect that many of the sun's most enduring mysteries, from how the solar wind accelerates to why the corona is so much hotter than the sun's surface, may have solutions in this elusive region. The mission is "really a game changer," Zhukov says.

He and colleagues expect to start collecting data this spring.

The mission — launched from India in December — consists of two satellites that will fly together in lockstep, as if they were a single rigid structure in space. While in formation, the satellites will stay 144 meters apart to an accuracy of one millimeter.

One satellite will, when directed, block the sun from the perspective of the other, emulating a total solar eclipse. The observing spacecraft will then send back high-resolution images of the innermost part of the sun's diaphanous atmosphere.

Normally, scientists can use satellites to observe the corona right at the surface of the sun. Scientists can also build an artificial eclipse into a telescope by putting a disk called a coronagraph in front of the lens. But light waves bend around the sharp-edge disk in a process called diffraction, ruining the image. So the coronagraph must block out a considerable area around the sun, limiting how close such observations can get to the star itself.

The in-between region, at distances from the surface of about one to three times the sun's roughly 700,000-kilometer radius, can be observed only during a total solar eclipse. "But they are too rare," Zhukov says. The alignment of sun, moon and Earth happens roughly once per year, can be viewed only

from specific spots on the planet and lasts just a few minutes.

Proba-3 will create eclipses on demand that will last six hours. That long duration will let scientists see how the corona moves and changes over time.

And the large distance between the two spacecraft means diffraction is less of an issue. The farther away the light-blocking object, or occulter, is, the more diffracted light can spread out before reaching the observer. It's basically casting a sharper shadow, says physicist Amir Caspi of the Southwest Research Institute in Boulder, Colo.

"The cool thing about Proba-3 is they're going to put the occulter much farther away than what you could reasonably do with a single spacecraft," Caspi says. "That means that you can make the occulter exactly the right size, and you can see closer down to the solar surface."

Staying in eclipse formation all the time would use too much fuel, so the satellites will spend most of their time flying freely. But scientists still expect more than 1,000 eclipses over the full two-year mission.

Caspi thinks the observations from Proba-3, in combination with other spacecraft, will set the stage for the next decade of solar science. One of those spacecraft is NASA's Parker Solar Probe, which is studying the corona from the inside.

On Christmas Eve, the spacecraft made its closest flyby of the sun yet, coming within 6.1 million kilometers of the solar surface. A few days later, mission scientists confirmed that Parker survived the encounter and collected science data.

Parker will make two more flybys at this distance in March and June before its primary mission ends in September. ✖

BRETT AFFRUNTI

↑ Pablo Guerrero surveys *Copiapoa* cacti in the Atacama Desert in Chile. Increased poaching and trade are pushing the plants closer to extinction, the botanist says.

PLANTS

This botanist is on a mission to save the Atacama's cacti

By Rebecca Dzombak

● **Pablo Guerrero has been visiting** cacti in the Atacama Desert his whole life, first on family trips to the Chilean coast and later as a researcher studying the impacts of climate change and illegal poaching on the fragile flora.

The desert, which is the driest spot on Earth beyond parts of Antarctica, can be so desolate that NASA uses it to test Mars rovers. But from a young age, Guerrero learned to spot pockets of life hidden within the arid landscape.

Cacti, a smorgasbord of funky shapes and showy flowers, easily became his favorite.

Guerrero began visiting the Atacama as a researcher in the early 2000s, observing the plants of his childhood with a botanist's eye. Their ability to flourish in such extreme conditions impressed him, and he grew concerned CONT. ON PAGE 22

CONT. FROM PAGE 21 about their ability to continue surviving as humans infiltrated the desert.

"Encountering these plants, especially those facing conservation challenges, was almost an epiphany for me," says Guerrero, of the Universidad de Concepción in Chile.

Cacti in the Atacama are particularly vulnerable to disturbances. Many species are found in only a few square kilometers of the desert. And in the driest reaches, cacti depend on fog alone for water. But as the desert gets hotter and drier due to climate change, the fog is disappearing in some places.

Humans' direct impact on the Atacama is increasing too. In Guerrero's youth and earlier in his research career, the only way to access remote hot spots of biodiversity was to trek through the desert on foot. As the mining and energy industries began to grow, more roads were built, turning hours-long treks into quick drives.

Litter now pools along the roadside, Guerrero says. Once-bursting spots feel lifeless, haunted by desiccated cacti husks. Because the desert is so dry, remains are slow to decompose and linger for years. And many remaining cacti populations are sparse.

Comparing today's populations with historical photos, "it's easy to see the change in the presence of plants," Guerrero says. "They're much less abundant now."

In recent years, Guerrero began hearing from colleagues about an increasing number of cacti being seized at the Chilean border. Interest in having cacti as houseplants has grown around the world — and so has cactus theft. From the American Southwest to South Africa, desert plants have been targets of plant poaching. Even the remote Atacama wasn't safe.

"Encountering these plants... was almost an epiphany for me."

— Pablo Guerrero

How, he wondered, was poaching affecting the desert's cacti?

Guerrero looked to *Copiapoa*, a diverse genus found mainly in the Atacama that has been a hot commodity in recent years. From his field visits, it seemed obvious that many species were threatened, if not already near extinction. In a 2015 assessment, 28 percent of *Copiapoa* species and subspecies were classified as critically endangered or endangered. But nearly half of the 39 known species and subspecies hadn't been evaluated.

Guerrero used new evolutionary histories of the species, careful mapping and outside experts to reclassify *Copiapoa*'s extinction risk. The results were stark: Seventy-six percent of all *Copiapoa* species and subspecies are critically endangered or endangered, drastically more than the 2015 assessment's finding.

Guerrero then analyzed factors of extinction risk, such as landscape condition, human footprint, plant poaching and legal trade to determine which factors were most likely responsible for the increase. Poaching and trade clearly stood out, affecting almost all critically endangered species, he and colleagues report in *Conservation Biology*.

"The situation is really bad," Guerrero says.

Determined to help conserve the Atacama's cacti, he is researching how the cacti are surviving despite the disturbances and collaborating on state and international efforts to document poaching. Creating new conservation areas with the greatest biodiversity and training park rangers to identify rare cacti are essential, he says.

But the rapid rise of extinction risk for the Atacama's cacti alarms Guerrero. "I'm scared for the future of some of these species." ✖

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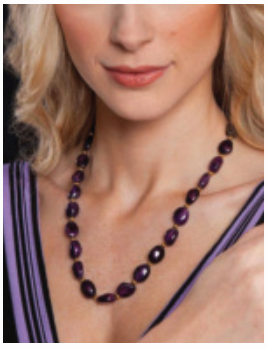

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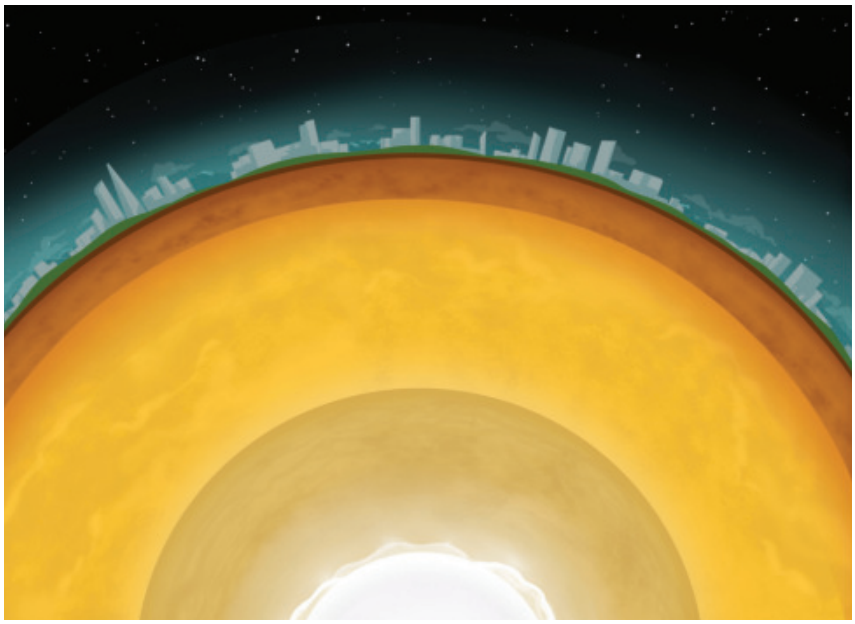


EARTH

Earth's inner core may be changing shape

By Nikk Ogasa

● **Earth's inner core,** a solid metal ball gyrating within the molten outer core, may be both slowing down and changing shape.

Recent analyses of earthquake waves have suggested that about 15 years ago, the inner core's rotation may have slowed so much that it appeared to pause or reverse direction relative to the surface. But a new analysis suggests something more must be changing at Earth's center.

The most probable explanation is that the inner core is not only rotating differently — its surface is probably also morphing, geophysicist John Vidale of the University of Southern California in Los Angeles reported at a meeting of the American Geophysical Union that was held in Washington, D.C. The finding could help resolve a long-standing debate over what is changing at the inner core.

No instrument can physically probe Earth's core. So, researchers study it using seismic waves from earthquakes. Scientists typically use quakes that occur in the South Sandwich Islands near Antarctica, which repose on the opposite side of the planet from instrument arrays in Alaska. The earthquake waves travel through the planet like sonar waves through water, with some passing through the inner core on their way to Alaska. Instruments there then record the waves as squiggly signatures called waveforms, which contain information about what the waves encountered on their journey through Earth.

For robust detections of changes in the inner core, researchers compare similar-sized quakes that occurred in the same place but at different times. Such twin temblors, known as doublets, should

↖The surface of Earth's solid inner core, which rotates within the liquid outer core, may be changing.

SAM FALCONER

generate the same waveforms if their journeys through Earth were identical. But researchers have observed that some doublets in the South Sandwich Islands generate different waveforms in Alaska, indicating that something in the inner core had changed between the times the two quakes in those doublets occurred.

In 2023, geophysicists reported that the waveform differences stemmed from the inner core's rotation slowing down so much that it appeared to have stopped moving — or even reversed — relative to the surface sometime around 2009. Then, in 2024, Vidale's team seemingly confirmed the reversal. They were able to match some waveforms before and after the turnaround, identifying times when the inner core had reassumed a previous orientation toward the surface.

For the new study, Vidale and colleagues analyzed about 200 pairs of earthquakes that occurred from 1991 to 2024. They examined matching waveform pairs from before and after the reversal, recorded at two separate receiver arrays located near Fairbanks, Alaska, and Yellowknife, Canada.

Intriguingly, 10 doublets showed subtle differences in waveforms at Yellowknife that were not present in the Fairbanks waveforms. The team knew that the waves reaching these arrays, which are roughly 1,600 kilometers apart, take slightly different paths through Earth: Waves reaching Fairbanks penetrate deep into the inner core while those reaching Yellowknife graze its exterior.

"The simplest explanation is deformation to the shallow inner core," Vidale says.

It's possible that the entire geoid-shaped inner core is deforming, like a football being reshaped so its ends point in two new directions. Or perhaps patches of the inner core's surface may be swelling or contracting, he says. That would be like small bumps and dents forming on the metaphorical football. It's also possible that both processes are occurring. Such changes could be driven by the gravitational pull of the mantle — Earth's largest internal layer — or by material flowing in the outer core, Vidale says.

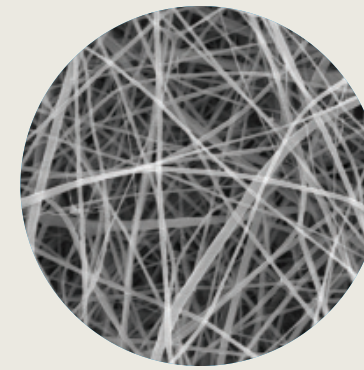
This is not the first time researchers have reported that the inner core's surface changes over time. In 2006, geophysicist Lianxing Wen of Stony Brook University in New York reported that patches of the region's surface may rise or subside by hundreds of meters per decade, possibly due to material exiting the inner core as it cools. But unlike Vidale, Wen and colleagues maintain that the inner core does not rotate differently than the rest of Earth.

"Surface changes can fully explain all the results," says geophysicist Xin Zhang of the University of Science and Technology of China in Hefei.

Geophysicist Xiaodong Song of Peking University in Beijing, who was one of the first to report that the inner core rotates differently from the rest of the planet, generally agrees with Vidale's findings. While the waveform differences are probably caused mostly by rotational changes, other processes such as surface changes may also be occurring, he says. "It's not either or."

As for how all of this affects life on Earth, "we don't know that this is going to affect anything on the surface," Vidale says. "But we can't say for sure until we figure out what's happening." ✖

BEATRICE BRITTON, A. CLANCY



MATERIALS SCIENCE

RECORD-THIN PASTA COULD DRESS WOUNDS

By Skyler Ware

● The new record holder for world's thinnest pasta may not be destined for the dinner table.

A new starchy fiber made from bleached flour averages 370 nanometers thick, about 200 times as thin as a human hair. The fiber could be used in biodegradable bandages, scientists report in *Nanoscale Advances*.

Chemist Adam Clancy of University College London and colleagues made a dough by mixing formic acid into flour, which uncoiled the flour's starch molecules. Warming the dough made it suitable for pulling through a needle and onto a plate using an electric charge.

The molecules tangled with each other as they left the needle, forming a continuous jet. As the jet flew through the air and onto the plate, the acid evaporated, resulting in a fiber that after about 30 minutes formed a mat (shown in a microscope image, above).

Starchy nanofiber mats typically have pores that are too small for bacteria to enter, making them attractive options for bandages, the team says.

Since the fiber is flour-based, it qualifies as pasta. That makes it the thinnest on record, roughly a thousandth the width of su filindeu — a pasta about half the width of angel hair that's exclusively handmade by just one family in Italy.

But is the new nanopasta edible? "I certainly hope so," Clancy says. ✖

PARTICLE PHYSICS

PHYSICISTS ARE BUILDING TELESCOPES UNDER THE SEA

BY EMILY CONOVER

Deploying a telescope in space is one thing. Making two of them deep underwater is a task in a league of its own.

On a ship bobbing in the Mediterranean Sea, physicists — not typically known for their sea legs — brave weeklong voyages and rough waters, working around the clock to deploy the telescopes' detectors.

The telescopes are designed to detect not starlight, but neutrinos. These subatomic particles are spewed at high energies from mysterious, unidentified realms of space. Such high-energy neutrinos are so rare, and so stealthy, that the detectors that study them must be enormous. So scientists are outfitting a cubic kilometer of the Mediterranean with light-collecting devices designed to snag them.

"It's weird if you think about that. We want to do astronomy, and to look at the universe, we place a telescope underwater," says physicist Simone Biagi of the National Institute for Nuclear Physics in Catania, Italy.

The Cubic Kilometre Neutrino Telescope, or KM3NeT, consists of two telescopes made up of glass baubles arranged on vertical cables. Each strand dangles in the water like a pearl necklace that's up to 700 meters long. Each bauble, a pressure-resistant sphere 44 centimeters wide, contains 31 photomultiplier tubes that sense light generated when neutrinos crash into the water.

The researchers deploy detectors in one monthlong campaign every year. At the end of the last campaign, in October, the telescopes boasted 57 strands. Eventually, hundreds of such cables will sway in the currents, a few kilometers below the surface off the coasts of Sicily and the South of France. "It's really like a forest, an underwater forest in the total black, because we are in the abyss," says astroparticle physicist Daniele Vivolo of the University of Campania "Luigi Vanvitelli" in Italy.

The Sicilian telescope is designed to study high-energy neutrinos from space. The French one will study neutrinos from the atmosphere to understand how they oscillate, or change from one type of neutrino to another. The concept is similar to the IceCube Neutrino Observatory at the South Pole, which searches for light flashes in ice, rather than liquid water. Scientists are already using

↖ KM3NeT, underwater telescopes being built in the Mediterranean Sea, will spot ghostly particles called neutrinos using spheres packed with photomultiplier tubes (gold circles).

KM3NET

the partially completed telescopes to search for effects of quantum gravity on neutrinos and measuring neutrino oscillations.

During deployment campaigns, scientists must be at the absolute top of their game. Every second on the ship costs approximately $1, Biagi says. "If you lose one hour doing stupid things, this has an impact on the cost." Weary from sleeping odd hours, perhaps seasick, they must make critical decisions if something goes wrong, be it with the devices or unfavorable weather.

A crane on the ship lowers each strand, spooled up in a roughly 2-meter-wide launching structure, to the seabed. A remotely operated vehicle plunges down to inspect the equipment. With a pull of a handle by the submersible, the strand begins to unfurl. A buoy floats the strand upward and the device spins to release the baubles, like a fern frond opening.

Back on shore, other researchers check the device's performance. Any issues must be dealt with immediately. Once a strand is planted in the forest, there's no adjusting or fiddling with connections. "It's like sending something to the moon," Biagi says. Everything must be in perfect working order at the outset. (One analogy, it seems, is not enough. The telescope is like a forest, a pearl necklace, fern leaves and spacecraft bound for the moon.)

"Typically, physicists find creative ways to answer complicated questions," Biagi says. That quest has brought the scientists to other strange locales, including the South Pole and deep underground in mines. Life in the Mediterranean isn't so bad in comparison. Sunsets and beautiful beaches come with the territory — and that's nothing to complain about. ✖

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ANIMALS

Poop is on the menu for more than 150 species

By Susan Milius

● **Feces don't get enough credit as food.** The stinky stuff is not just an end product after food gets eaten, digested and discarded by animal guts. It can also be something nutritious, useful and actually eaten (again) in its own right, researchers report in *Animal Behaviour*. Tallying just the examples from vertebrates reported in scientific journals, the team documents coprophagy in more than 150 species, from adult black bears to baby koalas.

"I had no idea how many baby animals ate their mom's poop to get microbes to help populate the gut," says evolutionary biologist Elaine Power, now retired in Eugene, Ore. The list of youngsters includes species as varied as koalas, desert tortoises and ostriches. And that's just one reason why a species might recycle previously eaten meals.

Power and microbial ecologist Sally Bornbusch explored fecal scientific literature at the Smithsonian's National Zoo and Conservation Biology Institute in Washington, D.C., with zoo clinical nutritionist Erin Kendrick. "Poop is a wonderful [food] source if you don't care about being infected by diseases and parasites," Power says. Some species can't live without it. Pikas may make it through CONT. ON PAGE 28

CONT. FROM PAGE 27 harsh winters on the Tibetan Plateau thanks to yak poop. But among the most extreme are cave fish that depend on guano from foraging bats.

When it comes to lab rats, the rodents eat up to 40 percent of the poop they produce. "If you stop them from doing it, they get vitamin B12 deficiencies. They get sick," Power says. It's something caretakers have to watch for.

For small animals with plant-rich diets such as rabbits, poop-eating makes up for not having cowlike stomachs, which have microbe-rich compartments that convert tough molecules into easily absorbed slosh. Eating food that's been through a gut once helps the animals get hard-to-extract nutrition.

Poop-eating takes a special form in some of these non-cows. The cecum, part of the large intestine, catches some waste as soft, fine-grained masses that an animal "can lick off its anus," Power says. The review cites a paper that includes portraits of a capybara in a yogalike twist, angling to eat cecal lumps.

Eating poop can also show up in parenting. Swifts tending to frail new hatchlings will gulp down a sac-like dropping. Sanitation? Thirst? It's hard to tell for birds, but Power suspects that both motives apply for lactating black bears alone in a den with young cubs.

Human coprophagy doesn't surface in the review. Some traditional medicines include fecal elements and could be swallowed, says Sachi Sri Kantha, a biochemist and historian in Tokyo. Western medicine uses fecal microbes in gut therapies, but they're inserted via the rectum. Fecal ingestion shows up on the internet now and then, but this isn't very informative, he says. "Some people will do anything for money." ✖

ANTHROPOLOGY

DNA pinpoints when humans and Neandertals mated

By McKenzie Prillaman

● **The time frame in which** Neandertals and *Homo sapiens* heavily intermingled just got a little clearer. DNA analyses of ancient and modern *H. sapiens* reveal that Neandertals spread their genes to humans during a single epoch about 47,000 years ago, researchers report in two new studies. Previous estimates dated the era of interbreeding to sometime between 65,000 and 41,000 years ago.

The findings suggest that all living people without recent African ancestry descended from the same population of humans that mated with Neandertals in this newly identified period, says evolutionary geneticist Kay Prüfer of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, who coauthored one of the papers.

Before this mating period, *H. sapiens* left Africa and encountered Neandertals residing in Europe and Asia. Neandertals went extinct about 40,000 years ago, but people alive today without recent African ancestry can trace about 1 to 3 percent of their genetic inheritance to Neandertals. Modern-day people of African descent possess a smaller percentage of Neandertal DNA, possibly from people migrating back to Africa over the past 20,000 years.

To investigate humans' Neandertal inheritance, one group of researchers built an evolutionary timeline with data from more than 300 *H. sapiens* individuals spanning the last 45,000 years. Changes to the Neandertal DNA in the *H. sapiens* samples over time hinted that most genes inherited from Neandertals came during a single period lasting from 50,500 to 43,500 years ago, the team reported in *Science*.

"Our analysis shows that the out-of-Africa migration must have [been] completed 43,500 years ago, and earlier waves that occurred before 51,000 years ago may have been from individuals that have not contributed to living non-African individuals," evolutionary geneticist Priya Moorjani of the University of California, Berkeley said in a news briefing.

Some genes inherited from Neandertals — including those involved with skin color, immunity and metabolism — became beneficial quickly, nestling into human DNA within about 100 generations.

The other study, published in *Nature*, echoes the first study's findings, though it looks at a population with no present-day descendants. Prüfer and colleagues examined DNA from six

OPPOSITE: MAREK JANTAČ/ANTHROPOLOGY DEPT./NATIONAL MUSEUM, PRAGUE

ancient *H. sapiens* whose remains were found in Germany and one in the Czech Republic. All seven were found to be part of a small population of early humans that mated with Neandertals 49,000 to 45,000 years ago. Though that group died out, their Neandertal DNA traces back to the sole interbreeding event common to all modern-day people of non-African descent.

"I found [these papers] really exciting because they came at a similar set of questions from two different angles," says evolutionary geneticist Tony Capra of the University of California, San Francisco. "There were likely other [interbreeding] events that were happening in other human groups that were living at the same time, but just were not lucky enough to make it into the present."

As Prüfer's colleague Johannes Krause, an archaeogeneticist at Max Planck, noted at the news briefing, "the human story is not always a story of success." ✖

DNA from the remains of ancient humans (a skull, known as the Zlatý kůň skull, from one individual, shown) suggests *Homo sapiens* and Neandertals hooked up about 47,000 years ago. ↙

ARCHAEOLOGY

COMMUNAL RITUALS GO WAY BACK IN THE MIDDLE EAST

BY BRUCE BOWER

An ancient ritual compound has come to light in the deepest, darkest part of a cave in Israel. *Homo sapiens* groups assembled at Manot Cave to hold torchlit ceremonies, probably inspired by mythological or religious beliefs, as early as about 37,000 years ago.

This discovery unveils the earliest known evidence for collective ritual practices in the Middle East, archaeologist Omry Barzilai of the University of Haifa in Israel and colleagues report in *Proceedings of the National Academy of Sciences*. Some 100 individuals might have fit in this space. The compound resembles an even older cave chamber in France, where Neandertals built circular structures out of broken rock formations about 176,500 years ago, though it's unclear what activities occurred there. European Neandertals and *H. sapiens* also painted and drew on cave walls by 40,000 years ago.

"The apparent concern with creating a bounded space in the depths of a cave is shared [by Middle Eastern *H. sapiens*] with Neandertals and early *Homo sapiens* in Europe," says archaeologist Paul Pettitt of Durham University in England. Rituals attended by groups of hunter-gatherers may have occurred in caves before anyone decorated cave walls, he suggests.

Stone tools, butchered animal bones and other items excavated near Manot Cave's entrance point to regular human occupations from about 46,000 to 33,000 years ago. Activity in the ritual chamber dates to a time when artifacts in the living areas display influences of Europe's Aurignacian culture. "Manot Cave's ritual compound is associated with incoming Aurignacian populations from Europe, likely reflecting their established ritual traditions," Barzilai says.

A row of slender, natural rock formations rising from the cave floor stand guard just outside the cave's rear chamber. A round boulder placed in a niche just inside the chamber displays engraved lines that create a 3-D representation of a tortoise shell, Barzilai says. Spiritual meanings of tortoises to ancient Middle Easterners, who collected the creatures to supplement their diets, remain unknown. But tortoise shells increasingly appeared in the graves of prominent individuals in this region near the end of the Stone Age. ✖

THE HEALTH CHECKUP

SLEEP REMAINS A MEDICAL MYSTERY

BY LAURA SANDERS

So many of us struggle to fall asleep and stay there through the night. About a third of U.S. adults don't sleep enough. Teenagers' sleep is even worse; 8 in 10 teens are sleep deprived. Our collective exhaustion isn't good for us. Lack of sleep can come with a range of health problems. Our immune systems, hormones, hearts — maybe all the body's major systems — are influenced by sleep. In the brain, our memory, creativity and ability to learn are, too.

But for something so entwined with our health, the actual jobs of sleep are still, in many ways, a mystery. Scientists have tons of ideas: Perhaps sleep is for rifling through memories and choosing which ones to keep. Or maybe it's a quiet, still time for growing bones in children. Or maybe it's a time to let the brain loose on whatever problem vexed you that day. (One delightfully myopic theory posits that sleep, especially the rapid eye movement stage, is for squeezing fluid around to keep the eye lubricated.)

Figuring out why we sleep has puzzled scientists for as long as the question has existed. It's like following hundreds of disappearing breadcrumbs on paths through a forest of trees that keep shifting spots, only to realize you're standing alone in your underwear. Oh, and you forgot to study for the test. Given this hazy scientific landscape, it's no surprise that efforts to help the sleep-deprived catch some z's might fall short or have unintended consequences. That's clear from a study of the sleep medicine zolpidem.

Zolpidem, sold as Ambien, messes with another possible job of sleep — housekeeping. Every 20 seconds or so, a wave of cerebrospinal fluid pulses through the sleeping brain. Scientists suspect these rhythmic pulses clear out waste, including the sticky proteins that accumulate in Alzheimer's disease. This brain wash is sort of like running the dishwasher overnight, says neuroscientist Maiken Nedergaard, who helped discover the system. Washing up isn't a flashy job, but an important one that hasn't been fully appreciated.

Mice on zolpidem fell asleep faster and slept deeper than naturally sleeping mice, says Nedergaard, of the University of Rochester in New York. But they had less power washing, her team recently reported in *Cell*.

Scientists don't yet know if this also happens in humans or what the consequences might be. But the results point out potential pitfalls in our attempts to kick-start sleep.

Zolpidem targets GABA, a chemical messenger that sends "hush" signals. "That means it's shutting down everything in your brain," says MIT sleep scientist Robert Stickgold. It's a powerful, blunt-force tool.

Ambien-assisted sleep may be justified for short stretches, says Nedergaard. But long-term use brings considerable side effects. The brain-cleaning disruption may be one. "We need a new sleep aid that gets people to sleep but preserves these oscillations," she says.

Scientists aren't just trying to help people sleep better. They're also pushing the limits of what sleeping brains can accomplish. Scientists can instruct a sleeping person to dream about particular objects like trees, sharpen their piano-playing skills and maybe even learn new languages. These feats are impressive but may involve trade-offs, Stickgold warns. If you're forcing the sleeping brain to do something specific, "then you're getting less of something else," he says. "We have to assume that something else is there for a reason."

Humility is the way forward to understanding — and tinkering with — a system as complex as the sleeping brain. So maybe we shouldn't expect one simple answer to the question of why we sleep. It could be for growing bones, sharpening memories, cleaning the brain and many more tasks. In the years to come, we'll no doubt find new clues about how sleep keeps our bodies and minds healthy. And these scientific breadcrumbs may lead us to yet more mysteries. ✖

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Features

SCIENCE & SOCIETY

THE ART AND SCIENCE OF MUSEUM DIORAMAS

● Keeping museumgoers engaged has never been an easy task. Around the turn of the 20th century, museums began posing taxidermied animals in nature scenes. In this 1946 photo, artist and explorer Belmore Browne paints a glacier behind a mountain goat surrounded by rocks and plants at New York City's American Museum of Natural History. This new type of display dazzled and educated visitors. Today, though, dioramas can feel antiquated. So exhibit experts are looking at ways to breathe new life into the museum staples (see Page 44). — *Cassie Martin*

Holding back a GLACIER

Plans to engineer ice sheets could forestall devastating sea level rise—but are they too audacious?

By Douglas Fox

West Antarctica's Thwaites Glacier (seen here in the background behind an iceberg) hemorrhages 80 cubic kilometers of ice per year, through melting and the shedding of icebergs. It is a prime target of glacial engineering proposals.

Only four ships have ever visited the place where Thwaites Glacier pours off the coast of West Antarctica. This swath of ocean resembles a rugged, white desert — a plain of wind-sculpted ice dotted with sheer-sided mesas that tower seven to 10 stories above the surrounding terrain.

Those mesas are icebergs larger than aircraft carriers. They break from the glacier itself and from the rest of the West Antarctic Ice Sheet, a dome of ice as large as Mexico slowly oozing seaward like a heap of frozen custard.

As the winds and ocean currents push the icebergs around, they plow through the meter-thick sea ice that covers the water, as if it were the fragile skin that forms on a cooling bowl of tomato soup.

In the coming century, a pivotal drama between humans and nature could play out here. In a quest to slow down sea level rise, a few researchers are sketching out massive engineering and construction projects that could block ocean currents, alter the flow of some of the world's largest glaciers and potentially delay or prevent a major collapse.

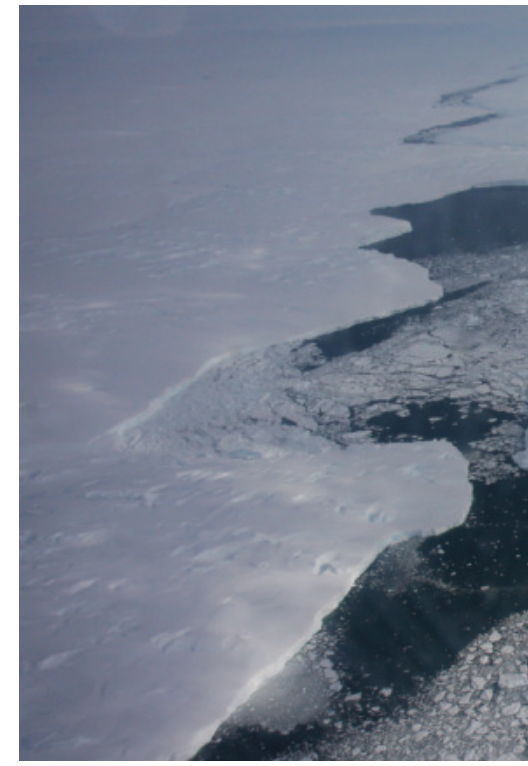
Even compared to the Great Wall of China, some of the proposed projects would be "just enormous," says Christian Rodehacke, a glaciologist at the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven, Germany. With structures potentially as tall as the Empire State Building, such a project could be the largest effort ever undertaken by humans to modify Earth.

The West Antarctic Ice Sheet is stabilized by undersea mountains that rise to form a jagged dike beneath its outer edges, but low spots in the dike provide gaps where gigantic corridors of fast-moving ice slide into the ocean. Thwaites, reaching more than 400 kilometers upstream into the heart of West Antarctica, is the most vulnerable of these glaciers, and the widest glacier in the world. Its coastal outlet is 130 kilometers across and dips as far as 1.2 kilometers below sea level — exposing it to warm, dense, salty ocean currents that flow like rivers along the seafloor.

Thwaites holds 480,000 cubic kilometers of ice. It's losing about 80 cubic kilometers per year — a sixfold increase since the 1990s — and its rate of loss is expected to increase more. As the glacier thins, it lifts off the seafloor, gradually losing its connection with the dike below. Because of this, the speed of the glacier's western branch has accelerated by more than 70 percent since 1973, reaching 4 kilometers per year. It is losing volume ever more quickly as it melts and sheds icebergs.

The events unfolding here present humankind with a range of possible futures: At the optimistic end, the glacier keeps its death grip on the protective dike long enough for us to dramatically curb greenhouse gas emissions and remove planet-warming carbon dioxide from the atmosphere. In this case, Antarctica contributes only about 10 centimeters of sea level rise by 2100 and roughly a meter by 2300, with the rate of rise gradually tapering off over the next few centuries.

At the other extreme, Thwaites thins enough to lose its grip, further accelerating and fragmenting into icebergs. This could unleash an irreversible collapse across the West Antarctic Ice Sheet, with the continent contributing 20 to 50 centimeters of sea level rise by 2100, and up to four to seven meters by 2300, drowning population centers in California, Florida, Louisiana, South Carolina, the Netherlands, Pakistan, Bangladesh, Vietnam, Thailand, the Philippines and many other places.



In all of these scenarios, many more centimeters of sea level rise will come from other sources, like thermal expansion of oceans and melting Arctic glaciers, further worsening the situation.

There is no consensus on when Thwaites will start to collapse or what temperatures will trigger it. Some scientists believe that Thwaites has already entered the early stages of its demise. Others think it will cross that invisible threshold in the coming decades. This is prompting some researchers to step beyond the role of simply documenting the demise of glaciers — and make audacious plans to intervene, to save a handful of crucial glaciers that

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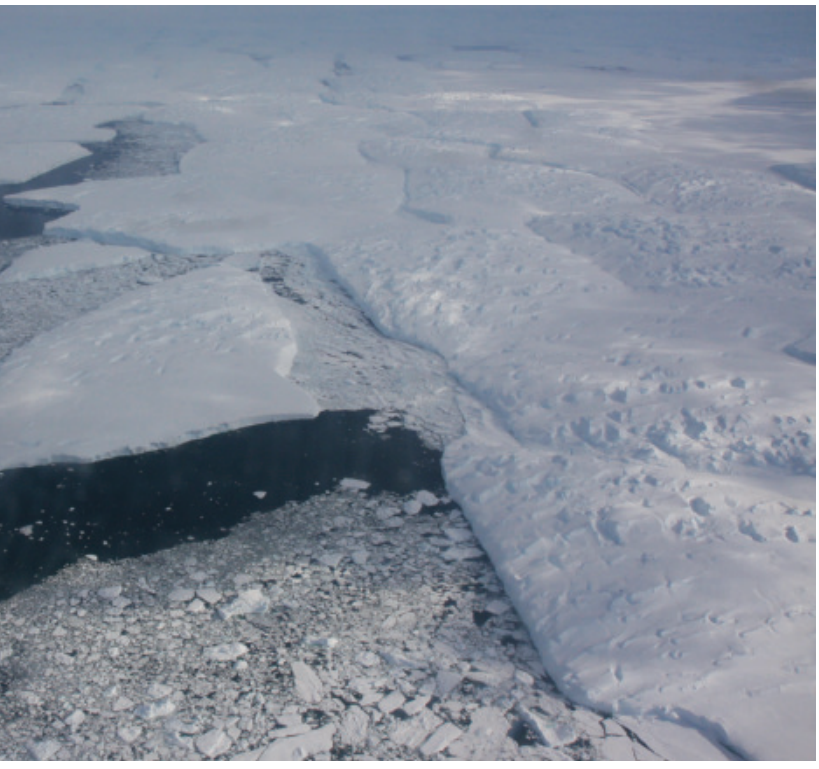

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The front edge of Thwaites Glacier is one of the most inaccessible places on Earth.

could set off runaway sea level rise.

Normally staid and cautious scientists are now willing to speak aloud the things that they've been quietly thinking for years. A prominent science-fiction novelist has launched the idea into public consciousness. And tech entrepreneurs have volunteered to find ways to fund the research, which government agencies consider too controversial to touch.

The proposed ideas would be expensive, logistically challenging and legally fraught. The mere idea of engineering glaciers has provoked heated disagreement among well-respected scientists who have worked together for decades, reflecting deep philosophical and political divides over how society should respond to climate change.

Not talking about this because it makes people uncomfortable feels like "a dereliction of duty" for scientists who are taxpayer-funded, says Slawek Tulaczyk, a glaciologist at the University of California, Santa Cruz who has long thought about engineering glaciers. "Maybe the conclusion will be that we should not do it," he says, but to shut it down before real research has happened feels "politically motivated."

Erin Pettit, a glaciologist at Oregon State University in Corvallis, sees it differently. Pettit, who has studied West Antarctica for two decades and has collaborated with Tulaczyk, says glacial engineering is a Band-Aid that could divert money and attention from addressing the underlying problems of climate change. If people are working to stop sea level rise from Antarctica, she fears, "we're not going to care as much about solving the problem" by stopping carbon emissions. She also fears that engineering glaciers or ocean currents could alter the environment in unexpected ways.

Even proponents admit that glacial engineering will address only one symptom of climate change — sea level rise — while leaving problems such as heat waves, permafrost thaw, intensified hurricanes and ocean acidification unchecked. What's more, unlike in Antarctica, glaciers in Greenland and the Arctic are experiencing massive surface melting, making them a bit less likely to respond to the same interventions.

Yet glacial engineering might become necessary. Even optimistic scenarios for global warming, in which CO_2 levels peak in 2070 and start to fall quickly, might still lead to Thwaites' collapse. "Every ice dynamicist on the planet ought to be looking at this," says John Moore, a glaciologist at the University of Lapland in Finland.

Lessons from the ice

People have talked for decades about engineering ice to serve human purposes in one grand way or another. During World War II, the Allied countries considered building artificial icebergs reinforced with sawdust to create aircraft carriers impervious to German torpedoes. In the 1960s, Soviet scientists proposed building an 80-kilometer barrier across the Bering Strait, from Alaska to Russia, to change ocean currents, reduce sea ice and open vast swaths of Arctic permafrost for farming. During the 1970s, a pair of physicists suggested that nuclear waste could be stored deep in ice sheets. And in the '70s and '80s, engineers in Saudi Arabia suggested that icebergs towed from Antarctica could provide freshwater to places lacking it.

Douglas MacAyeal was a graduate student at Princeton in 1983 when he read about those proposals to use icebergs as a source of freshwater. Inspired, he submitted

a brief abstract to a scientific meeting suggesting a way to prevent glacial flow from speeding up in the face of a warming climate: Large amounts of seawater pumped onto the floating fronts of glaciers would freeze there, thickening the ice and causing it to rest more heavily on submarine mountains beneath. Anchoring the floating ice to submerged mountains would help it buttress and slow the glacier flowing from behind.

MacAyeal never pursued the idea. "That was a time of life for me when I have to write papers that are taken seriously, so I can get a job," he says. This "silly idea" wouldn't get him there. He eventually landed at the University of Chicago, rejoining the conversation on glacial engineering only in 2023, as he was retiring.

For Tulaczyk, the roots of his own idea for glacial engineering began in the 1990s while working on his Ph.D. He was studying the Siple Coast of West Antarctica, roughly 1,200 kilometers east of Thwaites, where six massive glaciers called ice streams ooze off the coastline.

These glaciers generally slide 300 to 700 meters forward per year. But scientists found that one, the Kamb Ice Stream, flows only about one-fiftieth that speed. Though Kamb used to move as quickly as its neighbors, it ground to a near-halt around 150 years ago.

Some scientists, such as Tulaczyk, attributed this slowdown in part to the loss of lubrication that normally allows glaciers to slide easily over their rough, gravelly beds. Most glaciers have a thin layer of liquid water beneath them. It's produced as the bottom of the ice slowly melts, a few penny thicknesses per year, from both the heat of friction and the heat trickling out of the earth. The water beneath Kamb seemed to have migrated beneath a different glacier, like a river jumping its banks, causing Kamb to stagnate.

By the late 2000s, Tulaczyk had started wondering if it might be possible to slow down other glaciers intentionally, by mimicking what might have happened at Kamb. He imagined drilling a narrow hole through a glacier and pumping out the water beneath. The glacier might eventually freeze to its bed, as Kamb had, remaining stalled for decades or centuries.

Tulaczyk presented his idea to a small gathering of climate scientists in 2008. But when he asked the U.S. National Science Foundation to fund a workshop so scientists could further discuss it, he was sharply rejected. Tulaczyk suspects the agency was uncomfortable supporting such a seemingly radical idea because it might provoke negative reactions from a public that ordinarily supports climate research, or draw unwelcome attention from Congress, which approves funding for the agency.

A pair of coincidences helped revive the idea a decade later.

Around 2018, Tulaczyk received an email from the sci-fi novelist Kim Stanley Robinson, who happened to be one of the few nonscientists in the audience when Tulaczyk gave his talk in 2008. Robinson chatted with him about the idea, and later included it in his 2020 novel, *The Ministry for the Future*, in which humans successfully respond to climate change and sea level rise. In the book, a glaciologist — named Slawek with Tulaczyk's OK — concocts the same strategy for slowing and stabilizing glaciers.

Later, in 2023, Tulaczyk received an email from Alex Luebke, who had spent years founding tech companies, developing satellites and running advanced projects at Google X. Luebke had read Robinson's book, loved the idea of engineering glaciers and wanted to talk with Tulaczyk about how to advance it.

Luebke, glaciologist Kenneth Mankoff, a former graduate student of Tulaczyk's, and several other people convened a workshop at Stanford University in December 2023 aimed at

Thwaites and Pine Island are West Antarctica's fastest-shrinking glaciers. If they collapse, it could doom the whole ice sheet and cause devastating sea level rise. ↗

T. TIBBITTS, ADAPTED FROM A. SHEPHERD, D.J. WINGHAM AND J.A.D. MANSLEY/*GRL* 2002

mapping out how to test the feasibility of glacial engineering and how to find private funding.

The very idea provoked strong reactions among the people invited. "My first reaction was, 'This is crazy'," admits Martin Truffer, a glaciologist at the University of Alaska Fairbanks who has known Tulaczyk for 30 years. "I was really hesitant whether I should go or not."

But Mankoff, of NASA's Goddard Institute for Space Studies in New York City, persuaded Truffer and many others. Fifty scientists from around the world showed up. When the group was asked on the first morning who was against glacial engineering, roughly half the hands went up. When asked who was undecided, the other half went up, including Tulaczyk's. And when the moderator asked who currently supported the idea, a couple of hands might have wavered, but none went up.

To Tulaczyk, it was a good start. "Nobody is saying that we are ready to do anything at scale," he says. This current effort "is about calling for this type of research to become a legitimate research area."

Mankoff, Truffer and Tulaczyk are now making plans to test Tulaczyk's idea along with Christine Dow, a subglacial hydrologist at the University of Waterloo in Canada, and Jenny Suckale, a geophysicist at Stanford. The team, which is looking for funding from private foundations, might conduct its first small experiments as soon as next summer, at a small glacier in Alaska. The researchers will use a jet of hot water to melt a bowling ball–sized hole through the ice and then pump water out from underneath it for the next month or two.

Even if this never leads to glacial engineering, it would still be "useful science," Truffer says. It could answer key questions about how basal water controls a glacier's movement, improving the models that are used to predict how quickly glaciers will accelerate as temperatures rise.

These experiments would also hint at how many holes might be needed to slow down a massive glacier like Thwaites. Roughly 1 to 3 cubic kilometers of subglacial water flow out from beneath Thwaites each year, according to one estimate. If the holes were strategically placed in an area where the glacier slides over rough bedrock, Tulaczyk speculates that removing just 1 to 3 percent of that water might vastly increase the drag, slowing the glacier. It might mean as few as 10 holes, each with a pump pulling out 100 liters of water per second, which existing well pumps are capable of. At the other extreme, it could mean 100 holes and 10 times as much water.

Other researchers are developing variations on Tulaczyk's idea. Brent Minchew, a glaciologist at MIT, has suggested that removing heat from the glacial bed would cause the subglacial water to freeze, accomplishing the same thing. He would do this using something called a thermosiphon. Such siphons create a convection current, with warmer gas bubbles constantly rising in a sealed pipe of condensed CO_2 and colder liquid constantly sinking to take its place at the bottom. The heat from the gas bubbles would escape through the top of the pipe and into the environment.

Thermosiphons are used along the Trans-Alaska Pipeline to prevent permafrost beneath the pipe from thawing and sagging (which could destabilize the pipe). They are also being studied for possible use in geothermal power plants to transport heat from several kilometers underground. At Thwaites, thermosiphons would drain the heat slowly over a period of years before the glacier started freezing onto its bed. But that would be enough, Minchew says: "Slow and steady wins this particular race."

Removing Thwaites' lubrication was one of two major strategies kicked around at the December 2023 workshop. The second was newer and complementary.

Draw the curtains

The Southern Ocean surrounding Antarctica is known for its rough seas. Nowhere else on Earth can westerly winds circle the globe without encountering land. These winds pile the water into waves that can reach the height of a four-story building and drive the most powerful ocean current on Earth — the Antarctic Circumpolar Current.

The westerly winds are strengthening due to climate change, causing the circumpolar current to intensify and shift south, in toward the edges of Antarctica. As the current ruffles along the perimeter of Antarctica's continental shelf, the resulting turbulence causes a steady stream of water to billow up from more than a kilometer below the ocean's surface onto the edge of the shelf. This circumpolar deep water, owing to its high salt content, is several hundredths of a percent denser than the cooler, less salty water on the shelf. That slight difference is enough to guide the warm, dense water into a deep groove called the Pine Island Trough, which dips several hundred meters below the rest of the shelf.

This trough was carved by Thwaites and Pine Island glaciers as they advanced across the continental shelf during the last ice age. Today, the trough provides an easy path for dense, salty water to flow inland and access the fronts of those glaciers.

Though the water that reaches

the front of Thwaites is just 2 to 3 degrees Celsius above its freezing point, a vast amount of it flows through, roughly 2,800 cubic kilometers per year. That's nearly enough water to fill Lake Ontario twice. It delivers 900 billion watts of thermal power to the front of Thwaites year-round — similar to the output of 450 nuclear power plants.

Michael Wolovick thought often about these currents during his early career in glaciology. In 2017, during a postdoc at Princeton, he gave public voice to an idea that he'd been mulling for years. While attending the European Geosciences Union meeting in Vienna, he presented a research poster suggesting that massive dikes built across seafloor troughs like the ones in front of Pine Island and Thwaites glaciers could block warm currents and delay glacial retreat.

The meeting space was huge, with thousands of posters displayed. Wolovick's was an oddball in a section otherwise devoted to standard measurements of ice shelves and tidewater glaciers. Sometime in the early evening, a scientist named John Moore showed up and introduced himself. He was excited about Wolovick's idea.

"I didn't realize that anybody else was working on this," says Wolovick, now at the Alfred Wegener Institute for Polar and Marine Research.

In March 2018, he, Moore and colleagues published an essay in *Nature* calling for research into glacial engineering. It drew a sharp retort from seven prominent scientists, who warned that it was a fool's errand, likely to distract from the ultimate goal of reducing greenhouse gas emissions.

The next September, Moore and Wolovick proposed that an 80- to 120-kilometer-long dike in front of Thwaites could block incoming warm currents by cutting off several branches of the Pine Island Trough. The dike would rise 300 meters above the seafloor, topping out at 250 to 300 meters below the sea surface. Calculations suggested it might stabilize the glacier. But building it would consume 30 to 50 cubic kilometers of rocks, gravel and mud — several dozen times the volume of material moved in the decade-long digging of the Suez Canal.

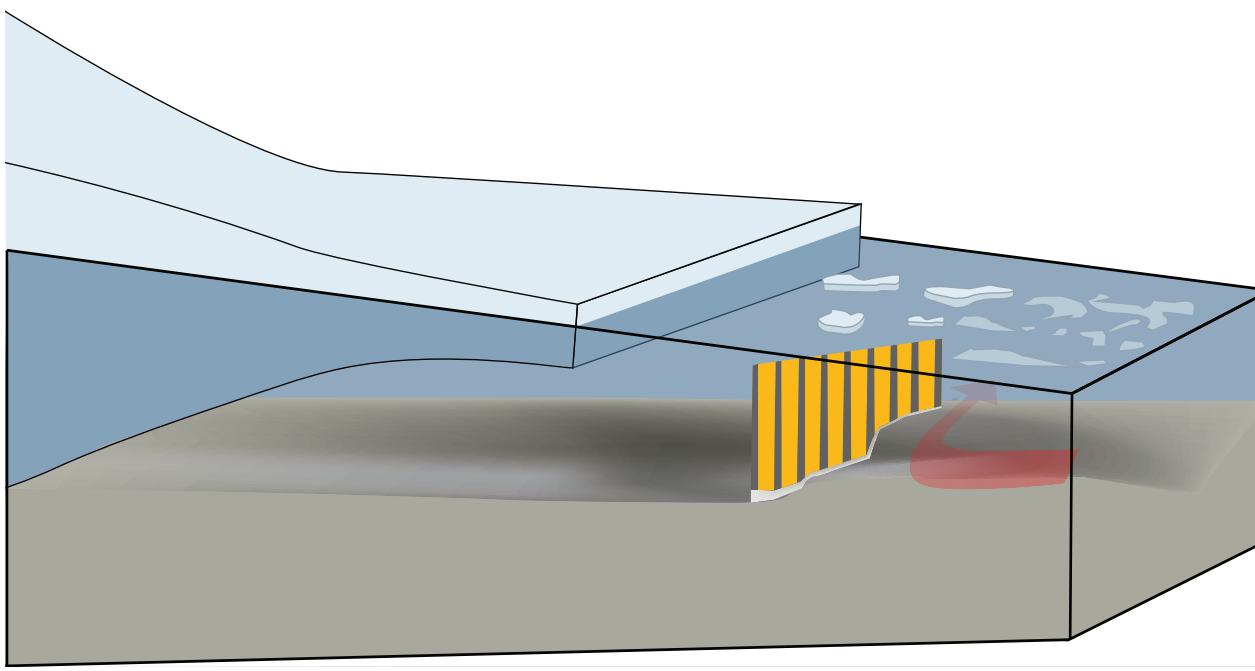
Among the people who read those papers was Bowie Keefer, an engineering physicist living near Canada's Vancouver Island. He had worked on desalination, renewable energy and harnessing tides to generate electricity. He loved the idea of blocking ocean currents and contacted Wolovick and Moore to suggest a design more likely to survive the harsh environment.

Anything constructed on the seafloor would be under constant threat from the icebergs that crowd the front of Thwaites. Some are up to 400 meters thick. Their undersides frequently scrape and gash the seafloor. If you build a barrier, Keefer says, "you have to configure it so icebergs can go over it without destroying it." He imagined something akin to the flexible

T. TIBBITTS

KEEPING A GLACIER COOL

Much of the West Antarctic Ice Sheet is grounded below sea level. That makes glaciers like Thwaites vulnerable to melting from below. Warm, dense, salty currents snake through grooves in the seafloor like submarine rivers. They erode the glacier's foothold, destabilizing it. One engineering plan calls for building sea curtains made of overlapping panels (yellow) anchored to the seafloor to block this warm water (red arrow).



streamers of kelp that his kayak frequently slid over as he paddled the waters near his home.

In March 2023, Wolovick, Moore and Keefer published two papers in *PNAS Nexus* rolling out a new design: a series of thin, buoyant sea curtains anchored on the seafloor. The curtains would easily bend as icebergs drifted over, while still blocking the dense, salty, bottom-hugging currents. Keefer imagines a modular design, composed of a couple thousand overlapping panels, each about as wide as a football field, that could be replaced individually if damaged.

Examining the layout of Pine Island Trough and its various seafloor branches, the team plotted four sections of curtain that would protect Thwaites and Pine Island glaciers, as well as several other nearby glaciers. These flexible barriers would top out a little more than 500 meters below the sea surface — just high enough to block the warm bottom currents. But in spots where the troughs are especially deep, that means the curtains would have to reach as much as 250 to 450 meters above the seafloor, equaling the height of the Empire State Building in some places.

The estimated total building cost is $40 billion to $80 billion; on a per kilometer basis, that's similar to the cost of building some large bridges. Maintenance might cost another $1 billion to $2 billion per year. These costs might seem astronomical at first glance. But they could be small compared with the cost of building and maintaining dikes to protect coastlines from rising seas, estimated at $20 billion to $55 billion per year — every year — if global temperatures rise by 3 degrees.

But there's some question about whether a barrier might simply redirect warm currents — and thus melting — to other glaciers farther west along the coast. In 2019, Rodehacke and colleagues published a rough analysis suggesting that, for an 800-kilometer oceanic barrier, that might be the case.

Yoshihiro Nakayama, an oceanographer at Dartmouth College, is doing more detailed simulations of how a shorter barrier — a 260-kilometer curtain blocking the main trunk of Pine Island Trough — would impact the region.

Researchers are still considering what building materials to use. Constructing curtains with smooth plastics could allow icebergs to slide harmlessly overtop. But that would release microplastics into some of the world's most pristine ocean waters — a prospect that Keefer does not welcome.

Rather than a curtain, Ole Wroldsen, a marine civil engineer with Entr, the consulting arm of the company Aker Solutions in Fornebu, Norway, envisions a net fabricated from natural plant fibers. Over time, it would become encrusted with sponges, corals, mollusks and other marine animals, increasing its ability to block currents. The goal is to create a living structure "that is acting with nature rather than against nature," he says. "That would be a perfect match."

The first curtain-related field tests could start in a year or two — once private funding is arranged. A series of small, 10-meter-long curtains built with different materials could be rooted in a Norwegian fjord, then monitored to see how quickly they deteriorate. Larger versions might later be installed, temporarily, in a glacial fjord in Greenland or the Arctic archipelago of Svalbard, to study the impacts on ocean currents.

But even if these small field trials succeed, other political and societal challenges lie ahead.

Prepare for tension

Lessons from another type of geoengineering suggest that glacial engineering is likely to encounter opposition. For two decades, scientists have used computer models to study the idea of injecting millions of tons of sulfate aerosols into the stratosphere to reduce warming from the incoming sunlight.

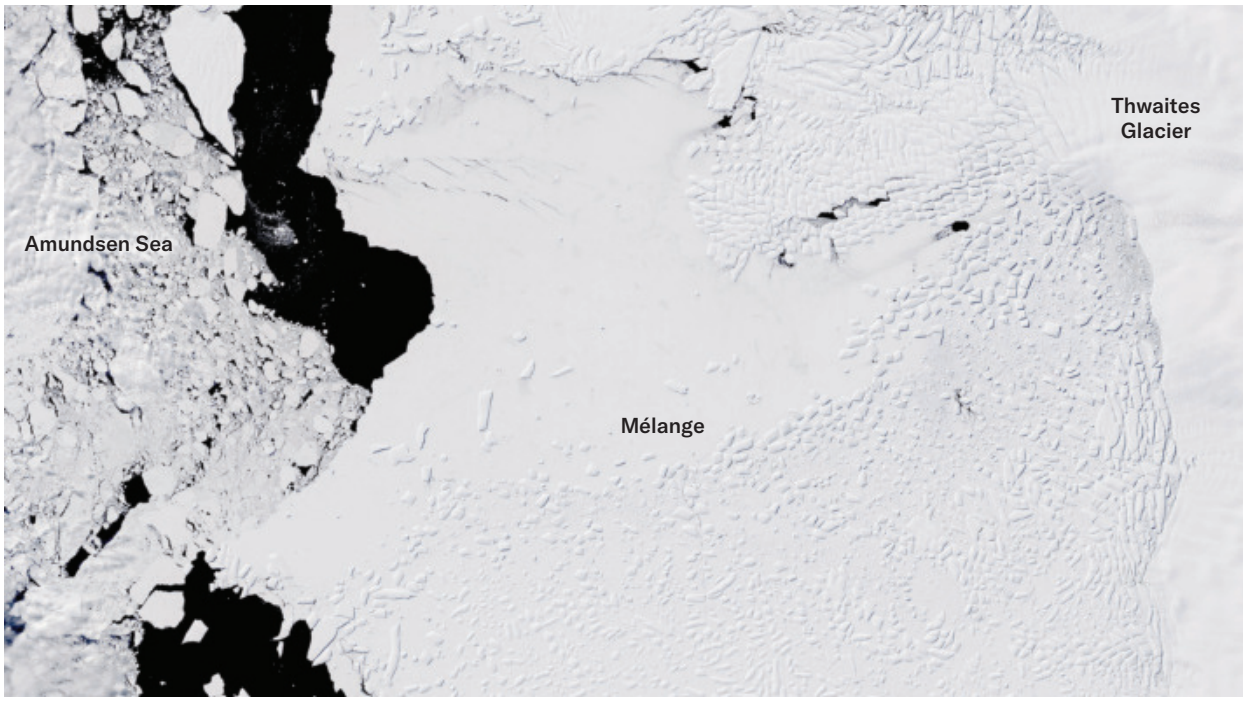
Proponents see sulfate aerosols as a way to forestall climate catastrophe for a century or two, giving humans time to stop emitting CO_2 and remove it from the atmosphere. But because of concerns about unintended side effects, researchers have not succeeded in getting a single field study off the ground. Many people distrust the notion that a handful of wealthy nations — having already messed up the planet by emitting greenhouse gases — will now fix the problem for everyone by messing with the planet some more.

Glacial engineering is far more targeted, geographically, than stratospheric aerosols. But it still may have unintended effects.

Sharon Stammerjohn, a sea ice scientist at the University of Colorado Boulder, believes that sea curtains, for example, might cause turbulence that mixes deep, warm water into the upper layers of the coastal ocean. The extra warmth could result in less sea ice production in those areas, she says.

A drop in sea ice could disrupt the interplay among photosynthetic plankton, which depend on the melting ice in spring and summer, the krill that eat them, and the penguins and whales that eat the krill. "There's winners and losers," says Stammerjohn.

Pettit does not distrust the intentions of people like Tulaczyk, whom she has known for decades. But she and some others are uncomfortable with the idea that at least in the near term, glacial engineering



↑ This satellite photo shows the mélange of sea ice and icebergs that piles up in front of Thwaites. Navigating this jumble is one logistical hurdle to any glacial engineering project that requires the use of ships.

LAUREN DAUPHIN/NASA, U.S. GEOLOGICAL SURVEY

research might be funded, in part, by billionaires from Silicon Valley. She worries whether they will have the humility to refrain from steering the research toward their own preferred outcomes. Any money should have no strings attached, with groups of scientists reviewing and deciding which experiments will be funded, she says. "If this is going to happen, we need to make sure there's some reasonable heads involved."

There's also concern that a strong move toward glacial engineering could upset the delicate geopolitics of Antarctica. It is by far the largest piece of land on Earth that is not owned by a particular nation. Though various countries made vast, overlapping territorial claims on the continent during the mid-20th century, the signing of the Antarctic Treaty in 1959 put these claims on hold. Countries pledged to limit their Antarctic activities to scientific research.

But tensions persist, says Klaus Dodds, a professor of polar geopolitics at Royal Holloway, University of London. The stations maintained by over two dozen countries there don't merely serve science: They maintain a national presence in Antarctica, allowing those countries to have a seat at the table if the continent is ever divvied up.

"The Antarctic is already in quite a precarious state at the moment, geopolitically," Dodds says. He believes that any serious glacial engineering effort would be undertaken by a small group of allied countries — say, the United States, the United Kingdom, Australia and New Zealand, or perhaps Russia, China and India. It would involve creating new infrastructure on the continent, and this could be viewed as a thinly veiled land grab, he says.

Construction in a frozen hellscape

If glacial engineering turns out to be scientifically and politically feasible, its ultimate fate will hinge on the ability of humans to build large and complex structures in an area that is notoriously harsh, even for Antarctica.

Thwaites Glacier sits midway along a 7,000-kilometer stretch of coastline (roughly the distance from Seattle to Quito, Ecuador) without a single permanent outpost. No human laid eyes on the glacier's ice front until the 1940s, when a U.S. naval plane flew over. No human stood on its heavily crevassed ice shelf until 2019, when a plane first landed. And although heavily armored icebreakers began plying Antarctic waters in 1946, not until 2012 did an icebreaker come within sight of Thwaites Ice Shelf. Even today, the icebreakers that are sent to conduct research have a 50-50 chance of getting there any given year.

The region owes its extreme inaccessibility to a quirk of geography that causes ice to pile up. During winter, sea ice up to 1.5 meters thick often extends more than 600 kilometers off the coastline. As the ice breaks up in spring, strong winds gather the ice and push it into the bay where it is compacted and piled up to 10 meters thick in some places. That jumbled ice might continue drifting west, but it's stopped by a

submarine ridge that extends 100 kilometers off the coast just west of Thwaites.

Hundreds of icebergs run aground on that ridge, creating "a huge log jam," Stammerjohn says. The stacks of sea ice and iceberg fragments the size of small apartment buildings pile up behind the bergs. The area in front of Thwaites and Pine Island is often choked with ice, even in summer.

A powerful, agile icebreaker working in this environment often has to abandon planned operations. That's because simply lingering for 20 hours in one place, to launch a submersible or drill a core from the seafloor, is sometimes too risky amid the drifting sea ice and hundred-million-ton icebergs. But a ship towing a 1- to 5-kilometer-long segment of preassembled sea curtains would present a much larger, and less nimble, target for drifting bergs. Workers would rush to lower the new curtain and cinch it to the seafloor over a period of several days, as the crew anxiously monitored the shifting ice.

People working 30 to 100 kilometers inland from the coast, drilling through Thwaites Glacier to pump out water, would face different challenges.

Subglacial water would have to be pumped from the boreholes year-round, transported through hoses and misted into the air to create snow that would settle harmlessly on the glacier's surface. The entire system would require constant heating, to prevent the kilometer-deep, water-filled holes from freezing shut — and to prevent water inside the hoses and pumps from freezing and rupturing the equipment. The power requirements for pumping 1,000 to 10,000 liters of water per second could range from 480,000 to 4.8 million watts — similar to the electricity consumption of 400 to 4,000 American households.

"Solar power is not an option" during the long, sunless winter, Truffer says. Wind turbines are used in some parts of Antarctica — and five to 50 of them could probably supply the energy for pumping Thwaites Glacier — but they would have to be built to survive hurricane-strength gales. If the power were generated by burning diesel on the other hand, it could require 260,000 to 2.6 million gallons of fuel per year, enough to fill as many as 250 semi tanker trucks.

This might sound like a ridiculous amount of pumping and energy. But it's a mere drop in the bucket, representing no more than 2 percent of the water pumped from all the wells in California each year — and a tiny percent of the energy used. Its main significance is that it would require major logistics in a remote region.

Hundreds of thousands of kilograms of food, gear and potentially fuel would likely be delivered annually by an icebreaker to an accessible spot on the coastline, 1,000 kilometers northeast of Thwaites. Supplies would be loaded onto convoys of shipping container–sized sleds and towed by tractors, traveling on routes carefully surveyed for crevasses, which the British Antarctic Survey often uses in this region.

Constant snowfall would bury pumping equipment. Alternating thaws and cold snaps could permeate the snow with layers of rock-hard ice. The machines would have to be dug out yearly with chainsaws, or mounted on stilts that could be raised above the new snow each year. The operation "would be extremely massive," Truffer says.

In Robinson's novel, scientists eventually use engineering on 30 glaciers. But the real-world scientists imagine targeting no more than a few: maybe Thwaites alone, maybe also Pine Island Glacier, and if things continue to worsen, maybe a couple of others in East Antarctica. If you had to protect glaciers around the whole continent, it'd be simpler to build seawalls around cities instead.

"The Antarctic is already in quite a precarious state at the moment, geopolitically."

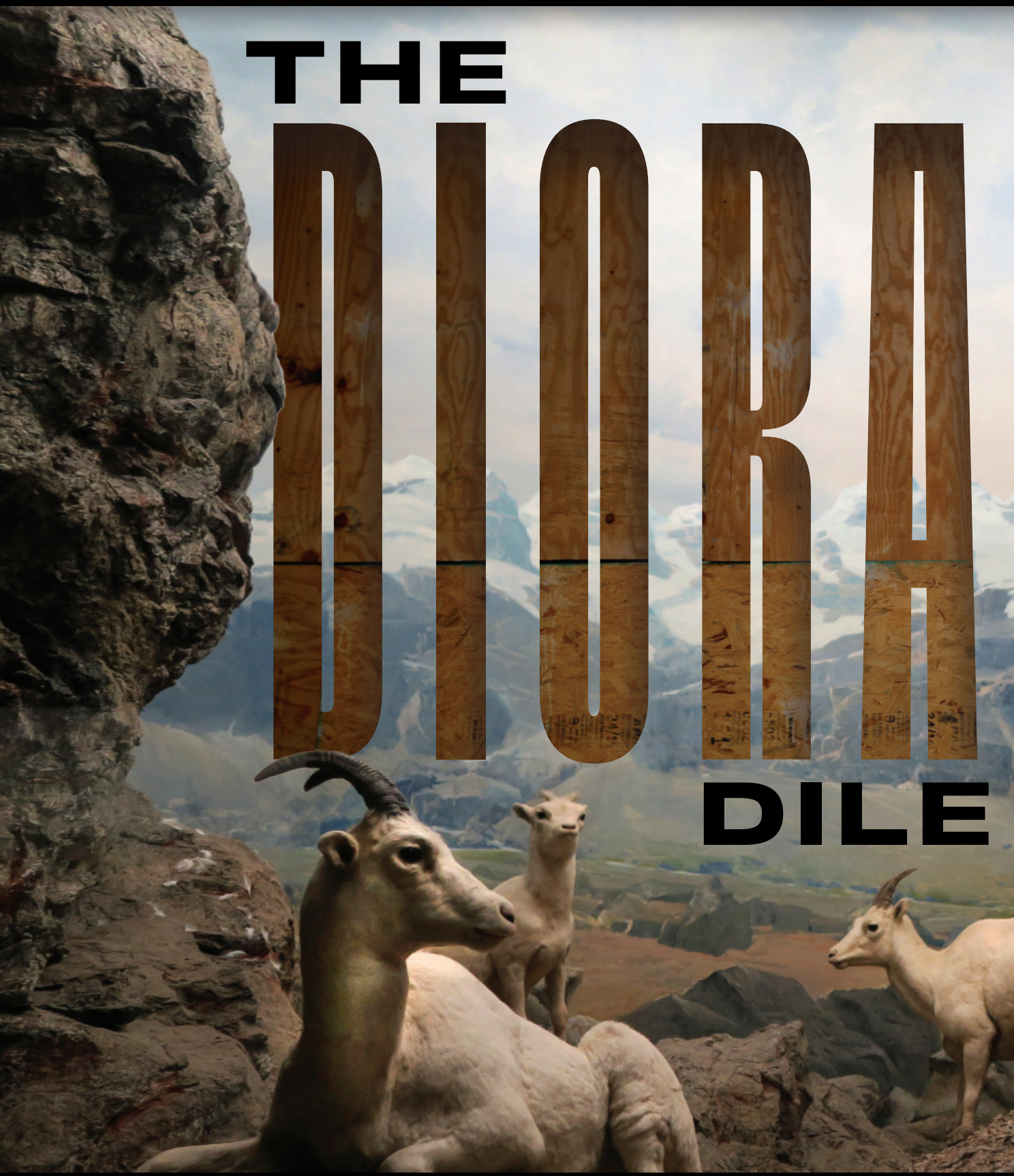
Klaus Dodds

The "key benefit of glacial geoengineering is that you can do this in a very limited geographic area and get big bang for your buck," MacAyeal says.

For Tulaczyk, now 58 years old, it has been a long journey since those early days. After the sharp rejection on his funding proposal, he decided to put glacial engineering on the back burner for fear that it would endanger the funding of his other research. But now, "I'm going to retire," he says. As a result, he feels more free to speak openly. "I want to stick to this issue."

He's pleased to see younger scientists like Wolovick and Mankoff also getting involved. They might live long enough to see the results, he says. "For a young scientist to be doing this, when they're trying to start a career, while there's so much hostility," Tulaczyk says, it's "amazingly courageous." ✖

Douglas Fox is a freelance journalist based in Northern California.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Museum exhibit experts are tackling biased, wrong or antiquated displays by reimagining, updating or even dismantling them

By Amber Dance

At first glance, it's a simple scene. Six adult bison and a calf mill around a stream. But Matt Davis invites me to look closer. We are at the Natural History Museum of Los Angeles, where Davis is an exhibition developer. As he shows me, there's more to the diorama's tale than a handful of once-living, now-taxidermied bison skins.

A well-worn path leads to the stream, and a bison skull sits to the side; this herd has been dropping by for some time. And they're contributing to the ecosystem. Perched atop that skull and scattered around the scene are birds that feast on bugs kicked up by the bison.

Then Davis encourages me to step to the left. From here, I can peer into the trees on the display's far right to spot what only one bison has noticed. Two wolves lurk, eyeing their next meal.

"Dioramas, they have such rich stories," Davis says.

I've been viewing dioramas since I was a young child — whizzing by them like many visitors do — so they seem like standard museum fare to me. But imagine, Davis says, seeing this scene when the museum's first diorama hall opened in 1925. There was no television yet; Technicolor movies had barely begun; *National Geographic* wouldn't publish a color photograph on its cover until 1959. For many city dwellers, the new dioramas were the only way to see animals as they might live. "It would be like the most crazy virtual reality experience you can imagine," Davis says. "People were totally blown away by this."

Dioramas presented lifelike scenes in a manner that earlier museum exhibits did not. While museums once used skeletons and other specimens to emphasize the classification of animals and their evolutionary relationships, dioramas — characterized by rich backgrounds, detailed foregrounds and a mix of taxidermied animals arranged as if they were alive and interacting — emphasized the nascent science of ecology in a way that spoke to viewers at an emotional level.

Over the decades, though, dioramas have become dusty museum pieces themselves. These time capsules preserve the thinking of their time, including some biases that can be scientifically inaccurate, like an overemphasis on prize male specimens. And taxidermied still lifes must compete for attention in a multimedia world.

Indeed, by 2000, many museums were wondering if they should toss their dioramas as old-fashioned space-hogs that stretched the truth in the name of storytelling. The displays were considered dull or downright creepy by some museum visitors; others criticized the echoes of an age when wealthy, white, male hunters grabbed fauna from native habitats to put on display.

PREVIOUS SPREAD: RICK COLLS/ALAMY STOCK PHOTO; BLOOMBERG CREATIVE/GETTY IMAGES (WOOD TEXTURE)
THIS SPREAD: INSA HAGEMANN/LAIF/REDUX

The bison diorama at the Natural History Museum of Los Angeles may look placid, but a closer look rewards viewers with a complex ecological tale.

This "diorama dilemma" prompted some museums to reduce or remove displays. Others, recognizing the powerful hold that dioramas can still have on visitors, kept the displays in place.

Nonetheless, modern sensibilities have forced a reckoning with dioramas' less-than-savory histories. In LA and elsewhere, curators and artists are experimenting with novel formats. At some institutions, curators are wrestling with challenges that come up when humans are depicted in offensive or blatantly racist manners. Sometimes, it turns out, no amount of effort can make historical dioramas fit the modern age.

"This reframing, it's the next step that needs to happen," says Aaron Smith, director of exhibitions at the California Academy of Sciences in San Francisco. But it's not a diorama death knell. "This awe and wonder aspect, that still exists."

The dawn of dioramas

It's hard to pinpoint the very first dioramas, but during the 1780s, Philadelphia painter, naturalist and taxidermist Charles Willson Peale displayed specimens in what one visitor described as "a romantic and amusing manner." In an exhibit area attached to his home, Peale erected an earthen mound with turf and trees, a thicket and artificial pond, and populated it with an array of lifelike specimens, from waterfowl and fish in the pond to birds in the trees and rattlesnakes, raccoons and a tiger on the land.

Later natural history displays would be influenced by the evolution of other forms of popular entertainment. By 1800, some cities were opening panoramas, circular or lengthy paintings that provided an immersive experience. These spawned a variety of other "-oramas," such as georamas that displayed Earth's features on the inner surface of a giant hollow globe. Natural history museums broadly adopted the habitat diorama approach around the dawn of the 1900s.

It is probably not a coincidence that dioramas became popular as a major change in biology was happening: the emergence of ecology, the study of how organisms interact with each other and their environment. Dioramas illustrate this concept in a way that individual specimens cannot.

In the United States, Carl Akeley and other skilled taxidermists led the charge to create dioramas with three key features: real animal specimens grouped in lifelike poses, painted backdrops and foregrounds with plants and rocks. These displays melded art and science in a new form of edutainment.

This educational entertainment always contained a bit of a paradox. The taxidermists led hunting expeditions, shooting the most spectacular specimens, often of endangered animals,

Taxidermist and big-game hunter Carl Akeley, photographed in Ethiopia after he killed a leopard in 1896 reportedly with his bare hands, created some of the earliest museum dioramas.

C. E. AKELEY/©FIELD MUSEUM OF NATURAL HISTORY

Plant samples, like these that were collected by botanist Alice Eastwood, could be used to help inform how to re-create a realistic, ecologically accurate habitat.

A. EASTWOOD/SMITHSONIAN NATIONAL MUSEUM OF NATURAL HISTORY

to bring home and display for the public. These hunter-taxidermists, worried about extinction, saw their work as a means to preserve the last of disappearing species for future generations. But the trips were also a good time for big-game hunters, whose fun was enabled by their relationships with museums. Today, this history of hunting and killing animals rubs some people the wrong way. "A lot of this was boys with their toys," says Marjorie Schwarzer, author of *Riches, Rivals and Radicals: A History of Museums in the United States*. "These were baggers and taggers."

These trips were genuine scientific expeditions, too. Researchers collected insects, plants and other specimens. Many explorers, as I am delighted to learn, were women — such as the botanist Alice Eastwood, a curator at San Francisco's Cal Academy, and Akeley's wife, Delia. While the prime skins went into the glass cases, bones and other material entered the museums' research collections. Explorers also collected the scenery itself, taking photographs or lugging home paintings that were reproduced to set some dioramas in real, specific locales.

The hope was these scenes would inspire viewers to want to conserve these charismatic species, though there's little direct research to confirm if this was the actual result. However, the fears of diorama designers — that many species would soon exist solely in museums — didn't always come to pass. Sometimes, this was a direct result of efforts by the taxidermists themselves.

For example, Akeley shot mountain gorillas in what was then the Belgian Congo on behalf of New York City's American Museum of Natural History, or AMNH. But he was so affected by the experience that he persuaded King Albert I of Belgium to establish Africa's first wildlife sanctuary, now called Virunga National Park. Today, the park — in the Democratic Republic of the Congo — is home to around 350 endangered mountain gorillas.

William Temple Hornaday, another of the early diorama makers, traveled to Montana in 1886 to collect bison for the Smithsonian Institution. Shocked by the rapid decline in their population, he became a conservationist and brought back live animals, too. These bison, initially displayed on the National Mall, became the first animals in the National Zoological Park, which was founded in Washington, D.C., in 1889.

Rescuing dioramas

But 100 years later, museums were beginning to wonder if dioramas still had a place. Feminist scholar Donna Haraway in 1989 decried a focus on virile male hunters and spectacular male specimens. In the face of multimedia and interactive exhibits, Willard Boyd, former director of the Field Museum in Chicago, has admitted that to some visitors, the diorama hall amounted to an unappealing "dead zoo."

In 2003, the Smithsonian's National Museum of Natural History in Washington, D.C., removed its scenic dioramas in favor of a mammal hall that emphasizes evolution with animals displayed against minimalist backdrops. And during a rebuild in the early 2000s, the Cal Academy slashed its diorama collection, making room for new exhibits such as a four-story, living rainforest. Other museums experimented with modernization, deploying interactive displays and animatronics.

But those decisions weren't necessarily rooted in research on dioramas' educational or historical value. So the Oakland Museum of California, as it considered dumping its dioramas, commissioned Schwarzer and a curator to study the concept first. After a thorough analysis of 30 studies of

"What are these really meant to do, how are they created, why do we still have them?"

—Lori Bettison-Varga

more than 3,800 people viewing dioramas at 17 institutions, the pair in 2009 came up with a strong case for dioramas. It turns out that the displays are second only to dinosaurs in getting visitors to stop to view them.

The dioramas did not change how people felt about conservation, though they did reinforce concerns people already had. They also sparked a range of emotional responses, including being creeped out by dead animals. But overall, most people love dioramas, the study found.

Modern museum staff corroborate this anecdotally. "I do walk-throughs all the time of the museum, and I can hear the 'Whoooooaaaa!' " says Mariana Di Giacomo, natural history conservator for the Yale Peabody Museum in New Haven, Conn. The Peabody's oldest and largest dioramas illustrate Connecticut's coastal region and a forest edge.

For many museums, dioramas have become something to preserve. New York City's AMNH began restoring its Bernard Family Hall of North American Mammals in 2011, reopening in 2012.

Chicago's Field Museum, meanwhile, finished a diorama started by Akeley more than a century earlier. He'd mounted four striped hyenas shot during an 1896 expedition, but they never received the full scenic treatment. In 2015, the museum started a social media campaign to fund a completed diorama. In just six weeks, about 1,500 donors raised more than $150,000.

"It showed us that there is an enduring interest in these dioramas," says Gretchen Baker, the museum's exhibitions planning and operations director at the time.

Reframing dioramas

Back in Los Angeles, upstairs from the placid bison, I encounter a drastically different scene. The diorama "Special Species" pulses with changing lighting and psychedelic colors. No one has to tell me to stand still and drink this one in.

It's part of the LA museum's new exhibit, "Reframing Dioramas: The Art of Preserving Wilderness," which opened in September 2024. The project aims to recognize dioramas for the historical artwork they are while incorporating modern science and sensibilities. "It's a hall on dioramas, not a hall of dioramas," Davis says.

In "Special Species," piñata-style sculptures depict at-risk California critters — including Chinook salmon and the desert tortoise — as fantastical Mexican creatures called *alebrijes* (as in the film *Coco*). Alhambra, Calif.–based artist Jason Chang, who goes by RFX1, was on a team of three who created the diorama. Echoing the diorama designers of old, he hopes viewers will walk away with "an urgency to protect the environment."

In "The Ever-Changing Flow," video projections illustrate how the Los Angeles River evolved over centuries. "A Peculiar Garden" shows an eerie, postapocalyptic scene in which wildebeest sip from a polluted stream amid metal-plated plants. Seattle artist Saul Becker explains that "a garden

After the Field Museum's crowdfunding effort in 2015, these striped hyenas, collected by Carl Akeley in the late 1800s, finally got the full diorama treatment.

JOHN WEINSTEIN/©FIELD MUSEUM OF NATURAL HISTORY

is a very unnatural arrangement of nature."

In other displays, "Reframing Dioramas" illustrates how dioramas came to be and inserts daring new scenes among more traditional ones. For instance, one shows a diorama-in-progress. Its backdrop is about 10 percent painted, and a table holds elements that would go into the scene: a fur, a sculpted body form, glass eyes, fake leaves, a few insects and more. Another display features a camp-style tent and acknowledges the power imbalances at work when wealthy, white hunters traveled to distant locales to extract specimens. Today, it notes, most large specimens the museum mounts died of natural causes and are acquired mainly from zoos or wildlife centers.

"Reframing is stepping outside of the way in which people view [dioramas]," Lori Bettison-Varga, president and director of the Natural History Museums of Los Angeles County, says. "What are these really meant to do, how are they created, why do we still have them, and then how can we think about humans' position in the environment differently?"

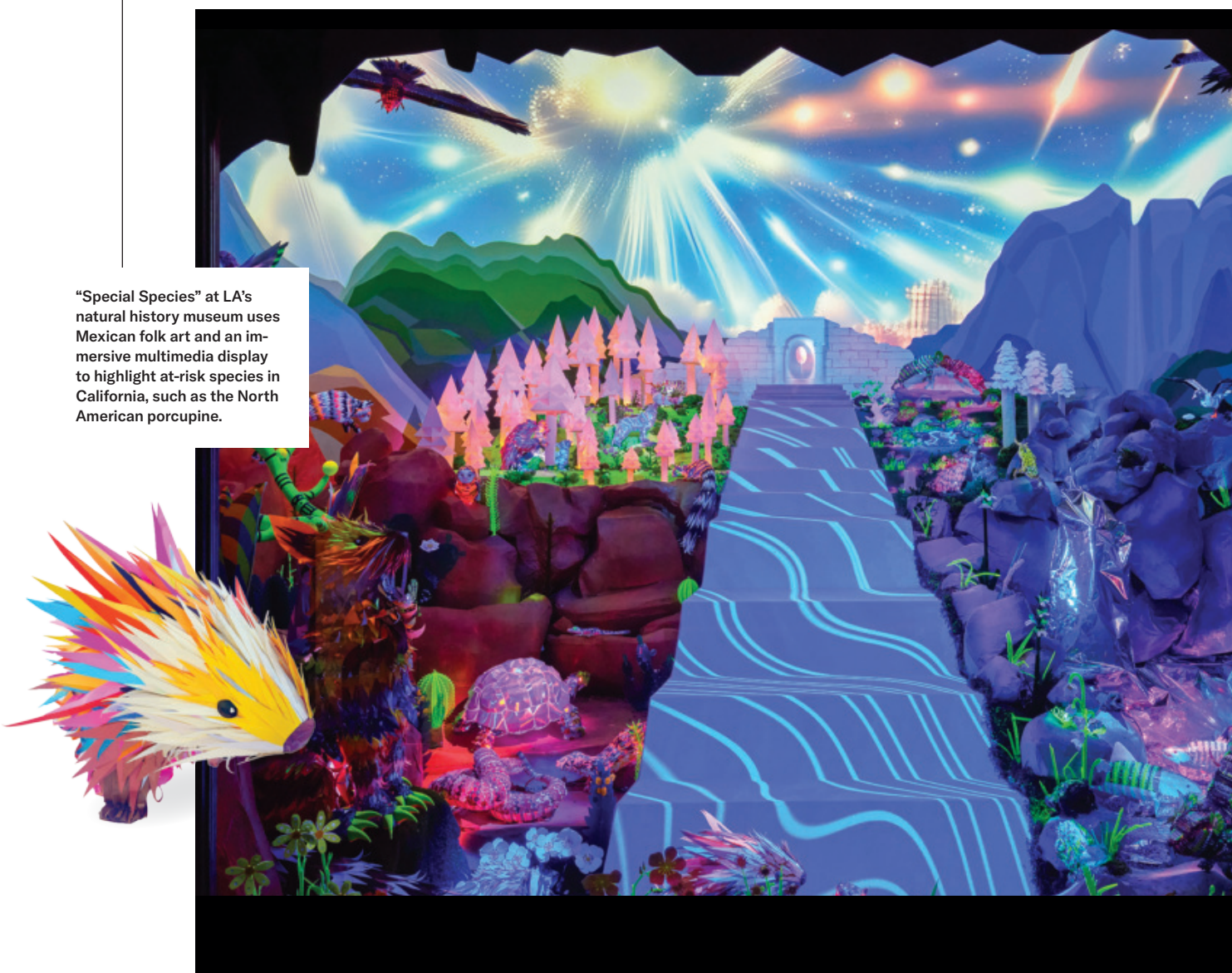
Battling biases

There's plenty to reframe. Despite painstaking research by their creators, many classic dioramas are not entirely scientific. "A lot of people have called them, in the past, 'bad science' because they personify animals," Schwarzer says.

Many illustrate nuclear family groupings that in no way reflect animal lifestyles. Berenstain Bears aside, papa bear does not stick around to help raise the cubs. "Papa bear might eat a couple of the cubbies," Schwarzer tells me.

Some exhibits misrepresent female animals, says Baker, now director of the Carnegie Museum of Natural History in Pittsburgh, as she shows me around the mammal hall. In the moose diorama, the female is standing in water, which allowed the designers to make her appear shorter than the male on land. And it's often females who lead animal groups, Baker notes. Homosexuality exists in nature, too, she adds—but rarely makes an appearance in the diorama hall.

In many cases, diorama designers probably



NATURAL HISTORY MUSEUMS OF LOS ANGELES COUNTY

"Special Species" at LA's natural history museum uses Mexican folk art and an immersive multimedia display to highlight at-risk species in California, such as the North American porcupine.

wanted to show the different developmental stages of a species, says Mark Alvey, the Field Museum's academic communications manager. Groupings that look like stereotypical human families were instead a convenient way to exhibit adult males, adult females and young.

"We always knew it was wrong," Davis says. "Now, we're slowly trying to fix some of those things." For example, the LA museum has added more females to its lion pride over the years.

The human element

Museum curators also acknowledge problems in how humans are — or aren't — depicted in dioramas. Some ignore humans completely, erasing the long-term presence of Indigenous peoples as well as the impacts of modern societies. Very little of the world exists in that virgin state. "The kind of nature that dioramas exhibit, it's very unnatural," says Martha Marandino, a professor of biology education at the University of São Paulo. As part of this ongoing reframing, museums are beginning to acknowledge that missing human element.

Some dioramas did, though, include hints of human presence. Peabody visitors, for example, see farms painted in the background of the two biggest displays; one also depicts a shell midden, a prehistoric trash pile left by Indigenous people.

AMNH faced a dilemma with its "Old New York" display. Fashioned in 1939, it illustrates a fictitious 1660 meeting between Dutch leader Peter Stuyvesant and a delegation of Lenape dignitaries, the original stewards of the land that became Manhattan. Stereotypes riddle the display. Only Lenape men are in on the discussion, and they are shown in loincloths — not how they would have dressed for a diplomatic conference. The women, inaccurately relegated to the background, are topless, with long, impractical skirts. Only Stuyvesant was identified by name.

Rather than remove the diorama, the museum decided to keep it on display for now to acknowledge and apologize for the harm done by the depiction. In 2018, curators added labels right on the glass to explain the various problems with the diorama and to name the Lenape leader Oratamin.

But sometimes reframing isn't possible. Take "Lion Attacking a Dromedary." This Carnegie natural history display showed a dark-skinned man on camelback under attack by the titular feline, a second lion below. It was never quite a diorama in the most traditional, natural history sense, as it wasn't always displayed with a detailed background and it lacked a foreground.

The display, which contained a real human skull in the mannikin's head, had a long and meandering history. It was created by brothers Édouard and Jules Verreaux, traveling collectors, taxidermists and known grave robbers, for the 1867 Exposition Universelle in Paris, where it received a gold medal. AMNH then acquired it.

That museum took the display down in 1898, reportedly because it was considered unscientific. One lion was male, but it's generally females who hunt. Worse, the man was garbed in an inaccurate mishmash of clothing that represents no specific culture. "It's not educating anyone on anything that ever existed," says Aja Lans, a bioarchaeologist at Johns Hopkins University.

Industrialist Andrew Carnegie bought it in 1899 for about $50 plus $45 shipping (equivalent to more than $3,000 today), for his new museum in Pittsburgh. In recent years, the museum has tried various forms of reframing. They covered the sides, and erected warning signs, so people who didn't want to view it could give it a pass. They added extra written material enumerating the problematic aspects.

The Black Lives Matter movement and the 2020 murder of George Floyd brought all of its problems to the fore. "This diorama was kind of like a poster child for all of these questions that were coming up at the moment," Baker says. "It was kind of this symbol of a time in natural history museums when we would display the other, the exotic, the colonized." That summer, the museum covered the display completely.

Finally, in the fall of 2023, after the museum's board of trustees voted to no longer display human remains, the diorama was permanently shuttered. It's now being dismantled. Using samples from two of the teeth, Lans and colleagues are trying to identify the geographic origin of the human remains and repatriate them. Lans expects to have preliminary results by April.

But in many cases, wildlife dioramas, despite little inconsistencies, still serve their intended purpose: bringing striking nature scenes to museumgoers who might never see such animals in the wild. And they retain an old-fashioned power to inspire wonder and a love of nature.

The ones museums keep around will continue to evolve, and Davis hopes the Los Angeles exhibit lights the way. "We don't think this will be the last word on dioramas," he tells me. "We hope it's the first word." ✖

Amber Dance is a freelance science journalist based in the Los Angeles area.

BETTER MALE BIRTH CONTROL

NEW OPTIONS THAT SUPPRESS SPERM PRODUCTION, BLOCK SPERM OR DISABLE THEM ARE FINALLY WITHIN REACH

BY FRED SCHWALLER

ILLUSTRATIONS BY ARIK ROPER

In 1960, a new drug revolutionized society from the bedroom to the streets. The introduction of a hormonal contraceptive, the birth control pill, gave women reproductive autonomy and a more effective way to plan a family. Since then, many more options have arrived: different pill formulations; hormonal implants, patches and vaginal rings; IUDs and barrier methods.

But over the last 60 years, exactly zero new options have been developed for men. They are stuck with only two choices, condoms or vasectomies. Both have their issues: Condoms, their relatively high failure rate (as high as 12 percent); vasectomies, their permanency. Neither offer men the same level of fertility control as options for women, says Alexandra Joice Berger, a urologist at Brigham and Women's Hospital in Boston.

New forms of male birth control are badly needed. "Male contraception is a particularly big concern in many states in the U.S. where access to women's services is not guaranteed anymore," says Jesse Mills, director of UCLA's Men's Clinic. The Supreme Court's Dobbs ruling that overturned Roe v. Wade in 2022 has curtailed access to abortion in some states and raised concerns about access to birth control. That seems to have changed public opinion about male contraception.

Although fear of permanent infertility has made some men wary of trying a male birth control, surveys show a sizable portion of men want new contraceptives, and women trust their partners to use them responsibly. In a recently published survey of more than 15,000 men in seven countries, 49 percent of U.S. men said they would use a new male contraceptive within the first year of availability (compared with 39 percent before Roe v. Wade was overturned). In some countries, such as Nigeria and Bangladesh, that willingness reached 76 percent. Meanwhile, about 50 to 85 percent of surveyed women trust their male partners to take contraceptives responsibly, depending on the country.

New options could arrive in the not-too-distant future. We're within touching distance of the first fertility-controlling, nonpermanent male contraceptive, which could enter pharmacies within five to 10 years. There could even be two. Research looks promising for a daily hormonal gel called NES/T that suppresses sperm production and for an injectable gel called ADAM that blocks the plumbing of sperm transmission. Other options, including drugs that work for just a few hours at a time, are also in development.

Given the diversity of people and lifestyles, multiple methods of male contraception are needed "to fulfill the needs of all potential users," says Brian Nguyen, a gynecologist at the University of Southern California's Keck School of Medicine.

Here's the major snag: regulatory approval. No male contraceptive has ever gained approval from the U.S. Food and Drug Administration.

While the risk of side effects from contraceptives in testing so far appears to be low, all of these scientific advances will be for naught if researchers can't convince the FDA to use different safety standards for contraception for men (who don't face health risks from pregnancy) than they do for women.

Stopping sperm production

In 2022, Oscar Ahlqvist, a 34-year-old health care worker in Sweden, enrolled in a clinical trial testing the efficacy and safety of the NES/T hormonal contraceptive. "My girlfriend Kerstin doesn't handle birth control well and has bad side effects," Ahlqvist says. "I wanted to share the burden of birth control."

Ahlqvist is one of about 400 men who participated in the NES/T trial, conducted in 16 sites globally, including the United States. Every day for more than a year, Ahlqvist and other participants rubbed a medicated gel containing Nestorone and testosterone into each shoulder. Nestorone, a synthetic version of the hormone progesterone, sets off a chain reaction that blocks the production of androgen sex hormones in the testes that are needed to produce sperm. Because Nestorone inhibits testosterone production, the gel adds back in just enough testosterone to maintain a man's libido and sexual function.

NES/T is long-acting. It takes four to 12 weeks of daily applications to lower sperm production to less than 1 million sperm per milliliter, the threshold to prevent pregnancy. After stopping NES/T, normal sperm production resumes within six months.

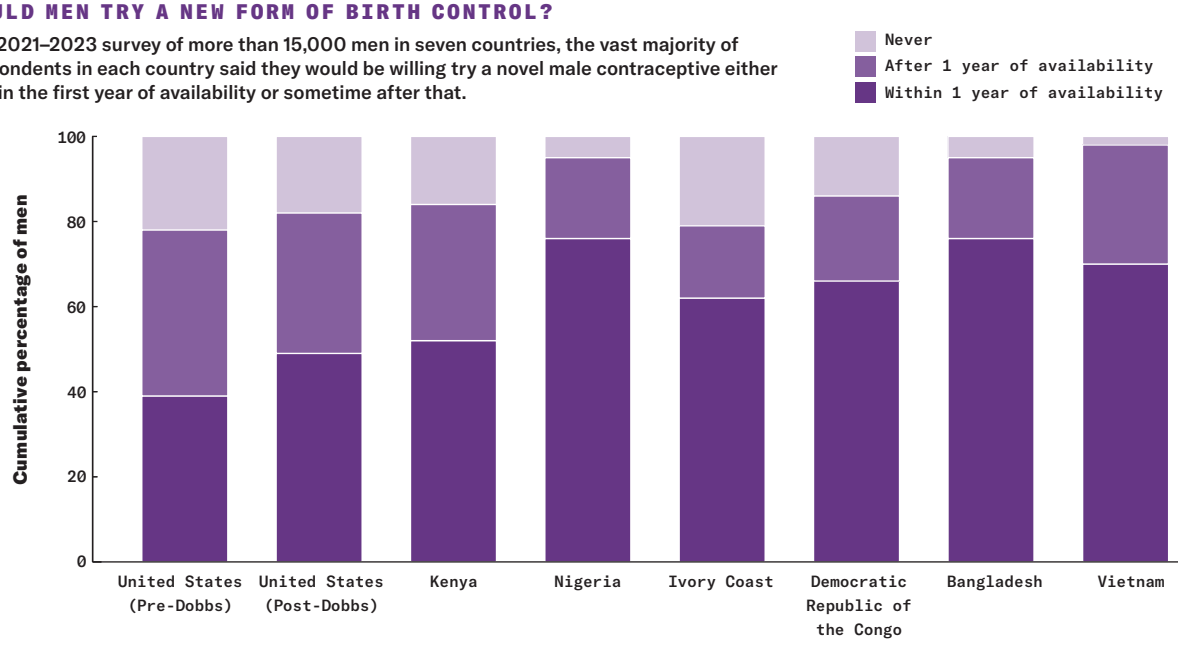
Overall, the findings have been "really terrific," even exceeding expectations, says Diana Blithe, chief of the Contraceptive Development Program at the National Institutes of Health in Bethesda, Md., who led the Phase IIb trial that Ahlqvist participated in. Blithe couldn't share specific data, but published results are expected early this year.

"Effectiveness is good. Reversibility is really good — we can be very reassuring about returning fertility [after stopping treatment]. We don't see any problems," Blithe says. Side effects also appear to be minimal. Some men had acne and mild mood alterations, but few participants dropped out of the trial because of severe side effects.

Ahlqvist says he would "definitely recommend NES/T to everyone who has the opportunity to try it." The only side effects he felt were

WOULD MEN TRY A NEW FORM OF BIRTH CONTROL?

In a 2021–2023 survey of more than 15,000 men in seven countries, the vast majority of respondents in each country said they would be willing try a novel male contraceptive either within the first year of availability or sometime after that.



DATA PROVIDED BY S. KRETSCHMER, GRAPH BY C. CHANG

LOTS FOR HER, LITTLE FOR HIM

Women have a variety of birth control methods to choose from, allowing flexibility in picking an option based on efficacy, cost, access, ease of use, health risks and other factors. In contrast, men have just two options: condoms and vasectomies.

	Women	Men
On-demand	Diaphragm, cervical cap, sponge, spermicide, female condoms, emergency contraception, rhythm method	Male condoms
Short-acting	Daily pill, weekly patch, monthly vaginal ring	Nothing
Medium-acting	Quarterly injection	Nothing
Long-acting	Implant (up to five years), IUD (up to 10 years)	Nothing
Permanent	Tubal ligation, bilateral salpingectomy	Vasectomy

feeling "pretty down" during the first month he started using the gel and the first month after stopping it.

John Amory, a reproductive health researcher at the University of Washington in Seattle who has seen the trial's results, says he's "hesitantly optimistic." His hesitancy comes from concerns that side effects could still derail NES/T during further testing. In 2016, a clinical trial of a promising two-hormone male birth control was stopped early after too many participants reported adverse side effects like mood disorders.

"Concerns around side effects are partly what's causing holdups in male contraceptive development," he says.

Amory also questions how reliable NES/T will be in the real world. "Adherence is critical — if men don't use it every day, it won't work." And the fact that it takes one to two months of daily use before NES/T kicks in might deter some people from trying it, he says. In contrast, women are protected from pregnancy within two to seven days of starting the pill.

The success of NES/T will live or die in the next stage of testing, if it gets that far. In a Phase III trial, efficacy and safety would be tested in a wider array of men and in more real-world settings in which participants are less supervised by medical experts. It would be the final test before regulatory approval.

If such testing gets funding and the go-ahead, it could start this year, Blithe says. Even if all goes well, she estimates it will be another eight to 10 years before NES/T is available. Two decades after the first NES/T study, "we've just finished the Phase IIb trial. It takes a long time to do this," she says, almost apologetically.

Other candidates that block sperm production are further behind in development. And some scientists are reviving older, abandoned candidates. In a trial more than 60 years ago, a compound that inhibits retinoic acid, which plays crucial roles in the production of mature sperm, proved to be safe and effective, but the work was never followed up.

"They found you can't drink [alcohol] when you take it," Amory says. "The joke is if you can't drink, then you wouldn't need it." He's developing new agents to block the creation of retinoic acid without causing sensitivity to alcohol, though he hasn't found a compound suitable for testing in humans yet.

Blocking sperm transmission

For men who don't want to take a drug that interferes with their hormones or sperm production, another option is a physical barrier that blocks sperm transmission. In the works are occlusion gels. A doctor injects a hydrogel into the vas deferens, the 30-centimeter-long tube that transports sperm from the testicles to ejaculatory ducts. In the body, the hydrogel morphs into a thick, semisolid substance that acts like a dam to keep sperm out of semen during ejaculation. It's similar to a vasectomy, but doesn't require cutting the vas deferens.

ADAPTED FROM MALE CONTRACEPTIVE INITIATIVE

The benefit of occlusion gels, Mills says, is the very low potential of adverse side effects compared with a hormonal contraceptive. The hydrogel is inert, acts only locally in the vas deferens and — at least theoretically — can be easily reversed with a second injection to break down the gel. The main risk comes with the injection, which needs a highly skilled provider to avoid unintended damage or entering the wrong spot.

Two companies have occlusion gels in the pipeline. Virginia-based Contraline is testing its product, ADAM, in an ongoing Phase I clinical trial in Australia. The main aim is testing safety. Preliminary data from 12 months in show that none of the 25 participants had adverse side effects and there were no unintended pregnancies.

"It's a very small trial, but it seems 100 percent reversible and safe," says Berger, who was not involved with the study.

Meanwhile, NEXT Life Sciences, based in California, is predicting regulatory approval of its product, Plan A, by 2026. That's "kind of crazy," Berger says, since Plan A has so far been studied only in lab animals. But medical devices like Plan A and ADAM go through a much faster regulatory approval process than medications like NES/T.

"CONCERNS AROUND SIDE EFFECTS ARE PARTLY WHAT'S CAUSING HOLDUPS IN MALE CONTRACEPTIVE DEVELOPMENT."

John Amory

On-demand contraceptives

The long-term dream is to develop on-demand, temporary fertility blockers. A man could pop a pill, wait half an hour and then be good to go without the risk of getting his partner pregnant. Such a drug would temporarily stop sperm's ability to swim so fertilization isn't possible. The sperm then return to normal once the drug wears off a few hours later, says Jochen Buck, a pharmacologist at Weill Cornell Graduate School of Medical Sciences in New York City.

On-demand contraceptives that act on sperm are not a new idea — they date back to the 1960s — but the trick has been finding drugs that are both effective and reversible. Recent advances in understanding the molecular machinery of male reproduction have led to several potential targets.

One is a protein called serine/threonine kinase 33, or STK33. Men with mutations in the gene that codes for STK33 are sterile due to defective sperm. A study published in *Science* in 2024 found that a molecule that binds to and blocks the function of STK33 can cause temporary infertility in mice.

Another target is soluble adenylyl cyclase, or sAC, an enzyme essential for sperm motility and maturation. In 2023, Buck and colleagues showed that blocking sAC renders male mice infertile until the drug wears off. The team is now searching for sAC-inhibiting compounds suitable to test in humans.

Buck credits industry-wide advances in drug design for recent successes. Methods such as X-ray crystallography reveal the molecular structures of proteins. By tweaking the structures in simulations, researchers can predict which modifications change how a drug binds to a targeted protein. This makes the search for drug candidates much faster and more precise than older methods of drug screening, Buck says.

"Thirty years ago, this kind of drug design wasn't possible. We needed breakthroughs in chemistry to create extremely sophisticated drug candidates," he says.

Buck is further ahead testing a vaginal ring for women that contains a sAC inhibitor. The ring prevents unwanted pregnancies by impeding sperm function, which he hopes will leapfrog the male contraceptive sAC inhibitor through development.

"So far it has a very low toxicology profile," he says, and he expects clinical trials to start next year. A sAC inhibitor for men could be less than 10 years away from regulatory

approval, if clinical trials go according to plan.

The hurdle of regulatory approval

With promising results for NES/T, experts are gearing up for the momentous task of applying for regulatory approval. One challenge is that the bar for male birth control medications is much higher than for female contraceptives.

The FDA approves or rejects a drug based on the health risks and benefits to the patient. For men preventing childbirth? "There's no [health] benefit for them. Zero," says Steve Kretschmer, founder and executive director of DesireLine, a health consultancy based in Istanbul. "There's no drug that will be approved unless it has a perfect side effect profile."

Women on hormonal birth control may endure a range of side effects, including headaches, mood changes and even blood clots. But the FDA has deemed those risks acceptable given the risks of childbirth.

Low-level concerns of hormonal side effects are one thing, but the specter of permanent infertility haunts the male birth control field. Gossypol, a promising male contraceptive tested in the 1970s, worked too well — by some estimates, 10 percent of men who took part in trials in China became sterile, even after stopping gossypol.

"Permanent infertility was my biggest concern before I went into the [NES/T] trial. What if my body doesn't kick-start again after?" Ahlqvist says.

But permanent infertility is not an inherent risk of male birth control, Nguyen says, referencing recent trial data.

Preconceived notions about male birth control plus the regulatory challenges have contributed to why pharmaceutical companies are not rushing to develop male contraceptives, Amory says.

Though it might take a change in how the FDA weighs the risk of NES/T for it to ever reach the finish line, that shift could be a game changer for other drug approvals too.

"The question really is, is it possible to get the FDA to shift their criteria to be at the relationship level?" Kretschmer says. The idea is to take equity into account, in which a man gives informed consent and is willing to take on the risks for the benefit of his partner. He points to models the FDA could follow from the World Health Organization and the European Medicines Agency, which are more receptive to the shared-risk argument.

Despite NES/T being further along in the development pipeline, ADAM and other occlusion gels may become available sooner. They're classified as medical devices, not drugs, Kretschmer says, which follow a different regulatory path. Most of the time, companies are not required to submit clinical data to demonstrate safety and efficacy for a medical device, speeding up the review process.

The best-case scenario, experts say, is that an occlusion gel wins approval within five years, and a hormonal contraceptive follows a few years later. If so, it would be the first new male contraceptives to hit the marketplace since goat-bladder condoms were used 5,000 years ago. ✖

Fred Schwaller is a science writer and editor based in Berlin.

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TECHNOLOGY

X-RAY 'VISION' TURNS 130

● In 1895, Anna Bertha Ludwig lent a helping hand to her husband, German physicist Wilhelm Conrad Röntgen. For 15 minutes, she held her hand on a photographic plate while Röntgen shot a mysterious type of radiation at it. He had just discovered "X rays," which can pass through opaque materials and alter film underneath. The image of Ludwig's finger bones (and ring) helped spur the adoption of X-rays into medical practice. Röntgen, meanwhile, won the first Nobel Prize in physics for this work. In the 130 years since they were discovered, X-rays have revolutionized astronomy, biology and other scientific fields. — *Cassie Martin*

THE EVOLUTIONARY ROMANCE BETWEEN PLANTS AND ANIMALS

By Alka Tripathy-Lang

WHEN THE EARTH WAS GREEN | *Riley Black*
St. Martin's Press | $29

Imagine being a paleontologist exploring Utah's Jurassic-aged rocks. Imagine discovering the bones of a 20-meter-long, 20-ton herbivorous dinosaur. Then consider: How could any beast become so big? The answer, according to science writer and paleontologist Riley Black, lies in plants.

Black narrates the story of this Jurassic saurian in a chapter of her latest book, *When the Earth Was Green*. The imagined *Apatosaurus* lumbers through lush cycads, ferns and conifers, vacuuming plant matter into her digestive system of "enormous fermentation vats," which allows her to extract maximal nutrients. The abundance of verdant foliage available for the adult *Apatosaurus* to inhale drove its species's gigantic size. Black even conjures the green pats of dung produced by the (probably) gassy animal as it farts along.

With a focus firmly on plants, Black masterfully uses science to breathe life into ancient worlds in which some of our favorite prehistoric animals lived. Each chapter — written as a vignette with its own appendix explaining the science behind Black's story choices — portrays a particular time and place.

Take the first chapter, set in Arctic Canada 1.2 billion years ago. This is a world of no forests, no fish, no seashells. Bare rock studded with snowcapped mountains presided over sediment-filled oceans stocked with mats of cyanobacteria and other mostly unicellular organisms. Against this backdrop, Black describes something that's not quite plant. It's a multicellular, photosynthesizing red alga. "It's only in this moment that what were once single cells are beginning to combine and coalesce into new and unexpected arrangements," she writes. We wouldn't be here without this evolutionary step.

This red alga and its photosynthetic brethren are ancestors of the first plants that crept onto land, inadvertently luring critters out of the ocean. "It was the plants, not fleshy-finned fish, that changed the world when they came ashore," Black writes.

Paleontology is often framed as stories of colonization and conquest — life colonized land, dinosaurs dominated the Mesozoic Era. Black rejects this framework, instead twining tales of communities into an "evolutionary romance." She reminds us that "we did not arrive here on our own, but as part of an ongoing relationship with the botanical." By itself, a dinosaur is just a dinosaur. Farting sauropods dining at the salad bars of Jurassic forests, warming the planet with their methane-rich malodors, is something else entirely. ✖

Life of the party

● *Margaret S. Collins, the first Black female entomologist in the United States to earn a Ph.D., overcame racism and sexism to become a field biologist and termite expert, life sciences writer Susan Milius reported in "Termite Pioneer."*

"I had the honor of knowing [Margaret S. Collins] in the early 1990s, when I was hired by the USDA at the National Museum of Natural History," wrote research entomologist Dr. M. Alma Solis. "I have many stories of her as a scientist at the museum, but one of the stories I have never heard anyone relate is her ability to capture the attention and imagination of scientists at parties. If there was a group of people around someone, you knew it was Margaret reading palms! She was very good at reading people and very funny."

Margaret S. Collins had a remarkable "ability to capture the attention and imagination of scientists at parties."

Diving deeper

● *A marine cyanobacterium dubbed "Chonkus" stores plenty of carbon and sinks rapidly in liquid. Those traits hold promise for sequestering carbon in the ocean to help fight climate change, earth and climate writer Carolyn Gramling reported in "A mutant cyanobacterium has an appetite for carbon."*

November 30, 2024

December 14, 2024 &
December 28, 2024

Reader Deborah Strod asked how long it would take for the carbon sequestered by this bacterium to make its way back into the atmosphere.

The timescale of carbon cycling in the ocean can vary depending on many factors, including the depth of the water. Generally, "if you sink organic carbon deep enough, it is expected to remain separated from the atmosphere for thousands of years," says microbiologist Max Schubert, formerly of the Wyss Institute at Harvard University. "It remains an open scientific question how much biomass sinks this deep" from the ocean surface, he says.

Scientists are attempting to measure this through models of ocean iron fertilization, the practice of fertilizing the ocean surface to increase the growth of phytoplankton. These organisms capture carbon throughout their lives and ultimately sink down to the seafloor when they die.

Though ocean iron fertilization could help remove atmospheric carbon, it poses some risks. The process can rob valuable nutrients, such as nitrogen and phosphorus, from the environment, potentially disrupting certain ocean ecosystems. "We were excited to see that [Chonkus] accumulated a large amount of carbon-rich polymers," Shubert says, which may allow it to sink carbon "while robbing fewer other nutrients along the way."

On the redesign

● Science News' *January 2025 issue unveiled a new look, with more pages and visual elements, a science-themed puzzle, and our usual comprehensive and in-depth science coverage.*

Some readers shared their first impressions.

"I love it," wrote Mark Waltz. "I've been subscribing for most of my adult life, and it's great to see your efforts to deliver scientific news in what I am sure continues to be a challenging news ecosystem."

Joel Sanet wrote: "I've been a fan of word and math puzzles most of my life ... I urge you to continue publishing them." Acrostics, a type of word puzzle that reveals a coded message, "would give even more opportunities to incorporate science into the clues and could result in a quote from a famous scientist or in a science tidbit," Sanet added.

Conversations with Maya

Maya Ajmera, President & CEO of Society for Science and Executive Publisher of Science News, chatted with Walter "Ted" Carter Jr., President of The Ohio State University. Before serving as Ohio State's President, Carter served as President of the University of Nebraska System. He also led the U.S. Naval Academy and retired as a vice admiral with 38 years of service and more than 6,300 flying hours. Carter is a 1977 alumnus of the International Science and Engineering Fair (ISEF), a program of Society for Science. Here is an edited version of the conversation.

DO YOU HAVE ANY FAVORITE MEMORIES FROM ISEF? Participating in ISEF was a pivotal moment in my life. I was a high school senior in Rhode Island, and the fair was in Cleveland. It was my first time flying in an airplane, and I got to attend a Cleveland Major League Baseball game at the old Municipal Stadium. I recall being able to hear the baseball players talking in the dugout.

My strongest memory of ISEF was the diversity of students from all over the world who were there. For a small-town kid like me, it was overwhelming how big a deal this was.

My project focused on using water Daphnia, or water fleas, to detect pollutants in well water in Rhode Island. I created a method for detecting certain water pollutants faster than the state of Rhode Island could. I won a couple of big awards, including an award from the U.S. Naval Institute. A week after I won that award, I was accepted to the U.S. Naval Academy even though I was a backup/alternate.

All of this is not disconnected. I was accepted into the Naval Academy because of what happened at ISEF. I went to the Naval Academy and studied oceanography and physics. Twenty years after I graduated, I commanded a nuclear-powered aircraft carrier and then returned to higher education. Everything started at ISEF in Cleveland.

YOU LED THE U.S. NAVAL ACADEMY AS ITS LONGEST CONTINUOUSLY SERVING SUPERINTENDENT SINCE THE CIVIL WAR. HOW DID YOUR EXPERIENCE IN THE NAVY SHAPE YOUR APPROACH TO LEADERSHIP IN HIGHER EDUCATION? For me, all the things that make me good at my job come from my curiosity about science and math. My technical skills served me well in high school and as an undergraduate at the Naval Academy. In the Navy, I became a nuclear engineer, which was a precursor to commanding a nuclear-powered aircraft carrier.

When the Navy asked me to lead in higher education, I took the lessons I learned while flying in high-performance; tactical jet aircraft; becoming a top gun graduate; teaching young men and women how to fly in the F-14 Tomcat and the F/A-18F Super Hornet; and rebuilding a nuclear-powered aircraft carrier. That gave me the tools to lead large, complex organizations.

What I found is that the basics of leadership matter. It didn't matter what organization I was in, certain principles seemed to work everywhere: Do things collaboratively; give people the resources they need to do their job; empower your team; praise them when they're successful and when things don't go right, take the blame.

AS THE PRESIDENT OF THE UNIVERSITY OF NEBRASKA, YOU LAUNCHED THE NEBRASKA PROMISE, A FINANCIAL AID PROGRAM GUARANTEEING FULL TUITION FOR STUDENTS FROM LOW- AND MIDDLE-INCOME BACKGROUNDS. WHAT HAS BEEN THE IMPACT? The impact was profound. We knew when we launched the Nebraska Promise at the beginning of the pandemic in 2020 that there was a need for such a program. I told my team that everyone in higher education was going to be focused on protecting themselves and making sure that they could just keep the ball rolling. I said, "This is our opportunity to do some really bold things that might normally take us three or four years to get done."

We offered the program in May 2020, and 5,000 students signed up. By 2024, the program had supported 18,000 students. We are now starting to see the first group of Nebraska Promise students graduate, and their performance is at the same level or higher than every other cohort.

YOU ARE NOW PRESIDENT AT THE OHIO STATE UNIVERSITY. YOU HAVE SAID OHIO STATE WILL PLAY A KEY ROLE IN CHANGING THE NARRATIVE OF HIGHER EDUCATION IN THE UNITED STATES. HOW? People are telling us that higher education costs too much. They're not sure there's a return on investment. This past summer, a Gallup Poll reported that only 36 percent of Americans have a high confidence in post-secondary education.

I think Ohio State is the institution that can change that narrative. According to a recent survey of Ohioans by the Association of American Universities, over 72 percent said they had high confidence in Ohio State. I believe the large public land grant R1 research universities like Ohio State are going to be the engine that will fuel higher education in the future.

Today, 58 percent of students who graduate from Ohio State, and are from Ohio, leave here with zero debt – that's 20 percent better than the national average. Those who do have debt owe about $24,000, which is about 20 percent better than the national average. We are going to improve on that going forward because I believe that nobody should make a decision about whether to go to college or university based on the cost. That's what we did in Nebraska, and we are going to continue to do that here in Ohio.

WHAT ADVICE DO YOU HAVE FOR YOUNG PEOPLE JUST STARTING OUT IN HIGHER EDUCATION OR THEIR CAREERS WHO ARE HOPING TO MAKE A POSITIVE IMPACT IN THE WORLD? The first thing I would tell them is to be a generalist and get exposure to different ideas. Then, follow your passion and become an expert in something that you care about. We need experts, and your expertise will allow you to stand out.

IN MAY, REGENERON ISEF WILL TAKE PLACE IN COLUMBUS. WHAT MAKES COLUMBUS AND OHIO A HUB FOR INNOVATION? People will be surprised when they come to Columbus and see how cosmopolitan and diverse it is. It's the fastest growing city in the United States. Large industry is already here and there's more coming, including an expanded presence of Honda, Amgen and Intel.

This also is a town with an entrepreneurial spirit that people will see and understand right away. Start-ups come to Columbus and thrive.

WHAT BOOKS ARE YOU READING NOW, AND WHAT BOOKS INSPIRED YOU WHEN YOU WERE YOUNGER? Full disclosure, my mother was an English teacher in my high school, and she was my English teacher for three out of my four years there. A lot of my early reading came from things that she taught in the classroom. I recall enjoying the *Hornblower Saga* book series, and I was interested in sports and read books about hockey players Bobby Orr and Gordie Howe.

Recently, I picked up *I Could Never Be So Lucky Again*, which is an autobiography of Gen. James H. "Jimmy" Doolittle.

THERE ARE MANY CHALLENGES FACING OUR WORLD TODAY. WHAT'S KEEPING YOU UP AT NIGHT? The thing that keeps me up at night is where people are going for the truth. There is so much information out there, and we like having it at our fingertips. But how do we know that what we're reading is really true? This is something we are going to have to address as we head into a new world of artificial intelligence, generative AI and large database computing.

CAN YOU DIE OF A BROKEN HEART?

BY BETHANY BROOKSHIRE

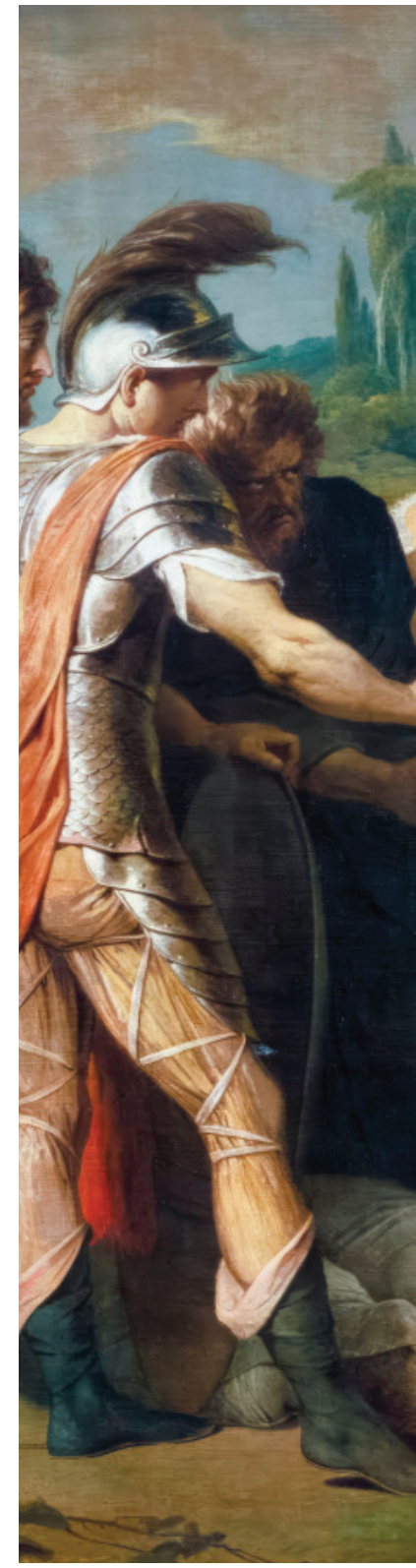
Passing quietly away from sheer heartbreak is a trope that pops up in myth and fantasy. In the *Star Wars* universe, Padmé Amidala may have died of a broken heart after her husband turned to the dark side, becoming Darth Vader, and she gave birth to Luke and Leia. Shakespeare's King Lear succumbs to heartbreak after hearing of the demise of his precious Cordelia. Drama aside, it's possible these characters fell to takotsubo syndrome — a short, intense dysfunction in the heart's left ventricle. It can occur after extreme emotional or physical stress, making "heartbreak" both real and potentially deadly.

While dying of heartbreak has been a popular theme in fiction for a long time, clinicians only began documenting real cases in the 1960s, says Trisha Singh, a cardiologist at University Hospitals Dorset in England. "It was very typically described as an elderly or a middle-aged woman who just lost a loved one, and a day or so afterwards, she died of heartbreak."

As imaging technology improved, doctors could directly study the hearts of afflicted patients. In many, the left ventricle — the chamber that pumps oxygenated blood to the body — balloons out. The shape reminded Japanese clinicians of a takotsubo, a round jar for catching lobsters and octopuses. In 1990, the term takotsubo was proposed to describe the condition.

What triggers it is still something of a mystery. One hypothesis is that an acute traumatic event causes a surge of stress hormones such as norepinephrine in the brain and epinephrine in the adrenal glands. Because the left ventricle is especially rich in receptors for these chemicals, a sudden flood could cause the taut, elastic muscle to become loose and puffy, making it incapable of delivering enough blood to the body. Another hypothesis is that a stress response "stuns" the heart temporarily. With the majority of cases observed in postmenopausal women, it's also possible that reduced estrogen plays a role.

Takotsubo syndrome is relatively rare, accounting for only about 2 percent of people who seek medical care for an apparent heart attack. Cardiologist Peter Rahko, of the



→ King Lear weeps over the dead body of his favorite daughter, Cordelia, in this 18th century painting by Irish painter James Barry.

ALBUM/ALAMY STOCK PHOTO

University of Wisconsin–Madison, recalls a case from the 1980s. An older woman was called to a hospital in rural Wisconsin and shown the body of her son, who had died in a car accident. "Within five minutes, she started having severe chest pain [and] collapsed on the floor," Rahko says. The woman was flown to Madison, where Rahko snaked a catheter into her heart to see if a blockage was causing a heart attack. To his surprise, "her arteries were totally normal, but her heart function was dramatically reduced." In takotsubo syndrome, the heart vessels are often clear.

In retrospect, Rahko now realizes his patient had takotsubo syndrome. Today, reduced heart function with no clear signs of disease is a tip-off. A doctor will look for acute stress, such as recent bereavement. In some cases, the tragic event is obvious. But even events with a more long-term effect like the COVID-19 pandemic or earthquakes in New Zealand have been documented as tipping points. Many patients, Singh notes, have mental illnesses such as anxiety or depression.

Though severe, takotsubo is remarkably short-lived and typically not fatal. About 4 percent of sufferers die, while about 75 percent fully recover after 10 days, as Rahko's patient did. Many recover after only 48 to 72 hours, Singh says.

Knowing that takotsubo syndrome happens today, Rahko says, it wouldn't surprise him if some deaths from "grief" in history were takotsubo. When people had little but belief to go on, it was reasonable to think that "some god struck down somebody for whatever malfeasance there was and they dropped dead," he says. Now "here's one potential physiologic explanation." ✖

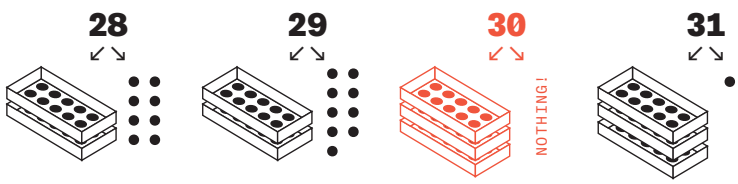
IMAGINE THERE'S NO ZERO

BY BEN ORLIN

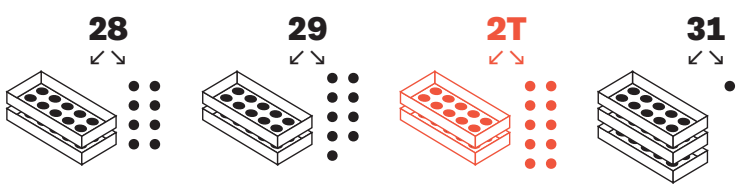
Here, count with me: 1, 2, 3, 4, 5, 6, 7, 8, 9, T, 11, 12 … Oh, what's that? You write 10 with "zero"? Fair enough. Zero, we have been told, is the foundation of our number system. Mathematician Tobias Dantzig once called it "a development without which the progress of modern science, industry or commerce is inconceivable." But that changed in 1947, when mathematician James Foster laid out a system that works like ours in every way — except that it lacks nothing. He called it "a number system without a zero-symbol."

Think of our familiar system as a series of boxes. You can leave up to nine loose objects unboxed. But if a 10th object arrives, you must pack the 10 into a box. When this happens, we use zero to denote an absence of loose objects. The numeral 30 means three boxes of 10, and no additional objects.

This principle continues. For example, in 407, the zero signifies that there are no loose 10s; they've all been boxed up as hundreds.



Foster's system, you might say, asks us to wait before boxing. We leave 10 objects loose, writing them as T. Thus, 30 becomes two boxed-up 10s, or 2T, plus another 10, this one unboxed. (An apter name might be "twenty-ten.") Only with another object (the 31st) does boxing become necessary.



This way, there are always loose objects — and thus, no need for zero.

Unlike Roman, Maya or Iñupiaq numerals, this isn't a total reimagining of numbers. Instead, it's an uncanny parallel universe. Any number without zeros retains its old appearance (1,776 is still 1,776), but any number with zeros is forced to take on a new name.

PUZZLES FROM A WORLD WITHOUT ZERO

1. What year would it be right now? For that matter, what century would it be?
2. Would a "six-figure salary" be more or less desirable than under the old system?
3. Map out the ways a zero-less culture would differ. Would towns commemorate 111th anniversaries? On a car's odometer, which mileage rollover would be most exciting? And would anyone care that Wilt Chamberlain once scored 9T points in a basketball game?

The numeral 20 becomes 1T (call it "ten-teen").

Likewise, 106 becomes T6 (10 10s, plus six units; call it "ten-ty six").

And 3,090 becomes 2T8T (call it "two thousand ten hundred and eighty-ten").

Weird? Yes. Disturbing? Yes. Logically valid? Again, yes. As Foster noted in 1947, his system challenges zero's "alleged essential character in an easily manipulated system of numbers." We still want zero. But we don't, strictly speaking, need it.

Spend a while in Foster's world, and I guarantee you'll soon feel grateful for nothing. ✖

Visit **sciencenews.org/puzzle-answers** for answers. We will publish science-themed crossword puzzles and math puzzles on alternating months. We'd love to hear your thoughts at **puzzles@sciencenews.org**.

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