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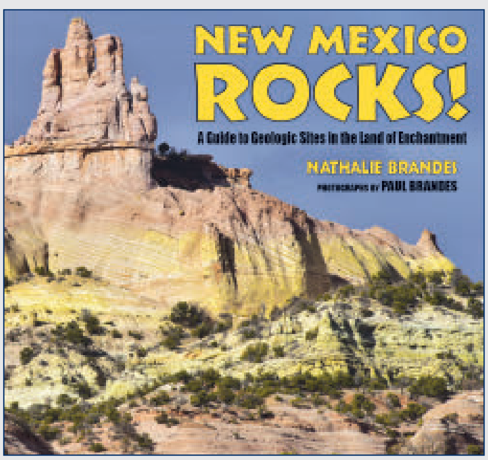

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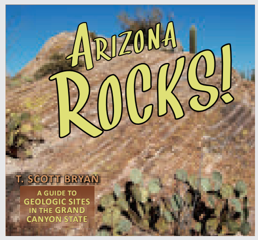

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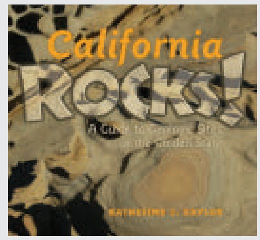

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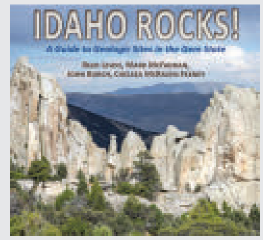

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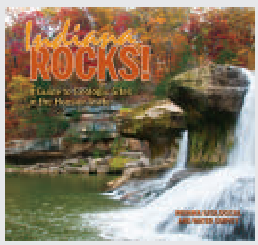

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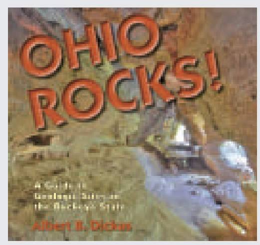

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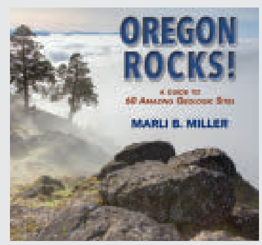

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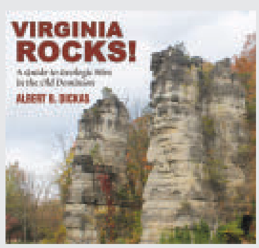

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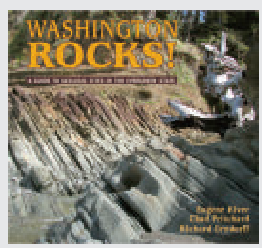

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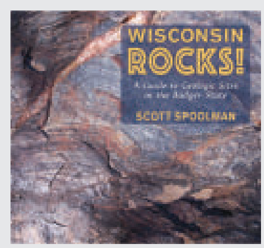

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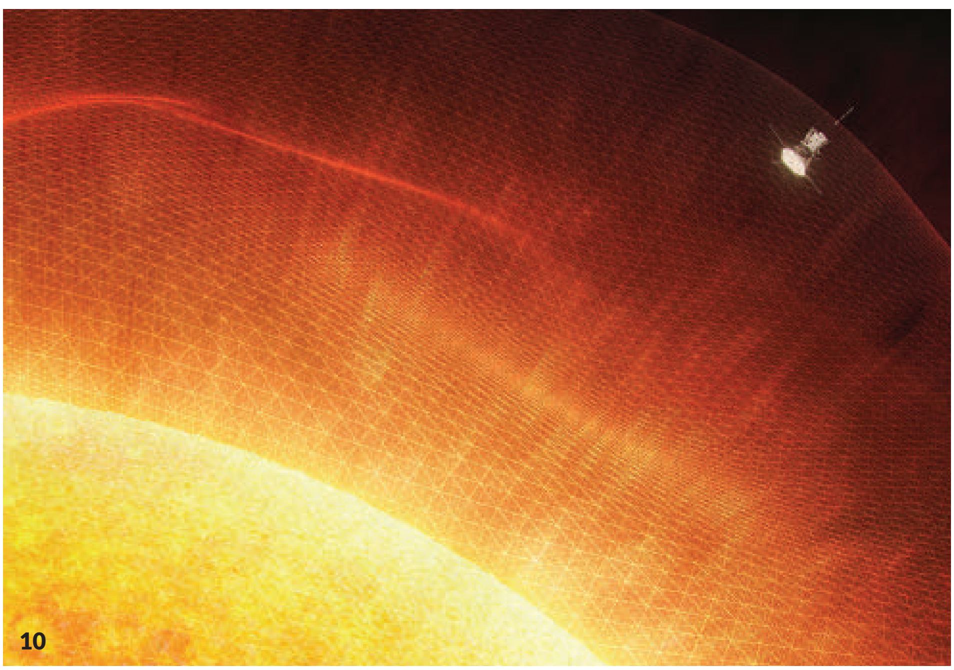

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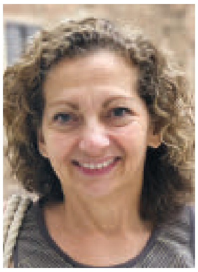
Departments

COVER The stuff of daily life — how we live, work, communicate and travel — is dramatically different from decades ago. *John Lamb/The Image Bank/Getty Images*

FROM TOP: DAVID SINCLAIR PHOTO; PARHAM BEIHAGHI; JOY NG/GSFC/NASA



It's time to manage elite expectations

The Winter Olympics start soon. We get another chance to watch and marvel at astounding feats of endurance, strength and precision (assuming the Beijing Games proceed amid the pandemic).

Just six months ago, a stunned world witnessed U.S. gymnast Simone Biles announce she was pulling out of several events in the Summer Games because her mind and body weren't in sync. She had serious worries that she could get hurt while performing her high-risk maneuvers.

"When Simone Biles made her announcement, I really felt for her," says associate news editor Ashley Yeager. "There's a lot of anxiety and judgment in sports. And a lot of your identity is wrapped up there." Yeager, who was a Division I swimmer at the University of Tennessee, remembers the pressures.

Eager to know what researchers had learned about elite athletes and mental health since she competed in the pool 15 years ago, Yeager dove into the research. She found recent studies suggesting the value of teaching mindfulness and training people to pay attention to the now rather than brood over past mistakes (Page 24). It was heartening, she says. "These issues haven't just emerged, but now it seems like there are efforts to help more people." Among athletes, who Yeager admits are a proud bunch, there's not a lot of sharing about struggles. But she hopes the data on how common anxiety and depression are among athletes will encourage individuals to get help.

"We're not just athletes or entertainment, we're human too," Biles said on August 4 while still at the Tokyo Games. "We have emotions and feelings and things that we're working through behind the scenes." That message seems to be hitting home among athletes and spectators.

Yeager plans to watch the Olympics. "The athletes trained most of their lives to reach this point," she says. She'll be rooting for them to shine physically and mentally.

— Cori Vanchieri, Features Editor

In the next few months, various *Science News* editors will share their thoughts in the Editor's Note.

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STACIE VANCHIERI

Excerpt from the January 29, 1972 issue of *Science News*

50 YEARS AGO

Marijuana usage high

Approximately 24 million Americans have used marijuana at least one time. A national survey reports that more than 8 million are still using the drug.... Usage figures are 33 percent higher than the [National Commission on Marijuana and Drug Abuse] had expected, but ... after age 25 pot smoking falls off rapidly.

UPDATE: Americans' interest in marijuana has grown over the last 50 years. Since 1972, the number of people age 12 and older in the United States who, in their lifetimes, have inhaled or ingested the drug has increased more than fivefold, to 126.5 million as of 2020, according to the National Survey on Drug Use and Health. The gain in users happened as the perceived danger of marijuana dropped over time (*SN: 6/14/14, p. 16*). And unlike in the 1970s, older adults are getting in on the action, though prevalence has risen among adults of all ages. Of the 49.6 million people who reported using pot in 2020, about 47 percent were ages 26 to 49, and about 24 percent were 50 or older.

Vulture bees forage for protein from a piece of rotting chicken in a Costa Rican jungle. Microbes in the bees' guts protect the insects from becoming sick, scientists say.

Q. MCFREDERICK

THE SCIENCE LIFE

How meat-eating vulture bees avoid food poisoning

Mention foraging bees and most people will picture insects flitting from flower to flower in search of nectar. But in the jungles of Central and South America, some bees have a taste for decaying flesh.

These vulture bees are "the weirdos of the bee world," says entomologist Jessica Maccaro of the University of California, Riverside. Most bees are vegetarian.

Scientists have puzzled over why vulture bees seem to prefer rotting carcasses to nectar (*SN: 2/14/04, p. 101*). Now, Maccaro and colleagues think they have cracked the case by looking into the guts of these stingless buzzers.

Vulture bees (*Trigona* spp.) have a lot more acid-producing gut bacteria than their vegetarian counterparts do, Maccaro and colleagues report in the December *mBio*. And those bacteria are the same types that protect vultures and hyenas from getting sick on rotting meat.

To probe the bees' insides, Maccaro's colleagues trekked into a Costa Rican jungle. Since vulture bees feed on almost any dead animal, including lizards and snakes, the researchers cut up store-bought chicken and suspended the raw flesh from tree branches with string.

"The funny thing is we're all vegetarians," says entomologist Quinn McFrederick, also of UC Riverside. "It was kind of gross for us to cut up the chicken." That gross factor quickly intensified in the warm, humid jungle: The meat turned slimy and stinky.

Bees took the bait within a day. The team trapped about 30 strictly meat-eating bees, as well as 30 or so of two other types of local bees — one that feeds on only flowers and one that dines on both flowers and rotting meat. All bees were stored in alcohol to preserve the insects' DNA for analysis, as well as the DNA of any gut microbes.

Strictly meat-eating bees had between 30 percent and 35 percent more acid-producing gut bacteria than strictly vegetarian bees and the ones that sometimes eat meat, the team found. Some types of microbes showed up only in the solely carnivorous bees.

Similar acid-producing bacteria in the guts of vultures and hyenas kill toxin-producing microbes in rotting meat, keeping the animals from getting sick. The microbes probably do the same for the meat-eating bees, the team says.

The health benefit extends beyond individual bees, says evolutionary ecologist David Roubik of the Smithsonian Tropical Research Institute in Balboa, Panama. Vulture bees regurgitate some of the meat into nests, where it serves as food for young bees. Acid-loving gut bacteria end up in this food reserve, Roubik says. "Otherwise, destructive bacteria would ruin the food and release enough toxins to kill the colony."

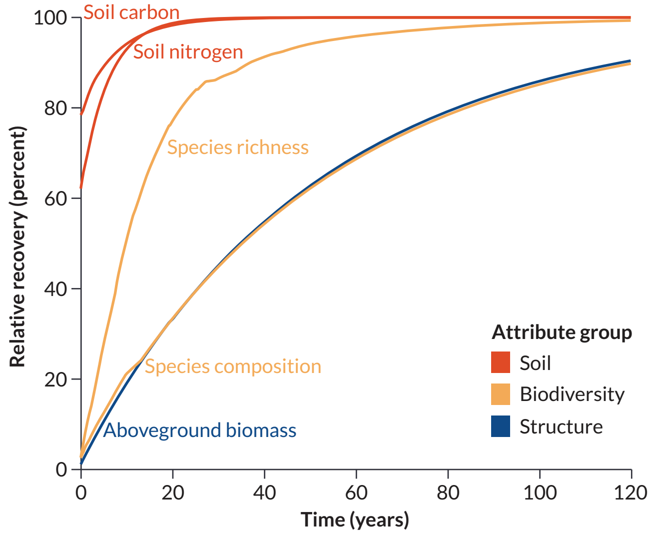
In the end, Maccaro says, it's hard to know which evolved first — the gut bacteria or the bees' ability to eat meat. But the bees probably first turned to meat because of intense competition for nectar, she suspects. *— Sharon Oosthoek*

SCIENCE STATS

Tropical forests can regain ground fast

When farmland is left alone, nature can make a surprisingly quick comeback. After just 20 years, tropical forests that were cleared for agriculture can recover by nearly 80 percent in certain key domains, including biodiversity and soil health, researchers report in the Dec. 10 *Science*. An analysis of 77 regrowing forests across the Americas and West Africa found that soil bounced back fastest: Carbon and nitrogen levels nearly reached those of old-growth forests — which show no signs of human use in at least 100 years — within a decade after abandonment (see graph, right). After 37 years, regrowing forests had nearly as many plant species on average as old-growth forests. But it may take 120 years for the species composition, or relative abundance of each species, to rebound, the team estimates. Total aboveground biomass may also take 120 years to rebound. Seeds and stumps left after clearing probably sped up recovery, the team says. Recovery could be slower on more intensely farmed land. — *Jonathan Lambert*

Predicted relative recovery rates for tropical forest attributes



SOURCE: L. POORTER *ET AL*/*SCIENCE* 2021

Scientists have discovered the first millipede with at least 1,000 legs. The specimen (shown), a 1,306-legged female member of a newfound species, is the leggiest creature on Earth.

FIRST

Finally, a millipede that lives up to its name

Millipedes, as we've known them, have been a lie. The Latin name for the arthropods implies an impressive set of 1,000 feet. Yet no millipede with more than 750 legs has ever been found, until now. The first millipede that lives up to its moniker uses 1,306 legs to tunnel through soil deep beneath Western Australia, researchers report December 16 in *Scientific Reports*. Dubbed *Eumillipes persephone*, it's the leggiest creature ever known to crawl Earth. Found in miners' prospecting drill holes, the specimen and seven other long, threadlike millipedes were sent to entomologist Paul Marek of Virginia Tech in Blacksburg for a closer look. While inspecting a 95-millimeter-long female under a microscope, he realized he beheld something special. "Oh, my God, this has more than 1,000 legs!" he thought. The team suspects *E. persephone*'s elongated, leg-packed body helps it maneuver through soil in up to eight directions at once, like a tangled strand of mobile pasta. *E. persephone* still holds many secrets, but Marek is sure of one thing: "Textbooks are going to have to be changed," he says."We finally have a real millipede." — *Jonathan Lambert*

MYSTERY SOLVED

Spider gecko diet divulges desert diversity

A handful of small geckos have spilled their guts for science, revealing how the creatures get by in a part of Earth's hottest landscape.

Surface temperatures in the Lut Desert in Iran, home to the Misonne's spider gecko (*Rhinogecko misonnei*), soar past 65° Celsius more frequently than anywhere else on the planet. The extreme heat makes it difficult for life to thrive, and for years, ecologists have regarded the desert as mostly barren.

To find out how the gecko (one shown below) sustains itself, entomologist Hossein Rajaei of the Stuttgart State Museum of Natural History in Germany and colleagues analyzed the stomach contents of six geckos. Within the digestive soup stewed DNA from 94 species, about 81 percent of which hail from outside the Lut, the team reports November 18 in the *Journal of Zoological Systematics and Evolutionary Research*. The outsiders were mainly flies, moths and wasps migrating from more temperate locales. There's more living here than meets the eye, Rajaei says.
— *Jude Coleman*

FROM TOP: C. CHANG; P.E. MAREK *ET AL*/*SCIENTIFIC REPORTS* 2021; PARHAM BEIHAGHI

News

BODY & BRAIN

Does COVID-19 trigger diabetes?

The coronavirus may cause fat cells to miscommunicate

BY TINA HESMAN SAEY

Nola Sullivan recently marked an inauspicious anniversary. A little more than a year ago, on November 16, 2020, the 57-year-old from Kellogg, Idaho, came down with COVID-19.

"I lost my taste and smell, with a very bad head cold, body aches, muscle spasm, fatigue, nausea, vomiting, diarrhea," she says. It took a month for her muscle spasms and a lingering headache to go away. She missed nearly three months of work. Her senses of smell and taste still haven't fully returned. "I still have the fatigue," she says. "It's horrible. I'm nauseous all the time."

Sullivan has another lasting reminder of her battle with the coronavirus too: diabetes.

When she finally returned to work at the pharmacy where she's a technician, she noticed she was thirsty all the time. "I just thought that was part of the COVID," she says. "I was drinking gallons of water." But she knew that excessive thirst can be a sign of diabetes. So she checked her blood sugar. A person is considered diabetic when levels of glucose reach 200 milligrams per deciliter of blood. Sullivan's was over 500.

Sullivan is not alone. In a study of more than 3,800 hospitalized COVID-19 patients, just under half developed high blood sugar levels. Many of the patients, like Sullivan, were not previously diabetic, cardiologist James Lo and colleagues reported in the Nov. 2 *Cell Metabolism*. About 91 percent of the intubated COVID-19 patients in the study had high blood sugar, as did almost 73 percent of people who died of the disease.

Lo's group, based at Weill Cornell Medicine in New York City, and others are now working to identify what's causing high blood sugar in people with COVID-19 and what to do about it.

Sugar spikes

In March and April 2020 — months before Sullivan caught COVID-19 — Columbia University Irving Medical Center in New York City was full of COVID-19 patients. Endocrinologist Utpal Pajvani says he noticed that "a lot of those people, but not a majority, were coming in with very high blood sugars. For some of those people, this was brand new for them."

Lo too noticed that many of the COVID-19 patients in his hospital's intensive care unit had high blood sugar. Preexisting diabetes is a risk factor for poor outcomes from COVID-19. But like Sullivan, many of the patients that Lo and his colleagues were seeing did not have diabetes before they got ill. People sometimes develop diabetes as they age, but Lo's patients with high blood sugar were often in their 30s and 40s, he says. And blood glucose levels were incredibly high, sometimes more than twice the level that indicates diabetes.

Such sky-high levels of blood sugar were associated with a 15 times higher risk of intubation and 3.6 times higher risk of death compared with people with COVID-19 who had normal blood sugar levels, Lo and colleagues found.

"We don't know if the high blood sugar is causal of the bad outcome or reflective of the bad outcome," says Pajvani, who wasn't involved in the study. Still, he and other doctors aren't totally surprised by the connection between COVID-19 and high blood sugar, or hyperglycemia.

High blood sugar has been documented in people with acute respiratory distress syndrome, or ARDS, caused by injuries or infections with viruses or bacteria. ARDS is a condition in which the lungs can't supply enough oxygen to the body.

COVID-19 patients with ARDS and high blood sugar spent three times as long in the hospital as people with ARDS caused by COVID-19 and who had normal blood sugar levels, Lo and colleagues found. But weirdly, people with hyperglycemia who had ARDS caused by COVID-19 were less likely to die than hyperglycemic people with ARDS due to other causes.

"The outlook was still bad, just not as bad in the group with ARDS and COVID, which is surprising," says Ralph DeFronzo, an endocrinologist and chief of the diabetes division at the University of Texas Health Science Center at San Antonio, who was not involved with Lo's study.

Finding a culprit

Exactly what sends blood sugar soaring in people with COVID-19 has been a mystery. Some evidence has suggested

After a bout with COVID-19, some people are left with diabetes and must monitor their blood sugar levels with finger pricks and testing devices.

TOM WERNER/DIGITALVISION/GETTY IMAGES

that the coronavirus infects cells in the pancreas that make insulin, a hormone that lowers blood sugar levels by signaling cells to take in sugar and burn it for fuel. But in Lo's study, people with COVID-19 who had high blood sugar still made high levels of C-peptide, a bit of protein that is made alongside insulin in pancreatic cells. High C-peptide levels indicate that the patients' pancreatic cells were producing insulin.

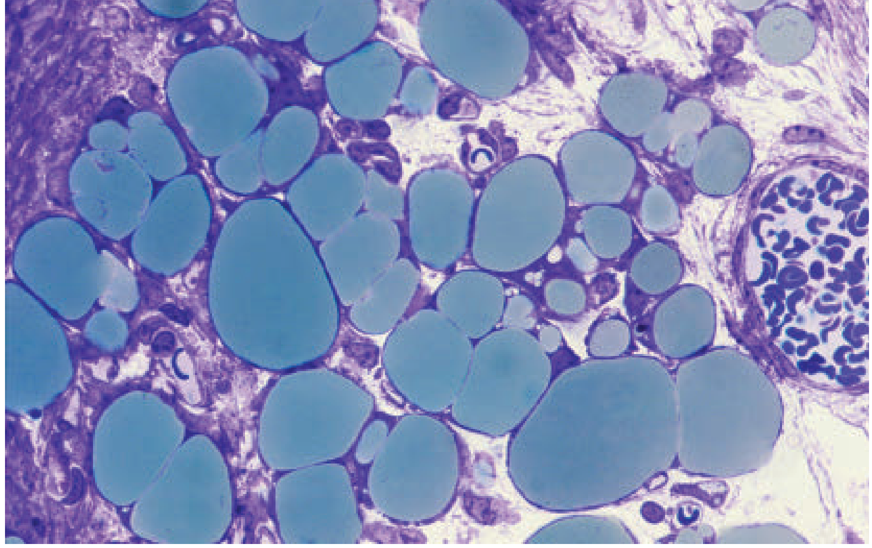
These people's blood sugar was still high, though. So if the pancreatic cells weren't the problem, something else must be going wrong.

That something else may be that fat cells infected with the coronavirus send the wrong message to other cells, ultimately leading to high blood sugar, Lo and colleagues suggest. Lo's team discovered that COVID-19 patients had low levels of adiponectin, a hormone produced by fat cells that helps other cells heed insulin's call to take in sugar. People with obesity also often make low levels of adiponectin, possibly explaining why they are at risk for poor outcomes from COVID-19. Levels of several other hormones produced by fat cells were also out of whack, the researchers found.

The results suggest that the high blood sugar levels of people with COVID-19 result from insulin resistance — a condition in which cells ignore insulin's message to take in glucose — brought on by a dearth of fat hormones rather than by an inability to produce insulin.

The coronavirus can infect fat cells, the researchers' experiments with hamsters and with cells grown in lab dishes showed. Damage done to fat cells directly by the virus, or indirectly by inflammation instigated to fight the virus, may interfere with fat cells' ability to make normal hormone levels and help maintain steady blood sugar levels, Lo says.

Experiments by other researchers have also indicated that the coronavirus can replicate in human fat, also known as adipose tissue, says José Alemán, an endocrinologist at the New York University Grossman School of Medicine. That's yet another clue that fat is involved in severe disease.



Fat cells, like these human cells seen in a light microscope image, do more than store lipids (blue-green). Fat also makes hormones that can help regulate metabolism. COVID-19 may disrupt production of some fat hormones, causing diabetes in some people.

MICROSCAPE/SCIENCE SOURCE

For instance, autopsies revealed that the coronavirus had infected the fat cells of nine of 18 men who died of COVID-19, researchers in Germany reported in the Jan. 4 *Cell Metabolism*. All nine of the men with coronavirus in their fat were overweight or obese. The researchers also found the virus in the fat cells of five of 12 women who died of COVID-19, but those women were not all overweight or obese.

Inspired by Lo's work, the German team uncovered evidence that coronavirus infection also affects fat cells' ability to metabolize some lipids, leading people with COVID-19 to develop higher levels of triglycerides in their blood. That's yet another clue that fat isn't working properly in some people with COVID-19. And these changes in fat may contribute to more severe disease.

Obesity is often associated with inflammation in fat and other tissues. Coronavirus infection may make that inflammation worse, tipping the scales toward messed-up hormone production and eventual diabetes, Alemán says. Lo's findings "lend credence to the idea that adipose is the reservoir for this low-grade inflammation that then gets triggered by COVID," Alemán says.

But the conclusion is not a slam dunk, Pajvani says. "This is an example of very good research done in very difficult settings." But because the study looked back at a group of patients, but didn't match their characteristics and limit other variables from the beginning, the work can't definitively show the cause of COVID-19–related diabetes. "This gives us a great hint of the type of study to do," he says.

A lasting legacy

Whether coronavirus infections cause diabetes or simply unmask the condition in susceptible people, such as people who are overweight or obese, is not yet clear, DeFronzo says. Alemán agrees. "A lot of these patients have an underlying state of insulin resistance, likely prediabetes, but then acute illness in the form of COVID-19 tips [them] over to diabetes."

Doctors may be able to counteract high blood sugar by giving COVID-19 patients drugs called thiazolidinediones or glitazones, which make cells more sensitive to insulin's action. DeFronzo says he hopes to test one of those drugs, called pioglitazone, in COVID-19 patients with high blood sugar. The aim is to prevent the worst outcomes from COVID-19, but patients' high blood sugar may linger.

For Sullivan, changing her diet and taking medication have helped her control her blood sugar levels. "I've lost almost 60 pounds," she says. But "they say that the diabetes will probably be for life." ■

Trishla Ostwal contributed reporting to this story.

HUMANS & SOCIETY

Neandertals shaped European terrain

The hominids are the first known to have left marks on nature

BY BRUCE BOWER

Neandertals took Stone Age landscaping to a previously unrecognized level.

Around 125,000 years ago, these close human relatives transformed a largely forested area bordering two central European lakes into a relatively open landscape, archaeologist Wil Roebroeks of Leiden University in the Netherlands and colleagues say. Analyses of pollen, charcoal, animal fossils and other material previously unearthed at two ancient lake basins in Germany provide the oldest known evidence of hominids reshaping their environments, the team reports in the Dec. 17 *Science Advances*.

The excavated areas are located within a site called Neumark-Nord. Neandertals' daily activities there had a big environmental impact, the researchers suspect. Those pursuits, which occurred over about 2,000 years, included setting campfires, butchering game, making tools and constructing shelters, the team says.

"We might be dealing with larger and less mobile groups of [Neandertals] than commonly acknowledged," Roebroeks says, thanks in part to rising temperatures after around 150,000 years ago that cleared ice sheets from resource-rich locations such as Neumark-Nord.

Whether Neandertals at Neumark-Nord set fires to clear large tracts of land, a practice that has been observed among some modern hunter-gatherers, is unclear. The geologic remnants of many small campfires may look much like those of a small number of large fires, Roebroeks says.

Finds at Neumark-Nord add to a debate about when *Homo sapiens* and their relatives began to have a dominating influence on the natural world. Some scientists regard this period as a new geologic epoch, the Anthropocene. It's unclear when this epoch began and whether its roots extend to the Stone Age.

Regular fire use by members of the *Homo* genus began around 400,000 years ago (*SN: 5/5/12, p. 18*). Until now, the earliest evidence of *H. sapiens* occupations associated with increased fire setting and shifts to open habitats date to around 40,000 years ago in Australia, 45,000 years ago in highland New Guinea and 50,000 years ago in Borneo.

Analyses of lake cores and stone-tool sites in southern-central Africa indicate that fires set by increasing numbers of *H. sapiens* kept the landscape open even as rainy conditions conducive to forest growth developed around 85,000 years ago. Open environments still predominate in this part of Africa, paleoanthropologist Jessica Thompson of Yale University and colleagues reported in the May 7 *Science Advances*. Humans and Neandertals had likely been modifying their ecosystems "for a very long time," Thompson says.

Pollen preserved in ancient sediments at Neumark-Nord indicate that grasses and herbs, signs of an open landscape, appeared around 125,000 years ago,

HUMANS & SOCIETY

Greenland Vikings faced rising seas

Climate change might have hastened the society's end

BY FREDA KREIER

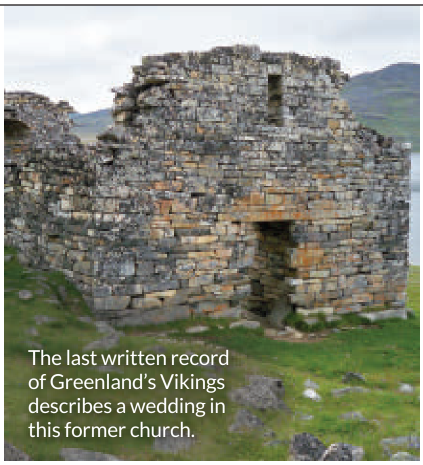
In 1721, a Norwegian missionary set sail for Greenland in the hopes of converting the Viking descendants living there to Protestantism. When he arrived, the only traces he found of the Norse society were ruins of settlements that had been abandoned 300 years earlier.

No known written record explains why the Vikings left or died out. But a new simulation of Greenland's coastline indicates that as the island's ice sheet started expanding around that time, sea levels rose drastically, Harvard geophysicist Marisa Borreggine and colleagues reported December 15 at the American Geophysical Union's fall meeting.

Vikings first colonized Greenland in 985. Settlers arrived during the Medieval Warm Period, when conditions there and across Europe were unusually temperate for a handful of centuries. By 1350, the climate took a turn for the worse with the beginning of the Little Ice Age, a period of regional cooling that lasted well into the 19th century.

Researchers have long speculated that a rapidly changing climate could have dealt a blow to Greenland's Norse society. The island probably became much colder in the last 100 years of Norse occupation, which would have made farming and raising livestock difficult, says Boyang Zhao, a paleoclimatologist at Brown University in Providence, R.I, who was not involved in the work.

Lower temperatures, Borreggine and colleagues say, would have had another impact on Greenland: the expansion of the island's ice sheet. Counterintuitively,



The last written record of Greenland's Vikings describes a wedding in this former church.

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sea level around Greenland tends to rise when the ice sheet grows. That's because the ice pushes the land down while gravitationally pulling on nearby seawater. Simulating the impact of the weight of the ice and its tug on the water, the team found that sea level rose enough to flood the coast by hundreds of meters in some areas at the start of the Little Ice Age.

Between the time the Vikings arrived

Roebroeks and colleagues say. Stone artifacts — some showing signs of having been heated — and animal bones displaying butchery marks date to the same time at Neumark-Nord, when Neandertals but not *H. sapiens* inhabited Europe.

Stone tools and bone fragments with signs of heating, burned wood, charred seeds and dense patches of charcoal particles suggest that Neandertals had frequently set fires near the lakes.

Pollen from two other sites in the same part of Germany, where researchers previously found small numbers of stone tools suggesting a limited Neandertal presence, show that forests dominated there when Neandertals inhabited Neumark-Nord's grasslands. That strengthens the view that Neandertals altered the Neumark-Nord landscape rather than settling there after forests had shrunk, Roebroeks says.

Archaeologist Manuel Will of the University of Tübingen in Germany agrees. The findings "should be a wake-up call" for the scientific community to include archaeologists studying the Paleolithic record in efforts to identify the start of the Anthropocene, he says. ■

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and when they left, there was "pretty intense coastal flooding, such that certain pieces of land that were connected to each other were no longer connected," Borreggine says. This flooding also could have destroyed land used for farming.

Though archaeological evidence suggests that Greenland's Norse people relied on seafood more and more in the last century of their occupation, learning to adapt may ultimately have been too difficult in the face of an increasingly harsh landscape, Borreggine says.

The idea that rising sea levels may have been among the challenges these Vikings faced has merit, Zhao says. "But there are still a lot of unsolved questions," he says, including why exactly they left.

The last written record of this society is a letter describing a wedding in 1408. That couple moved to Iceland soon after. Why the pair left is lost to history, but, as the new research suggests, sea level rise may have been part of the equation. ■

HUMANS & SOCIETY

Arctic ironmaking got an early start

Ancient hunter-gatherers were metalsmiths, new finds show

BY BRUCE BOWER

Discoveries from northeastern Sweden, including this molded bronze buckle (front and back shown), have uncovered advanced iron production and metalworking among hunter-gatherers who lived there more than 2,000 years ago.

Hunter-gatherers who lived more than 2,000 years ago near the top of the world appear to have run ironworking operations as advanced as those of farming societies far to the south.

Excavations at two sites in northeastern Sweden uncovered ancient furnaces and fire pits that hunter-gatherers used for metalworking. A mobile lifestyle did not prevent hardy groups based in or near the Arctic Circle from organizing large-scale efforts to produce iron and craft metal objects, archaeologist Carina Bennerhag of Luleå University of Technology in Sweden and colleagues say. In fact, hunter-gatherers who moved for part of the year across cold, forested regions apparently exchanged resources and knowledge related to metallurgy, the extraction of metals from ores, the team reports in the December *Antiquity*.

Ancient hunter-gatherers at the two Swedish sites "were more socially organized and sedentary than we previously thought," says Luleå archaeologist and coauthor Kristina Söderholm. Groups must have settled for substantial amounts of time at locations near crucial resources such as ores, wood, clay and stone.

Many investigators regard ironworking as an invention of large agricultural societies in southwest Asia more than 3,000 years ago (*SN: 10/5/13, p. 11*). From there, the technology has typically been thought to have spread elsewhere, eventually being adopted by people in northern Scandinavia and other Arctic areas between A.D. 700 and 1600.

But that view has been questioned in recent years. Increasing evidence indicates that small-scale societies mastered ancient technologies — including metallurgy — relatively early, says archaeologist Marcos Martinón-Torres of the University of Cambridge.

At the first Swedish site, Sangis, Bennerhag's team uncovered a rectangular iron-smelting furnace consisting of a stone frame and clay shaft. Holes in the frame served as inlets for air blown on burning charcoal inside, probably by bellows placed on flat stones, the team says.

By-products of heating iron ore at high temperatures were found in and near the furnace. Radiocarbon dating of furnace remains suggests iron production occurred between around 200 and 50 B.C.

Areas that hunter-gatherers occupied about 500 meters from the furnace contained at least three fire pits where iron was reheated and refined. There, researchers found several iron items and others made of steel, a bronze buckle and metallic waste with copper droplets on the surface, suggesting that different metals were produced at Sangis.

Excavations at a second site, Vivungi, uncovered two iron-smelting furnaces containing iron ore and by-products of iron production. Hunter-gatherers repeatedly occupied this location from around 5300 B.C. to A.D. 1600, the scientists say, with iron production starting around 100 B.C.

Evidence of iron production by hunter-gatherers in southern Scandinavia over 2,000 years ago already existed. So discoveries of similarly old ironwork farther north make sense, says archaeometallurgist Thilo Rehren of the Cyprus Institute in Nicosia. Preliminary work indicates that iron production also began in East Asia over 2,000 years ago, he adds. ■

ATOM & COSMOS

NASA probe is the first to visit the sun

The spacecraft journeyed into the solar atmosphere

BY LISA GROSSMAN

For the first time, a spacecraft has made contact with the sun. During a flyby last year, NASA's Parker Solar Probe entered the sun's atmosphere.

"We have finally arrived," Nicola Fox, director of NASA's Heliophysics Science Division in Washington, D.C., said December 14 in a news briefing at the fall meeting of the American Geophysical Union. "Humanity has touched the sun."

Parker left interplanetary space and crossed into solar territory on April 28, 2021, during one of its close encounters with the sun. While there, the probe took the first measurements of exactly where this boundary, called the Alfvén critical surface, lies. It was about 13 million kilometers above the sun's surface, physicists reported at the meeting and in the Dec. 17 *Physical Review Letters*.

"We knew the Alfvén surface had to exist," solar physicist Justin Kasper of the University of Michigan in Ann Arbor said at the briefing. "We just didn't know where it was."

Finding this layer was one of Parker's main goals when it launched in 2018 (*SN: 7/21/18, p. 12*). The Alfvén critical surface marks where packets of plasma can separate from the sun and become part of the solar wind, the speedy stream of charged particles that emanates from the sun. The solar wind and other more dramatic forms of space weather can wreak havoc on Earth's satellites and even on life (*SN: 2/27/21, p. 16*). Scientists want to pinpoint how the wind gets started to better understand how it can impact Earth.

The Alfvén critical surface also may hold the key to one of the biggest solar mysteries: why the sun's corona, its wispy outer atmosphere, is so much hotter than the sun's surface. With most heat sources, temperatures drop as you move farther away. But the sun's corona sizzles at more than a million degrees Celsius, while the surface is only a few thousand degrees.

In 1942, physicist Hannes Alfvén proposed a solution to the mystery: A type of magnetic wave might carry energy from the solar surface and heat up the corona. It took until 2009 to directly observe such waves, in the lower corona, but they didn't carry enough energy there to explain all the heat (*SN: 4/11/09, p. 12*). Solar physicists have suspected that what happens as those waves climb higher and meet the Alfvén critical surface might play a role in heating the corona. But scientists didn't know where this frontier began.

With the boundary identified, "we'll now be able to witness directly how coronal heating happens," Kasper said.

As Parker crossed the invisible boundary, its instruments recorded a marked increase in the strength of the local magnetic field and a drop in the density of charged material. Out in the solar wind, waves of charged particles gush away from the sun. But below the Alfvén critical surface, some of those waves bend back toward the surface of the sun.

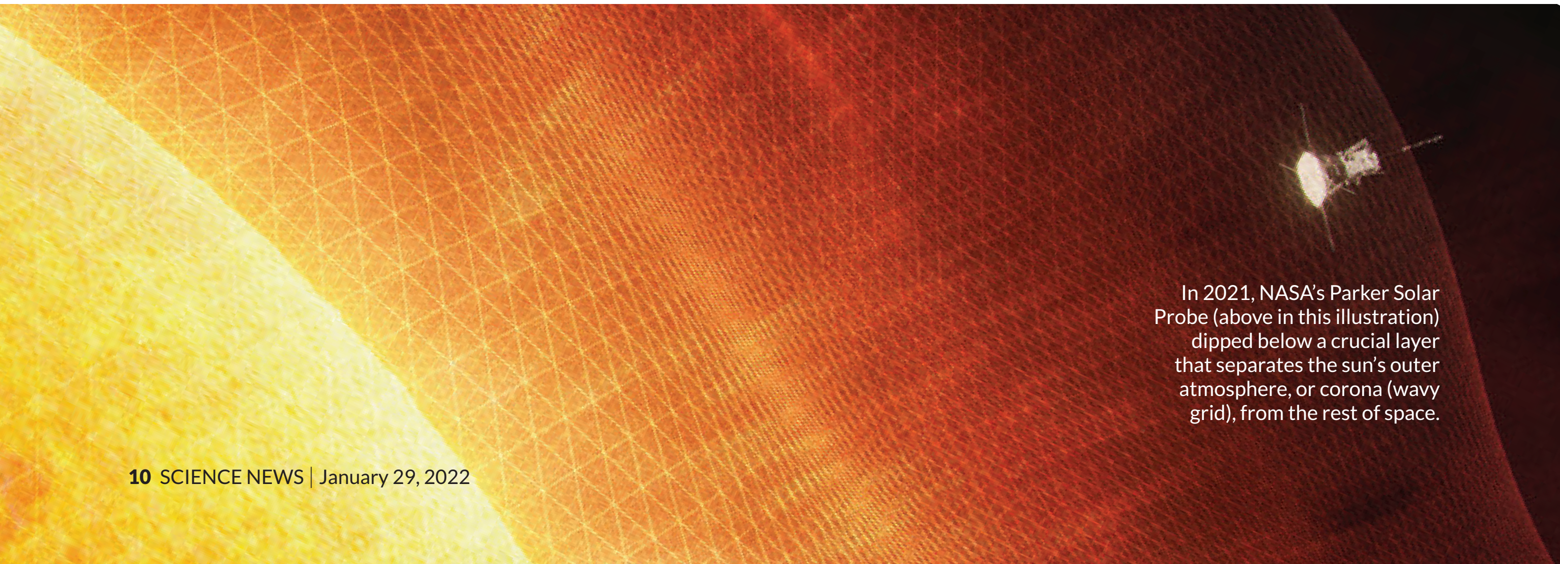
Measurements showed that the Alfvén critical surface is wrinkly. Decades ago, scientists imagined the boundary as a smooth sphere surrounding the sun like a snow globe. More recently, some thought it would be so ragged that it wouldn't be apparent when the spacecraft crossed it.

Neither of those scenarios is correct. The surface is smooth enough that the moment of crossing was noticeable, Kasper said. But Parker crossed in and out of the boundary three times. The longest trip lasted about five hours, while the shortest was only half an hour. "The surface clearly has to have some structure and warp to it," Kasper said.

That structure could influence everything from the way solar eruptions leave the sun to the way the solar wind interacts with itself farther out from the sun, says solar physicist Craig DeForest of the Southwest Research Institute in Boulder, Colo., who is a member of the Parker team but was not part of these measurements. "That has consequences that we don't know yet, but are likely to be profound."

Parker will make several more close approaches to the sun over the next few years and should cross into the corona again and again, solar physicist Nour Raouafi of the Johns Hopkins Applied Physics Laboratory in Laurel, Md., said in the briefing. But the boundary might not be in the same place every time. As the sun's activity changes, the level of the Alfvén critical surface is expected to rise and fall as if the corona is breathing in and out, he said. That's another thing that scientists hope to see for the first time. ■

JOY NG/GSFC/NASA



In 2021, NASA's Parker Solar Probe (above in this illustration) dipped below a crucial layer that separates the sun's outer atmosphere, or corona (wavy grid), from the rest of space.

Source of Enceladus' plumes is in doubt

Sprays may come from the moon's icy shell, not an interior ocean

BY LISA GROSSMAN

Saturn's icy moon Enceladus sprays water vapor into space. Scientists have thought that the plumes come from a deep subsurface ocean — but that might not be the case, new simulations suggest.

Instead, the water could come from pockets of watery mush in the moon's icy shell, researchers reported December 15 at the American Geophysical Union's fall meeting.

"Maybe we didn't get the straw all the way through the ice shell to the ocean," says planetary scientist Jacob Buffo of Dartmouth College. "Maybe we're just getting this weird pocket."

The hidden ocean makes Enceladus one of the best places to search for life in the solar system. Concepts for future missions to Enceladus rely on the idea that taking samples of the plumes would directly test the contents of the ocean, without needing to drill through the ice. "That could be true," Buffo says. But the simulations suggest "you could be sampling this slushy region in the middle of the shell, and that might not be the same chemistry as is down in the ocean."

Enceladus has beguiled planetary scientists since NASA's Cassini spacecraft revealed the moon's dramatic plumes in 2005. At the time, researchers wondered if the spray originated on Enceladus' icy surface, where friction from quakes could melt ice and let it escape as pure water vapor into space. Later evidence collected by Cassini convinced most scientists that the geysers erupt from shell fractures that reach down to a salty, subsurface sea (*SN: 9/6/14, p. 15*).

One of the most convincing pieces of evidence was the fact that the plumes contain salts, physicist Colin Meyer of Dartmouth said at the meeting. The quake idea couldn't account for those salts, and instead suggested that salts in the melted ice would be left on the surface as water escaped into space, he said, like the salt left on skin by evaporating sweat.

But Meyer, who has studied the physics of sea ice on Earth, realized that pockets of meltwater in the ice shell could concentrate salts. He, Buffo and colleagues applied computer simulations developed for sea ice on Earth to the observed icy conditions on Enceladus. The team found that this moon could easily generate pockets of mush within its shell and vent the salty contents into space.

The findings' implications "are huge" for proposed life-finding missions to Enceladus, says planetary scientist Emily Martin of the Smithsonian National Air and Space Museum in Washington, D.C. If the plumes don't tap into the ocean, that could shift scientists' perspective on what the plumes indicate about Enceladus' interior, Martin says. "That's a big deal." ■

EARTH & ENVIRONMENT

Ice shelf could collapse within 5 years

Loss of buttressing could hasten demise of 'doomsday' glacier

BY CAROLYN GRAMLING

The demise of a West Antarctic glacier poses the world's biggest threat to sea level rise before 2100 — and an ice shelf that's holding it back from the sea could collapse within three to five years, scientists reported December 13 at the American Geophysical Union's fall meeting.

Thwaites Glacier is "one of the largest, widest glaciers in Antarctica — it's huge," Ted Scambos, a glaciologist at the Cooperative Institute for Research in Environmental Sciences in Boulder, Colo., told reporters. Spanning 120 kilometers across, the glacier is about the size of Florida. If the whole thing slid into the ocean, it would raise sea levels by 65 centimeters (more than two feet). Right now, its melting is responsible for about 4 percent of global sea level rise.

But a large portion of the glacier is about to lose its tenuous grip on the seafloor and that will dramatically speed up Thwaites' seaward slide, the researchers said. The eastern third of the glacier is braced by a floating ice shelf, an extension of the glacier that juts out into the sea. Right now, the ice shelf's underbelly is lodged against an underwater mountain located about 50 kilometers offshore. That pinning point is helping to hold the ice in place.

Data collected beneath and around the ice shelf in the last two years suggest that brace won't hold much longer. Warm ocean waters are eating away at the ice from below (*SN: 5/8/21 & 5/22/21, p. 14*). As the ice shelf loses mass, the underbelly is retreating inland and will eventually retreat completely behind the underwater mountain pinning it in place. Meanwhile, fractures and crevasses, widened by these waters, are snaking through the ice like cracks in a car's windshield, shattering and weakening it.

This deadly punch-jab-uppercut combination of melting from below, ice shattering and losing a grip on the pinning point is pushing the ice shelf to imminent collapse, within as little as three to five years, Erin Pettit, a glaciologist at Oregon State University in Corvallis, said. "The collapse of this ice shelf will result in a direct increase in sea level rise, pretty rapidly," Pettit added. "It's a little bit unsettling."

Satellite data show that over the last 30 years, the flow of Thwaites Glacier across land and toward the sea has nearly doubled in pace. The collapse of this "doomsday" glacier alone would alter sea levels significantly, but its fall would also destabilize other West Antarctic glaciers, dragging more ice into the ocean and raising sea levels even more.

That makes Thwaites "the most important place to study for near-term sea level rise," Scambos said. So in 2018, research groups from the United States and the United Kingdom embarked on a five-year project to try to anticipate the glacier's imminent future by planting instruments atop, within, below and offshore of it.

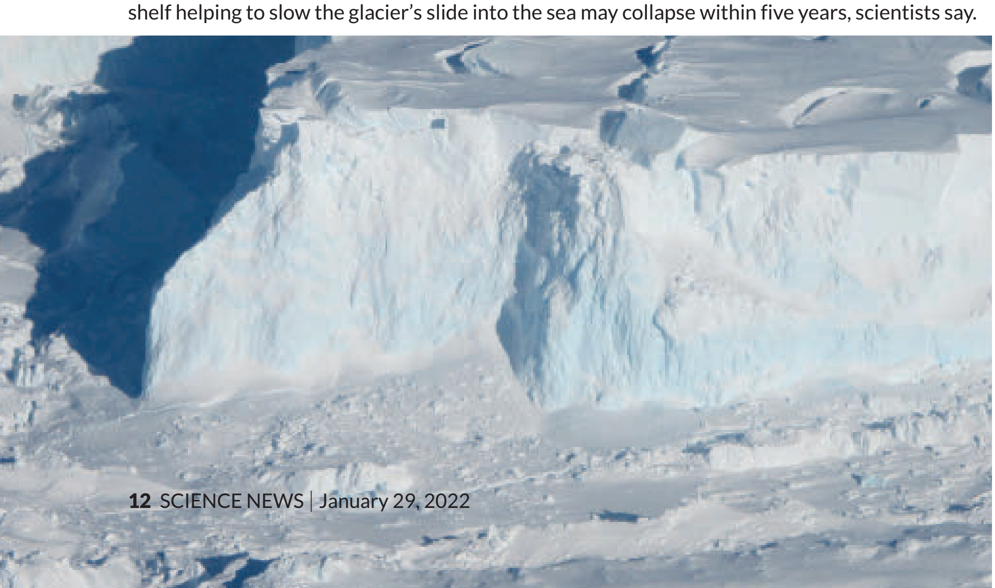
This pull-out-all-the-stops approach is leading to other discoveries, including the first observations of ocean and melting conditions right at a glacier's grounding zone, where a land-based glacier begins to jut out into a floating ice shelf. Scientists have also spotted how the rise and fall of ocean tides can speed up melting by pumping warm waters farther beneath the ice and creating new melt channels and crevasses in the ice's underside.

As Thwaites and other glaciers retreat, some scientists have pondered whether the glaciers might form tall ice cliffs along the edge of the ocean — and whether the potential tumble of such massive blocks into the sea might lead to devastatingly rapid sea level rise, a hypothesis known as marine ice cliff instability (*SN: 3/2/19, p. 6*). Predicting how likely such collapses are, researchers say, depends on our understanding of the physics and dynamics of ice behavior, something about which scientists have historically known very little.

The Thwaites collaboration is tackling this problem. In simulations of the further retreat of Thwaites, glaciologist Anna Crawford of the University of St. Andrews in Scotland and colleagues found that if the shape of the land beneath the glacier dips deep enough in some places, that could lead to some very tall ice cliffs. But, the team found, the ice itself might also deform and thin enough to make the formation of tall ice cliffs difficult.

The collaboration is only at its halfway point, but data collected so far already promise to help scientists better estimate the near-term future of Thwaites, including how quickly and dramatically it might fail, Scambos said. "We're watching a world that's doing things we haven't really seen before ... because we're pushing on the climate extremely rapidly with carbon dioxide emissions," he said. "It's daunting." ■

Antarctica's Thwaites Glacier (shown) poses the greatest near-term threat to sea level rise. An ice shelf helping to slow the glacier's slide into the sea may collapse within five years, scientists say.



JAMES YUNGEL/NASA

LIFE & EVOLUTION

A robot spooks invasive fish

Fear may render some exotic species less harmful

BY JONATHAN LAMBERT

Invasive mosquito fish are often fearless.

Free from the predators of their native range, these fish run rampant, throwing naïve ecosystems from Europe to Australia out of whack. To keep the fish in check, scientists are trying to strike fear back into the hearts of these swimmers with a high-tech tool: robots.

In a laboratory experiment, a robotic fish designed to mimic one of mosquito fish's natural predators increased fear and stress responses in the fish, impairing their survival and reproduction, researchers report December 16 in *iScience*.

While robofish won't be deployed in the wild anytime soon, the research highlights that there are "more creative ways of preventing unwanted behavior from a species" than simply killing it, says Michael Culshaw-Maurer, an ecologist at the University of Arizona in Tucson who wasn't involved in the study. "It's just wonderful seeing work in this area."

Native to parts of the eastern and central United States, mosquito fish (*Gambusia* spp.) were let loose in freshwater ecosystems around the world during the last century in a foolhardy effort to control malaria. But instead of eating malaria-transmitting mosquito larvae, introduced mosquito fish mostly gobble up the eggs and gnaw at the tails of native fish and amphibians. The International Union for Conservation of Nature calls mosquito fish one of the world's most destructive invasive species.

Efforts to combat mosquito fish, and many other introduced, invasive species, usually rely on mass killing with traps, poison or other blunt methods, says Giovanni Polverino, a behavioral ecologist at the University of Western Australia in Perth. "For most of the invasive species considered problematic, this doesn't work," he says, and can often harm native species too.

G. POLVERINO

Scientists designed a robotic fish (above left) to mimic largemouth bass, a natural predator of mosquito fish (right). In lab experiments, the robotic fish induced fear that led to behavioral, body and reproductive changes in the mosquito fish, which are an invasive threat around the world.

The problem isn't necessarily the presence of mosquito fish in these ecosystems, Polverino says, but their wanton behavior enabled by a lack of predators. Predation would prevent their numbers from ballooning, but fear of predation alone can influence prey behavior in ways that ripple throughout an ecosystem. Polverino and his colleagues wanted to see if a robotic fish crafted to mimic one of mosquito fish's natural nemeses, the largemouth bass (*Micropterus salmoides*), could be just as scary and take some of the bite out of mosquito fish's negative impact.

In the lab, the researchers set up 12 tanks that each housed six mosquito fish (*G. holbrooki*) with six tadpoles of the motorbike frog (*Litoria moorei*), a species native to Australia that is commonly harassed by mosquito fish. After a week of acclimatization, the team transferred each group to an experimental tank for one hour twice a week for five weeks. There, half of the groups faced a robotic predator designed to recognize and lunge at mosquito fish when they got too close to the tadpoles.

Fear of the robot altered the behavior, shape and fertility of the mosquito fish, both during exposure and weeks later. Mosquito fish facing the robot tended to cluster together and not explore the tank, while the tadpoles, free of harassment, ventured farther out. Even in the safety of their home aquariums, fish exposed to the robot were less active and more anxious — exhibited by seconds-longer freeze responses — than mosquito fish that weren't exposed.

The cumulative stress taxed the fish's bodies too. Exposed fish lost energy reserves, becoming slightly smaller than nonexposed fish. Exposed males became more streamlined, potentially to quicken escape behaviors, the researchers say. And the sperm count of scared fish decreased by about half, on average.

"Instead of investing in reproduction, they're investing in reshaping their body to escape better after only six weeks," Polverino says. "Overall, they became less healthy and less fertile."

The long-term impact that such robotic predators would have on wild mosquito fish and their neighbors remains unclear. That's beside the point for Polverino, who says the main contribution of this study is showing that fear has significant consequences that may reduce the survival and reproduction of invasive species.

"Our plan is not to release hundreds of thousands of these robots in the wild and pretend they will solve the problem," he says. But there may be more than one way to scare a mosquito fish. Giving the fish a whiff of their predator, for example, might induce similar changes.

"These are not invincible animals," he says. "They have weaknesses that we can take advantage of that don't involve killing animals one by one." ■

MATTER & ENERGY

Physics requires imaginary numbers

Quantum theory based on only real numbers fails in new tests

BY EMILY CONOVER

Imaginary numbers might seem like unicorns and goblins — interesting but irrelevant to reality.

But for describing matter at its roots, imaginary numbers turn out to be essential. They seem to be woven into the fabric of quantum mechanics, the math describing the realm of molecules, atoms and subatomic particles. A theory obeying the rules of quantum physics needs imaginary numbers to describe the real world, two experiments suggest.

Imaginary numbers result from taking the square root of a negative number. They often pop up in equations as a mathematical tool to make calculations easier. But everything we can actually measure about the world is described by real numbers, the normal figures we're used to. That's true in quantum physics too. Imaginary numbers appear in the inner workings of the theory, but all possible measurements generate real numbers.

Quantum theory's prominent use of complex numbers — sums of imaginary and real numbers — was disconcerting to its founders. "From the early days of quantum theory, complex numbers were treated more as a mathematical convenience than a fundamental building block," says physicist Jingyun Fan of the Southern University of Science and Technology in Shenzhen, China.

Some physicists have attempted to build quantum theory using real numbers only, avoiding the imaginary realm with versions called "real quantum mechanics." But without an experimental test of such theories, the question remained whether imaginary numbers were necessary or just a useful computational tool.

A type of experiment called a Bell test resolved a different quantum quandary, proving that quantum mechanics requires entanglement, strange quantum linkages between particles (*SN: 9/19/15, p. 12*). "We started thinking about whether an experiment of this sort could also refute real quantum mechanics," says theoretical physicist Miguel Navascués of the Institute for Quantum Optics and Quantum Information–Vienna. He and colleagues laid out a plan for an experiment in the Dec. 23 *Nature*.

> "From the early days of quantum theory, complex numbers were treated more as a mathematical convenience than a fundamental building block."
> JINGYUN FAN

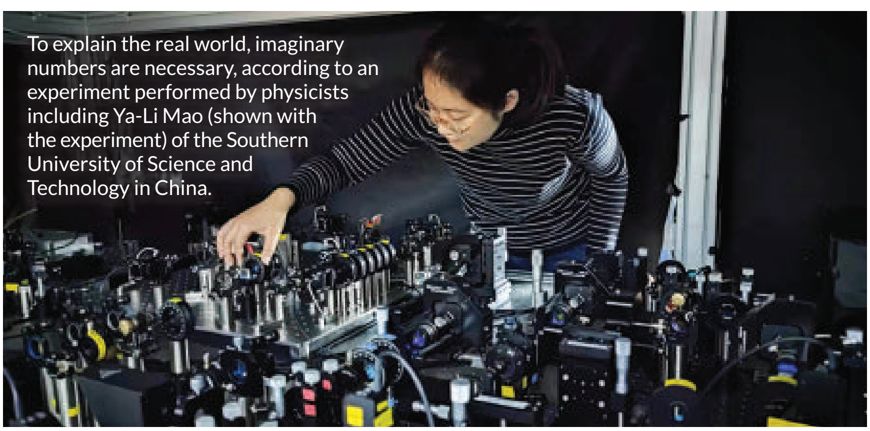
In this plan, researchers would send pairs of entangled particles from two different sources to three different people, named according to conventional physics lingo as Alice, Bob and Charlie. Alice receives one particle and can measure it using various experimental settings that she chooses. Charlie does the same. Bob receives two particles and performs a special type of measurement to entangle the particles that Alice and Charlie receive. A real quantum theory, with no imaginary numbers, would predict different results than standard quantum physics, allowing the test to discern which one is correct.

Fan and colleagues performed such an experiment using photons, or particles of light, they report in an upcoming paper in *Physical Review Letters*. By studying how Alice, Charlie and Bob's results compare across many measurements, Fan, Navascués and colleagues show that the data could be described only by a quantum theory with complex numbers.

Another team of physicists ran an experiment based on the same concept using a quantum computer made with superconductors, materials that conduct electricity without resistance. That test also found that quantum physics requires complex numbers, the team reports in another upcoming paper in *Physical Review Letters*.

But the results don't rule out all theories that eschew imaginary numbers, says theoretical physicist Jerry Finkelstein of Lawrence Berkeley National Laboratory in California. The research eliminated certain theories based on real numbers, namely those that still follow the conventions of quantum mechanics. It's still possible to explain the results without imaginary numbers by using a theory that breaks standard quantum rules. But those theories run into other conceptual issues, making them "ugly," he says. Still, "if you're willing to put up with the ugliness, then you can have a real quantum theory."

Despite the caveat, other physicists agree that the quandary of imaginary numbers remains compelling. "I find it intriguing when you ask questions about why is quantum mechanics the way it is," says Krister Shalm of the National Institute of Standards and Technology in Boulder, Colo. Asking whether quantum theory could be simpler or if it contains anything unnecessary "are very interesting and thought-provoking questions." ■



To explain the real world, imaginary numbers are necessary, according to an experiment performed by physicists including Ya-Li Mao (shown with the experiment) of the Southern University of Science and Technology in China.

J. FAN

THE FIFTH C?

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MATERIALS FOR MODERN LIFE

Chemistry, engineering and physics made a century of new things **By Carolyn Wilke**

Our vehicles, buildings, clothing and phones are very different than they once were because of new materials developed over the last century.

PEETERV/ISTOCK/GETTY IMAGES

A 1920s science headline, "Ice cream from crude oil," may best capture the era's unbridled enthusiasm for chemistry. "Edible fats, the same as those in vegetable and animal foods ... and equally nutritious ... can be obtained by breaking up the molecules of mineral oil and rearranging the atoms," exclaimed *Science News Letter*, the predecessor to *Science News*, in 1926. Synthetic ice cream was just one of the wonders that could lie around the corner.

Petroleum would become increasingly valuable, the article continued, "as a source of substances for which man has hitherto been dependent upon the chance bounty of nature." A rash of potential products included aromatics, flavorings, nitroglycerin for dynamite, plastics, drugs and more.

Petroleum-based ice creams never became the new big thing, yet the last century has witnessed a dramatic leap in humans' ability to synthesize matter. From our homes and cities to our electronics and clothing, much of what we interact with every day is made possible through the manipulation, recombination and reimagination of the basic substances nature has provided.

"The world is unrecognizable from 100 years ago," says Anna Ploszajski, a materials scientist and author of the 2021 book *Handmade: A Scientist's Search for Meaning Through Making*. And that, she says, is "simply because of the materials that we have around, let alone all of the new ways we use them."

At the turn of the 20th century, organic chemists

PETER DAZELEY/THE IMAGE BANK/GETTY IMAGES

learned how to turn coal into a variety of industrial chemicals, including dyes and perfumes. Later, motivated by wartime demand, chemists honed their craft with poison gas, explosives and propellants, as well as disinfectants and antiseptics. As a result, World War I was often called "the chemist's war." And at a fundamental level, the new century also ushered in greater understanding of chemical bonds and the atom, its constituents and its behavior.

In the decades that followed, approaches in chemistry and physics combined with engineering to give rise to a new field, now called materials science. An extensive survey of the field, put together by the National Academy of Sciences in the 1970s and titled "Materials and Man's Needs," described the pace of research: "The transitions from, say, stone to bronze and from bronze to iron were revolutionary in impact, but they were relatively slow in terms of the time scale. The changes in materials innovation and application within the last half century occur in a time span which is revolutionary rather than evolutionary."

ScienceNews 100

To celebrate our 100th anniversary, we're highlighting some of the biggest advances in science over the last century. To see more from the series, visit the Century of Science site at **www.sciencenews.org/century**

Alongside this new science came new and improved scientific tools. Scientists can now see materials at a much finer scale, with the electron microscope making individual atoms visible. X-ray crystallography unveils atomic arrangements, allowing for a better understanding of materials' structure. With equipment such as chromatographs and mass spectrometers, today's scientists can untangle mixtures of chemicals and identify the compounds within. Francis Aston first took advantage of a mass spectrometer in his study of isotopes in 1919, but for a long time the tool was seen by some chemists as, according to a description by mass spectrometrist Michael Grayson, "an unexplainable, voodoo, black magic kind of a tool."

Many new materials were birthed from basic curiosity and serendipity. But new techniques also made way for targeted innovation. Today, materials can be designed from scratch to solve specific problems. And explorations of the properties of solid substances — for instance, how matter interacts with heat, light, electricity or magnetism — along with iterations of design have further contributed to the stuff that surrounds us, giving way to transistors, eyeglass lenses that darken in sunlight, touch screens and hard disk drives. Explorations into how matter interacts with biological tissues have yielded coronary stents, artificial skin and hip replacements that include metal mélanges that are tough and nonreactive when they sit against bone.

The outputs of such efforts are all around us. Take air travel, and the global interconnectivity it introduced. It's possible thanks to alloys that are lightweight and robust. And today's personal connectivity — via smartphones and computers — came with transistors made of silicon. Their small size and low power requirements brought computing to our office desks, and then into our homes and pockets. An abundance of plastic housewares and comfy athleisure clothing options are made possible via improvements in polymers.

Yet innovation hasn't come without consequences. For each tale of progress, there

> "The iPhone contains about 75 elements from the periodic table — a huge proportion of all the atoms that we know about in the universe are in an iPhone."
>
> **ANNA PLOSZAJSKI**

are stories of the marks people have left on this planet. While enabling humans to flourish, many new substances have become pollutants, from PCBs to plastics. However people go about addressing these environmental problems, other new materials will likely be part of the solutions.

Going places

It was the summer of 1940, the early days of the Battle of Britain. Nazi Germany's air force, the Luftwaffe, began a months-long attack on the British Isles that eventually included the nightly bombing raids known as the Blitz. Going into the battle, the Luftwaffe believed it had the upper hand; in battles in France, the Germans had dominated in the air. Little did they know the Allies had a secret weapon — in their fuel tanks.

As Germans began flying over England, they were surprised to find the tables had turned. The British Spitfires and Hurricanes that the Germans had outmaneuvered in France could now climb higher and fly faster thanks to fuel made with a newly developed process called catalytic cracking.

Catalysts boost chemical reactions by reducing the energy needed to get them going. French mechanical engineer Eugene Houdry had developed a catalytic process in the 1930s to make high-octane fuel, which can withstand higher compression and allows engines to deliver more power. Simply increasing the octane rating of aviation fuel from 87 to 100 gave the Allies a crucial edge.

Houdry wasn't the first to attempt using catalysts to bust the big molecules of heavy fuels into smaller ones to improve performance. But as an avid road racer, he had a special interest in high-quality gasoline. He studied hundreds of catalysts until he landed on aluminum- and silicon-based materials that could do the busting more efficiently than an existing process that relied on heat. When he tested his gasoline in his Bugatti racer, he reached speeds of 90 miles per hour.

In the following decades, catalytic cracking and improvements to the process Houdry pioneered would contribute to the reign of automobiles. Catalytic cracking still produces much of the gas that cars guzzle today.

But all that driving soon took a toll on the environment. When the hydrocarbon molecules in gasoline burn, the engine exhaust contains small amounts of harmful gases: poisonous carbon monoxide, nitrogen oxide that can cause smog and acid rain, as well as unburned hydrocarbons. Los Angeles and other car-packed cities choked on smog in the 1940s and '50s.

Houdry looked again to catalysts to deal with the pollution that internal combustion engines caused. He designed a catalytic converter.

"When first considered, the problem seems simple," Houdry wrote in a 1954 patent application. "A great number of catalysts can be used for the reaction. By simply placing one of these catalysts in the exhaust line under controlled conditions, the exhaust fumes can be cleaned." The catalysts, precious metals such as platinum or palladium, provide docking sites for the harmful gases to hang onto; there, reactions involving oxygen convert them to less harmful forms.

In the 1950s, Houdry outlined a series of reactions, materials and conditions necessary for a working catalytic converter. But he was ahead of his time. For years, the adoption of catalytic converters in automobiles was stymied by leaded gasoline, which gummed up the catalysts' surfaces. Finally, with the passage of the Clean Air Act of 1970, which led to requirements for catalytic converters and lead-free fuel, the air in cities began to clear.

For air travel to serve the masses, a different dilemma needed solving: lightening the load. The earliest airplanes gained lift at the turn of the 20th century on wings of fabric and wood, but to really soar, airplanes needed light but strong materials. The first aircraft designed for passengers — the Ford Trimotor, nicknamed the Tin Goose — took to the air in 1926 with help from aluminum alloys.

Alloys have existed since ancient times.

French mechanical engineer Eugene Houdry (below) developed catalytic cracking in the 1930s. This 1940s ad says that 90 percent of all aviation fuel made by catalytic cracking came from the Houdry Process Corporation.

FROM LEFT: COURTESY OF SCIENCE HISTORY INSTITUTE; RETRO ADARCHIVES/ALAMY STOCK PHOTO

Astronauts in the Apollo 11 command module (left) were protected from high temperatures during re-entry through Earth's atmosphere (center) by a heat shield made of Avcoat, a reinforced plastic made from an epoxy resin within a honeycomb fiberglass network. A new NASA spaceship called Orion, destined to take people to the moon and beyond, uses Avcoat tile blocks bonded onto its heat shield (right).

CLOCKWISE FROM TOP LEFT: SMITHSONIAN INSTITUTION, TRANSFERRED FROM NASA; NASA; NASA; *SCIENCE NEWS LETTER*

Bronze Age artisans combined copper with arsenic or tin in crucibles to make tools, jewelry and more. From there, advances coincided with the ability to melt metals at higher and higher temperatures, eventually leading to steel. Scientists since have studied how materials' structures and properties — including desirable features like strength, bendability and resistance to corrosion — vary with composition, temperature and processing.

The fuselage of the Tin Goose contained a newly developed alloy named duralumin, a contraction of "Dürener" (for the company that originally made it) and "aluminum."

In 1926, *Science News Letter* described the promise of materials such as duralumin for safer dirigibles, which would carry large numbers of passengers into the air: "Of these sound materials, strong and light girders must be built. So light that a man can carry one of them in his hand and yet so strong that they will carry loads of thousands of pounds."

Dirigibles and duralumin were just the beginning. The 20th century saw an explosion in the types of alloys and their applications, from stainless steel cutlery to the titanium alloys used in prostheses and pacemakers to crucial components of vehicles. Today's jet engines are built of superalloys, which can withstand infernal temperatures.

Plastics and composites have also helped planes shed weight. Composites combine materials with very different properties — such as glass and plastic — by suspending one in the other or sandwiching them together, for instance. Because they can be tuned to be light and strong, composites have made their way into parts all over planes, from the engine to the wings. Boeing's 787 Dreamliner, which debuted in 2007, is made up of 50 percent composites by weight.

Making connections

For a testament to the power of materials to connect us, just look at an iPhone. "The iPhone contains about 75 elements from the periodic table — a huge proportion of all the atoms that we know about in the universe are in an iPhone," says Ploszajski, the materials scientist.

Some of those are rare-earth elements, a set of 17 metallic elements mostly on the outskirts of the periodic table. Though they are difficult to mine and process, rare earths are sought after because they lend unusual magnetic, fluorescent and electrical properties to materials made from them. Neodymium, for example, mixed with other metals makes the strongest magnets known. These magnets make your cell phone vibrate and its speakers produce sound.

Despite the hazards associated with mining them, these elements show up in a lot of other 20th century applications too. Rare earths are in color televisions, camera lenses, fiber-optic cables, nuclear reactors, nickel-metal hydride batteries, aircraft engines, PET scanners and much more.

A more familiar element — silicon — is the reason cell phones and laptops are available in such a widespread way.

As a semiconductor, silicon conducts electricity better than ceramics and glass do, but not as well as metals. This in-between status makes it possible to control how electrons zip around a semiconductor, a control that's ideal for creating electrical switches for circuits in radios, televisions or computers. In the 1930s and '40s, these and other electronic devices relied on bulky, breakable glass vacuum tubes to control electric current flow. Decades of semiconductor research pointed to a more reliable, slimmer way.

The first semiconductor switch, dubbed the transistor, was made of germanium and invented

In 1948, *Science News Letter* reported that "the glass vacuum tube in your radio has its first rival in 40 years": a germanium transistor.

Vacuum Tube Has Rival

New transistor, made of semi-conducting germanium metal, may result in more stable and durable radios, television sets and electronic devices.

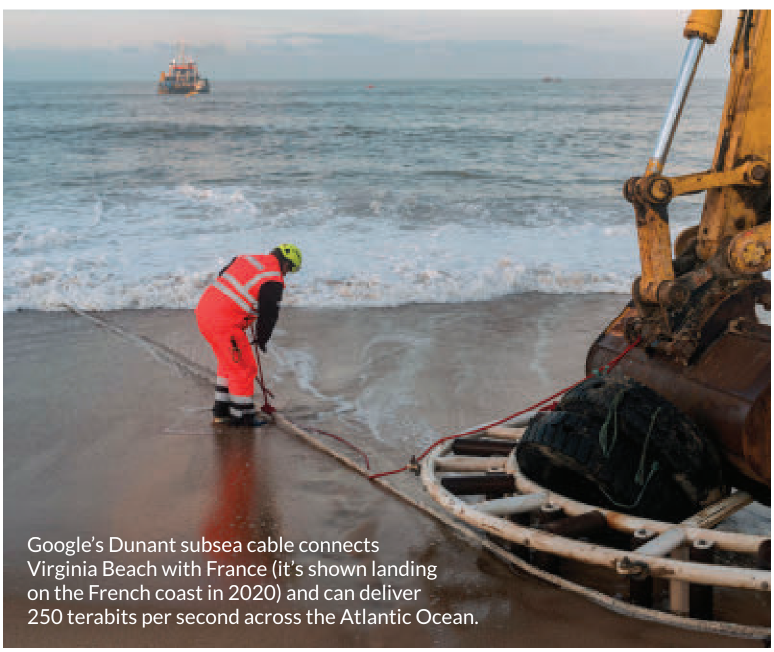
at Bell Laboratories in 1947. But teams at Texas Instruments and Bell Labs were both eyeing silicon, which holds up under higher temperatures. Silicon is also less likely than germanium to leak current when a switch is off. Though the two teams independently developed silicon transistors, Texas Instruments' Gordon Teal gets the credit as his announcement came first, in May 1954.

At a conference in Dayton, Ohio, toward the end of the day's talks, Teal matter-of-factly revealed his company's success. "Contrary to what my colleagues have told you about the bleak prospects for silicon transistors," he said, "I happen to have a few of them here in my pocket." His announcement, which followed other talks suggesting that the devices were years away, jolted the audience, which stampeded to the back of the room for copies of Teal's talk, and out to the telephone booth to share the news.

4
billion kilometers
Approximate length of all the glass strung out in the world's optical cables

Our attention-sucking phones are right in front of our faces. But out of sight are the fiber optics that relay messages around the world in a flash.

All the glass strung out in the world's optical cables could tether Earth to Uranus and then some, stretching some 4 billion kilometers. These cables ferry messages across countries and continents and across the seafloor. Optical fiber "really has strung the world together in a new way," says Ainissa Ramirez, a materials scientist and author of the 2020 book *The Alchemy of Us* (*SN: 4/25/20, p. 28*). Messages from across the Atlantic used to come by boat, she says, then came copper cables



Google's Dunant subsea cable connects Virginia Beach with France (it's shown landing on the French coast in 2020) and can deliver 250 terabits per second across the Atlantic Ocean.

In the 1920s, German chemist Hermann Staudinger showed that small molecules can link up in chains to form very large molecules. The discovery helped set the stage for a boom in synthetic materials, including plastics.

to relay telegraph dispatches in the 1840s. The first live telephone traffic sent through fiber-optic cables was in 1977 in Long Beach, Calif. Now e-mails from abroad arrive nearly instantaneously thanks to thin-as-hair optical fibers.

The list of materials that helped put oceans of information at our fingertips goes on and on. All of these developments, including today's lithium-ion batteries and more, led to today's abundance of electronic devices (*SN: 1/21/17, p. 22*). But ever more improvements, and our constant urge to upgrade, creates a new problem: "How do we unmake this stuff and recycle those substances safely?" Ploszajski asks.

A plethora of plastic

In a quest to really grasp the omnipresence of plastics, Susan Freinkel, author of the 2011 book *Plastic: A Toxic Love Story*, pledged to go a day without touching any. Glimpsing her plastic toilet seat, Freinkel gave up the experiment mere moments after it began. Instead, she spent the day cataloging all the plastic stuff she encountered.

Plastics covered her body — in yoga pants, sneakers and eyeglasses. Plastic made up the entire interior of her minivan and parts of kitchen appliances. Plastic packaging protected her food, and after eating, she dumped her trash in a plastic bin. Even the walls around her contained plastics, from the paint to the synthetic insulation.

Today, we're awash in plastics. Yet at the beginning of the 20th century, only a handful of plastics had made their way into homes.

The story of commercial plastics began in the 1860s, when John Wesley Hyatt, seeking a substitute for the ivory popularly used in billiard balls, landed on a material later called celluloid. At the

FROM TOP: ETH-BIBLIOTHEK ZÜRICH, BILDARCHIV, FOTOGRAF: UNBEKANNT, PORTR_14413-016-AL, PUBLIC DOMAIN MARK; MARIO FOURMY/SIPA VIA AP IMAGES heart of celluloid, however, was the natural substance cellulose.

The first fully synthetic plastic, Bakelite, arrived in 1907. It was a fluke discovery by Belgian-born chemist Leo Baekeland, who was seeking an alternative to the natural shellac that insulated electrical cables. Celluloid was a suitable substitute for ivory and tortoiseshell, but sleek, shiny Bakelite gleamed with modernity. It quickly made its way into a host of products, including the casings for radios, jewelry and telephones. A new era of innovating on nature's materials, rather than merely mimicking them, was born, Freinkel writes.

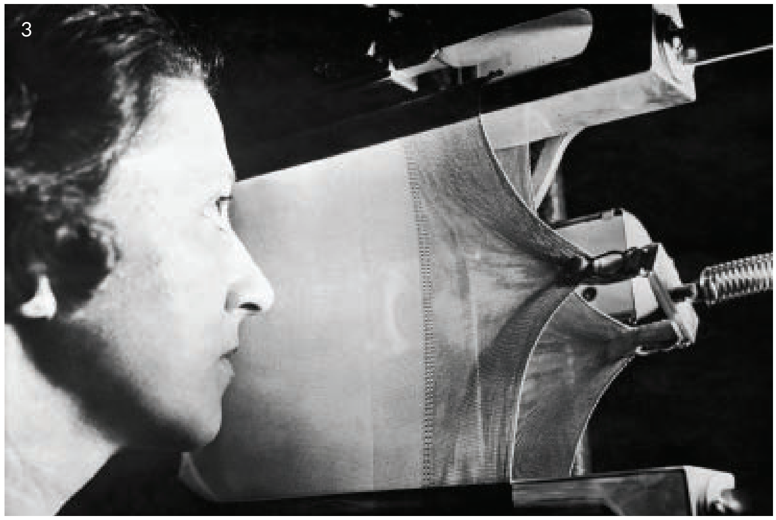
Yet it wasn't until the 1920s that researchers started to understand plastics' chemical nature. Plastics are made of polymers, large molecules made of repeating units. At the time, what gave natural polymers like cellulose, shellac and rubber their properties remained unknown. So inventors seeking new human-made substitutes relied on trial and error to make something similar. Credit for changing all that goes to the German organic chemist Hermann Staudinger.

From experiments on natural rubber, Staudinger showed that large, heavy molecules could be formed by linking many smaller molecules into chains. As *Science News Letter* put it in 1953, when Staudinger was awarded the Nobel Prize in chemistry: "The way the molecules regiment themselves determines the differences between springy rubber, hard plastic and tough fiber." It might sound obvious today, but Staudinger's finding was controversial. Chemists at the time thought that what we now call macromolecules were simply aggregates of smaller molecules.

Staudinger's ideas gradually gained acceptance and formed a basis for new research on polymers. In the following decade, industrial chemists worked to figure out the chemical reactions needed to create new polymers, plastics among them. One early success story was nylon, a carbon-based polymer patented in 1938 as a substitute for silk. American women were introduced to nylon stockings in 1940. Within a year, nylons grabbed 30 percent of the hosiery market.

But it was World War II that drastically increased demand for plastics. The military turned to the new industry to make substitutes for strategic materials such as glass, brass or steel, Freinkel says. Nylon was needed for military uses, so women offered up their stockings to be recycled.

"Great piles of stockings retired after faithful



1. Bakelite, the first fully synthetic plastic, was invented in 1907 and used in casings for telephones, radios and jewelry, among other products. 2. In a photo from the Dow Chemical Company, two models demonstrate the sturdiness and durability of Styrofoam, invented in 1941. 3. The resistance of nylon stockings is tested in 1940, the year women in the United States were introduced to the product. 4. Arthur Melin (left) and Richard Knerr (right), cofounders of the U.S. toy company Wham-O, introduced their Hula-Hoop, made of Marlex polyethylene, in 1958. The toy's popularity boosted demand for the high-density plastic.

FROM 1 TO 4: BRUNO VINCENT/GETTY IMAGES; DOW CHEMICAL COMPANY/SCIENCE HISTORY INSTITUTE; KEYSTONE-FRANCE/GAMMA-KEYSTONE VIA GETTY IMAGES; BEN MARTIN/GETTY IMAGES

The Tupperware parties of the 1950s exemplify what author Susan Freinkel calls the "flood of plastic into everyday life" — and the enthusiasm that came with it.

380+
million metric tons
Amount of plastic produced per year

and intimate service are awaiting resurrection — thousands of pounds of them," reported *Science News Letter* in 1943.

Though small at the start of the war, the plastics industry got better at making its wares and boosted production. Processes such as injection molding, which spurts melted plastic into a mold "sort of like a Play-Doh Fun Factory," Freinkel says, made it possible to mass-produce plastic. A technique called blow molding, invented in the 1930s and based on the same principle as glass blowing, offered a quick way to form plastic bottles.

As wartime demand dried up, the plastics industry began to bring its products to the people. "You start to get this flood of plastic into everyday life," Freinkel says.

The promise of plastic was on display in 1946. Held in New York City, the first National Plastics Exhibition featured wares made of the wonder material. "Thousands of people lined up to go to this trade show and walk through this conference hall and gawk at stuff that had an almost magical quality," Freinkel says. Visitors saw durable nylon fishing line and window screens in a riot of colors. Mass-produced plastic offered "a new way to have the good life on the cheap."

We've come a long way from the days of celluloid and Bakelite. Tens of thousands of plastic compounds exist today. The world now produces in excess of 380 million metric tons of plastic a year — that's more than a hundred pounds of what's typically very lightweight stuff for every person on the planet every year.

Consequences

By the mid-1960s, researchers started noticing plastic pieces in the ocean, Freinkel says. Today, plastic pollution is found virtually everywhere, in bits wafting in the winds, high in Mount Everest's snow and as trash piling up on the seafloor.

Plastics are the quintessential example of the journey from material marvel to environmental nuisance. But they're not the only problem.

The organic chemistry advances of the early 1900s made new and exciting materials possible, but also allowed people to make more and more materials that weren't recyclable, says Thomas Le Roux, a historian at the French National Center for Scientific Research in Paris and coauthor of the 2020 book *The Contamination of the Earth*. By the 1970s, new disposable products, from pens to razors to packaging, signaled

Plastics, which help make modern life convenient, are polluting lakes, rivers and oceans, as shown here on the beach of Costa del Este in Panama City.

FROM TOP: HULTON ARCHIVE/GETTY IMAGES; LUIS ACOSTA/AFP VIA GETTY IMAGES an ease of life. "It was modern to throw away what we buy," he says.

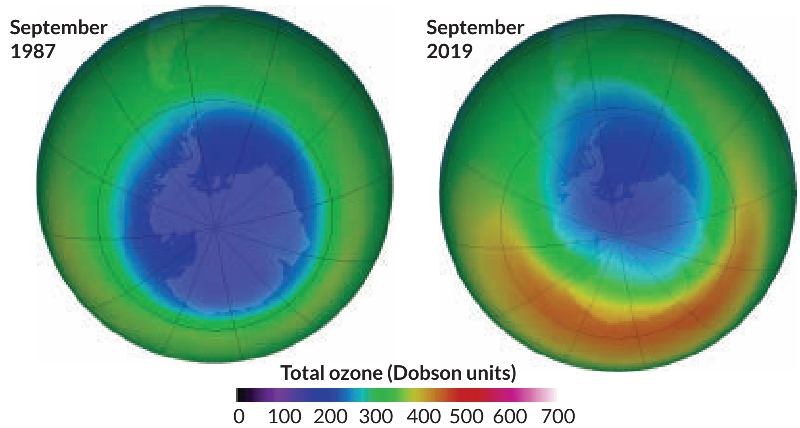
The consequences of this easy-come, easy-go relationship with our stuff soon appeared in the environment. Our unabated demand for fossil fuels, used not only as fuel but as raw materials for making plastics, releases emissions that contribute to Earth's changing climate.

Many of our modern substances were created to solve problems, says Mark Jones, a chemist and member of the National Historic Chemical Landmarks committee of the American Chemical Society. For instance, before the 1930s, air conditioning and refrigeration relied on ammonia, which is flammable and toxic. That changed with the introduction of Freon and other chlorofluorocarbons, or CFCs for short, which were created by chemists in the 1920s. These molecules appeared to have little effect on living things. "They were presumed to be incredibly safe," says Jones, who recently retired from Dow Chemical.

But Freon and its CFC cousins had unforeseen consequences on the atmosphere when they escaped air conditioning and refrigeration systems. In the 1980s, scientists discovered a hole in Earth's ozone layer that forms when CFCs rise to the stratosphere, break down and react with ozone, destroying it. In solving one problem, humankind found itself with another.

The history of science offers up abundant examples of solutions begetting new problems. Polychlorinated biphenyls, or PCBs, useful insulators in electronics, can cause serious health problems, including cancer, when they enter the environment. The compounds that allow food to slide out of kitchen pans without sticking belong to a family that has earned the title "forever chemicals" for the tendency not to degrade. Lithium mining, which has increased with demand for lithium-ion batteries, guzzles water and can release harmful chemicals that contaminate ecosystems and poison drinking wells. Other battery ingredients, such as cobalt, are mined unethically — sometimes using child labor.

Perhaps the largest unintended consequence that humankind faces today is climate change. Human activities — factories, mining, growing food, traveling, using air conditioning and heating to keep indoor climates comfortable — have released greenhouse gas emissions that have heated the world by around 1.25 degrees Celsius since preindustrial times. The world is already experiencing extreme weather events linked to climate change.



NASA OZONE WATCH

CFCs' creation
In 1985, scientists discovered a hole in the ozone layer, created by chlorofluorocarbons in the stratosphere. The Montreal Protocol turned things around: 2019 saw the smallest ozone hole ever recorded (compared above with 1987).

Clearly chemists and materials scientists have contributed to these problems. But they will inevitably be part of finding solutions as well. There's a cyclical nature to the promise and perils of new molecules and materials. "The entire history of chemistry is, 'Hey, look what I can do! Darn, I wish I hadn't done it that way! But I have another way I can do it.' And that keeps us kind of moving forward," Jones says.

Chemists are now creating plastics that will break down after use and can be recycled more easily (*SN: 1/30/21, p. 20*). Materials scientists are developing better membrane materials to filter pollutants out of water (*SN: 11/24/18, p. 18*). Engineers are deploying new materials to capture carbon dioxide at smokestacks.

New iron-based catalysts could someday convert captured carbon dioxide into jet fuel, potentially cutting greenhouse gas emissions from air travel (*SN: 1/30/21, p. 5*). And researchers continue to innovate to turn more and more of the solar spectrum into energy, and so cut our reliance on fossil fuels (*SN: 8/5/17, p. 22*).

Chemistry and materials innovation can't solve all our problems. People's choices also matter. Weighing the risks and rewards that come with new materials will require recognition of the potential problems, regulations to combat them, willpower, collaboration and collective action. History holds plenty of lessons, but it's not yet clear whether we'll learn from them. ■

Explore more

- François Jarrige and Thomas Le Roux. *The Contamination of the Earth.* MIT Press, 2020.
- Ainissa Ramirez. *The Alchemy of Us.* MIT Press, 2020.

Carolyn Wilke is a freelance science journalist based in Chicago.

U.S. Olympian Simone Biles and other elite athletes are prioritizing mental health. Over the last decade, researchers have identified some tools to help competitors on and off the field.

MENTAL gymnastics

Elite athletes need support to manage anxiety, depression and other mental health challenges **By Ashley Yeager**

On yellow poster board, blue letters spell BELIEVE, a nod to the Emmy-winning TV show *Ted Lasso*. The sign hangs above psychologist Tommy Minkler's office door at West Virginia University, a reminder to trust in the work he's doing to help elite athletes.

In the show, Lasso, an American football coach, is recruited to head an English football team. His experience coaching American football, an utterly different game than soccer, leaves him lacking overseas, so he relies on his positive attitude and folksy charm to bond with his players. On his first day coaching, Lasso posts the BELIEVE sign above his office door. The team often rallies around the sign just before hitting the field.

But belief alone can't get athletes to the goal when they run into the psychological speed bumps or full-on roadblocks that can arise during training and competition. When Lasso's striker Dani Rojas faced the yips — suddenly unable to nail his usually flawless penalty kicks — a therapist was called in. In real life, when the twisties hit U.S. gymnast Simone Biles at last summer's Olympics in Tokyo, she withdrew from five of six event finals. Biles' mental block was petrifying; one wrong move on the uneven bars or a failed flip on the balance beam could cause a devastating injury, or even death. Her decision to withdraw from competition after years of intense training shocked the world, from commentators to armchair athletes.

Elite athletes are expected to be unflappable. Admitting vulnerability is "so fundamentally at odds with being a competitor," retired U.S. figure skater Sasha Cohen, who won a silver medal at the 2006 Winter Olympics, explained in the 2020 HBO documentary *The Weight of Gold*. Sport is war. Competing at the elite level requires strategy and posturing. "You need to show the world you are

LOIC VENANCE/AFP VIA GETTY IMAGES

strong. You need to show your competitors you are strong," Cohen said. "If you were to say, 'Oh, I have mental health issues,' that just cracks the facade."

In society, those cracks are often seen as weakness, a faulty perception that prevents athletes from talking about their problems. That stigma is, in fact, the strongest barrier to athletes seeking help, says psychiatrist João Mauricio Castaldelli-Maia of the University of São Paulo. He and colleagues reviewed 52 studies on mental health and elite athletes in the *British Journal of Sports Medicine* in 2019.

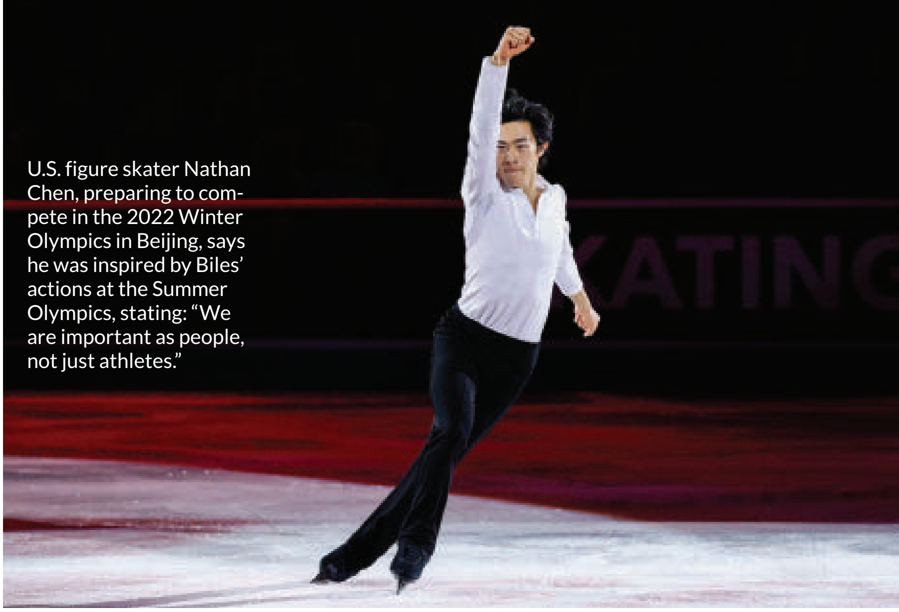
Reactions to Biles' decision made clear that the stigma still exists. She faced backlash after withdrawing from several Olympics events, as did Japanese tennis star Naomi Osaka, who pulled out of the 2021 French Open to focus on her mental health. But amid the vitriol, Biles and Osaka had supporters, including fellow athletes who were inspired by these choices. "I didn't even know that was an option," U.S. figure skater Nathan Chen, a medal favorite at the upcoming Winter Olympics, said of Biles' decision, at an October news briefing.

The International Olympic Committee, the U.S. Olympic & Paralympic Committee and other sports organizations have begun to acknowledge the importance of mental health. Just because elite athletes are at peak physical fitness, their mental fitness is not guaranteed. Since 2018, sports-governing agencies, including the IOC, and health organizations have released a rash of position statements on the mental health symptoms, such as anxiety, depression and eating disorders, that are common among elite athletes, the factors contributing to those symptoms and the psychological tools that might help competitors on and off the field.

There's also been an explosion of research into elite athletes' mental health in the last few years, says sports and clinical psychologist Carolina Lundqvist of Linköping University in Sweden, citing a 2020 analysis in *International Review of Sport and Exercise Psychology*. The research points to two promising psychological tools.

One is mindfulness — paying attention to, or staying in, the present moment without judgment. Another is acceptance and commitment therapy, or ACT. In conjunction with mindfulness, the therapy trains a person to accept difficult thoughts or feelings rather than actively work to get rid of them. Studies have shown that these tools can improve athletic performance — and, importantly, lead to a richer life off the ice or the court.

Athletes "are human beings first," says Minkler, the *Ted Lasso* enthusiast. Their life is not all about winning medals or championships. Mindfulness and ACT help athletes "learn more about themselves and engage differently with their thoughts and emotions," he says. It teaches them to be better people.



U.S. figure skater Nathan Chen, preparing to compete in the 2022 Winter Olympics in Beijing, says he was inspired by Biles' actions at the Summer Olympics, stating: "We are important as people, not just athletes."

TIM NWACHUKWU/GETTY IMAGES PLUS

Team tests

On the women's lacrosse field at Marymount University in Arlington, Va., players toss the ball with an intense focus on their grip of the lacrosse stick, the snap of their wrists and the weight of the ball as they catch it and pass it on. To an outsider, the drills might seem routine, but the women were paying extra attention to the task. The focused attention is a result of experiments that Minkler (a former lacrosse coach), Washington, D.C.–based psychologist Tim Pineau and colleagues have run with the team in the last few years.

The researchers wanted to know if mindfulness training could improve player performance and overall well-being. With buy-in from the school's athletic director and lacrosse coach, Pineau led the players through six weeks of mindfulness training during preseason, then monthly follow-ups over several seasons.

The mindfulness sessions started with stationary meditations focusing on breathing and self-compassion, then progressed to mindful yoga and walking, and finally to throwing and catching exercises. Along with the meditative work, the players talked about what they'd learned in group discussions, describing how they used the training to let go of mistakes. The coach reported that the players were more focused on the second-to-second decisions of the game, rather than dwelling on something that had gone wrong.

In post-training surveys, players reported feeling that they could slip into that state of being

Prevalence of mental health issues in elite athletes

Disorder	Prevalence
Depressive symptoms	4–68%
Generalized anxiety disorder, self-reported	14.6%
Eating disorders	0–19% in men 6–45% in women

SOURCE: C.L. REARDON *ET AL*/*BR. J. SPORTS MED.* 2019

A sizeable problem

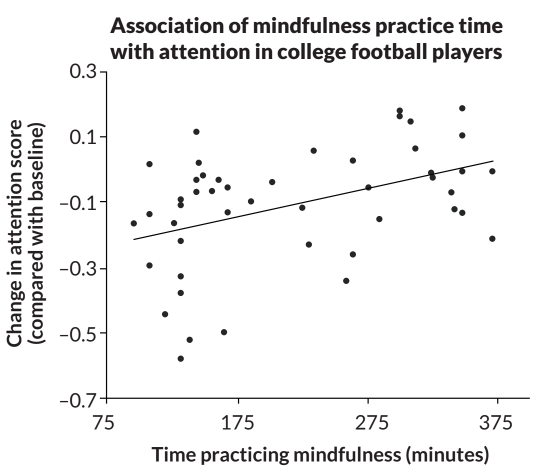
Athletes can be reluctant to report mental health problems because of stigma. In a 2019 consensus statement from the International Olympic Committee, data on mental health disorders in elite athletes were limited, but depression and anxiety rates appeared similar to the general public's. Eating disorder rates were higher in athletes.

The women's lacrosse team at Marymount University used mindfulness with stationary meditation, yoga and throwing and catching exercises over several seasons. Players' anxiety levels dropped and the team started winning more games than it lost.

totally immersed in the game, what is often called a flow state or being in the zone, much more easily after the mindfulness training. And they said they were less anxious about playing lacrosse. Before training, the team had four wins and 15 losses. In the season after the training, the team won more games than it lost and qualified for the regional conference championship. The next season, the team won the regional conference championship, the researchers reported in 2019 in the *Journal of Sport Psychology in Action*.

The findings reinforce results from a mindfulness study with the University of Miami football team, the Hurricanes. Amishi Jha, a neuroscientist at the university, teamed with Hurricanes head coach, Al Golden, and his players to track how well they paid attention during preseason

Practice boost The longer the University of Miami Hurricanes practiced mindfulness, the less their ability to pay attention dropped during a period of intense physical training. SOURCE: J.D. ROOKS *ET AL*/*J. COGNITIVE ENHANCEMENT* 2017



training. Jha and her colleagues measured the players' focus in the lab by having them hit the space bar on a keyboard when they saw certain numbers on a computer screen, such as 2 or 4. Players were told not to hit the bar when they saw other numbers, like 3. The stronger their attention, the better players were at not hitting the space bar when the number 3 flashed across the screen.

After measuring baseline attention of the players, the researchers divided the players into two groups: one worked through a four-week training with mindfulness meditations, while the other received four weeks of relaxation exercises. Mindfulness exercises focused on bringing attention back to the present moment whenever the mind strayed; relaxation exercises focused on relieving tension, without focusing cues.

In previous experiments with emergency medical and military professionals, Jha had found that high stress, poor mood and perceived threats can disrupt focus. In this study, she had the Miami players complete their mindfulness or relaxation work during preseason training, the grueling physical workouts that help coaches decide who gets cut from the team.

When given the computer attention test after preseason training ended, the players didn't focus as well as before. And they reported being more anxious, more depressed and less happy overall, a result of being stressed from the physicality of football training, Jha says.

Although their focus declined in the high-stress setting, the attention of players who regularly practiced mindfulness exercises dropped less drastically than those who regularly practiced relaxation exercises, Jha and colleagues reported in the *Journal of Cognitive Enhancement* in 2017.

"Attention is the fuel for our ability to not just think and do cognitively demanding tasks, but to regulate our emotion and connect" with other people, Jha says. Protecting the ability to pay attention can protect mental health, she explains in her 2021 book *Peak Mind*, which explains how to build mental "muscles" in as little as 12 minutes a day.

Learned discipline

Meditative trainings are like a push-up for the mind. It takes practice, Minkler says. "You can't meditate once for 10 minutes and say, 'I'm mindful and in the present,' just like you wouldn't go in the weight room and do five push-ups and say, "That's it, that's all I need to do,' " he says. "You have to work at it. You have to be disciplined."

Graham Mertz, quarterback for the University

FROM TOP: DAVID SINCLAIR PHOTO: T. TIBBITTS of Wisconsin–Madison, has said he's seen results with mindfulness training. After what he felt was a disappointing season in 2020, Mertz began working with the Wisconsin Badgers' director of meditation training, Chad McGehee. That training helped Mertz figure out how to reset himself mentally between a game's offensive plays, he told the *Wisconsin State Journal*. There's roughly 40 seconds between plays, and Mertz says he spent a lot of time identifying "anchors" to bring his attention back to the moment and leave the play that just happened in the past.

The best approach he found was to take a deep breath, close his eyes and rub his fingertips together. The Badgers finished the 2021 season with eight wins and four losses, plus a win in December's Las Vegas Bowl.

Mertz's story, while just one person's experience, supports Minkler's and Jha's findings, which suggest mindfulness could be an essential tool that athletes should pack in their bags for game day. But the work comes with caveats. Analyses have shown that mindfulness researchers tend to overreport positive findings. And for some people, studies suggest, focused breathing and other mindfulness exercises can bring up past trauma, causing distress, Minkler says. Having clinical psychologists on hand to work with athletes who have this reaction to mindfulness training is important.

No judgments

Acceptance and commitment therapy, or ACT, is another technique counselors are using to help athletes improve not only their performance but their overall mental health. The goal of ACT is to teach athletes to separate their competitor identity from their personal one.

ACT does not attempt to change negative thoughts, such as "I suck today," but to acknowledge the thought as something completely independent of who or how talented the athlete is. By accepting the negative thought, rather than getting stuck in a downward spiral of trying to combat it with counterarguments, an athlete can bring her focus back to the race or game at hand.

For a triathlete, who can spend up to 17 hours swimming, biking and running in a race, letting go of the detrimental self-talk can be extremely important when a competitor moves in front, or when the race is long and an athlete wants to give up, says Eugene Koh Boon Yau, a psychiatrist at the University of Putra Malaysia in Seri Kembangan. In the last few years, Yau worked with three triathletes competing to represent Malaysia at international competitions. All three struggled with self-doubt.

During its 2014 season, the University of Miami Hurricanes football team tested mindfulness and relaxation to improve attention and emotional well-being.

DOUG MURRAY/ICON SPORTSWIRE/CORBIS/ICON SPORTSWIRE VIA GETTY IMAGES

Over six weeks, he walked each athlete through a mental training on mindfulness so each learned to notice and label their thoughts and emotions, especially negative ones, and then accept those thoughts without judgment. Then each athlete identified his values and what he wanted to be remembered for, should his career end the next day. Yau and each athlete then discussed how to use mindfulness and thought acceptance during a race to stay focused on performance without getting wrapped up in what competitors were doing.

The training "does help me with reducing anxiety and overthinking," says triathlete Edwin Thiang, who worked with Yau. Thiang says he's still surprised by how vital the training is, especially in high-stakes races. It calms him down and helps him stay focused.

The other athletes who worked with Yau agree. One triathlete said he found it easier to accept thoughts of self-doubt when a competitor overtook him. Before the mental training, the athlete would slow down in such situations, giving up hope of finishing high in the rankings. After the training, he identified his self-doubt as an emotion, not a reality. By shifting his attention back to the mechanics of either swimming, biking or running, he could keep the pace he set for himself during the race. Another of the triathletes reported that the training helped him stay committed to physical training, Yau and colleagues reported in the May 2021 *Journal of Sport Psychology in Action*.

Those results align with a study that pitted mindfulness and elements of ACT against some of the traditional, performance-focused psychological tools athletes have been taught for decades, such as visualization, relaxation (similar to what was used in Jha's study) and positive self-talk. In that experiment, 18 women's basketball players at a Division III university in New Jersey were divided into two groups. One worked through relaxation and stress management exercises developed by psychologist Richard Suinn and described in the 1986 book *Seven Steps to Peak Performance*. The other group worked through exercises for mindfulness and acceptance of thoughts described in the 2007 book *The Psychology of Enhancing Human Performance: The Mindfulness-Acceptance-Commitment (MAC) Approach* by psychologists Frank Gardner and Zella Moore.

A month after the study ended, MAC-trained players had dips in anxiety, substance use, eating issues and overall psychological distress, along with gains in emotional regulation. Players trained in traditional psychological skills had less improvement in those areas, Princeton University psychologist Mike Gross and colleagues reported in 2018 in the *International Journal of Sport and Exercise Psychology*.

On the court, mindfulness paired with elements of ACT can quickly keep players moving and help them stay in the game, especially if they make a mistake, Gross says. "There's less ... of those mental gymnastics or the tug-of-war in the mind" that can mess up a player even more. In fact, the MAC-trained players, he says, were less likely to get extremely upset or sad and were better able to cope with changes and try creative approaches to tasks than the players trained with traditional sports psychology tools.

Extending that idea further, Minkler argues that performance problems rarely have anything to do with technical skills. Mental hang-ups in training and competition are often related to interpersonal issues, like relationships with teammates, coaches or loved ones. Mindfulness and ACT can help athletes work through those issues to bring their focus back to their sport, he says.

12
minutes
Minimum daily mindfulness practice time it takes to build mental "muscles"

Mertz, the Wisconsin quarterback, would agree. He said he began to realize during his mindfulness training that he was focused so intently on football, he was neglecting the other parts of his life. He learned to pay attention to what he needed to do for his mental health, whether it was focus a bit more on prepping for the season or just taking some time to have fun. His overall mental health improved as a result, he said.

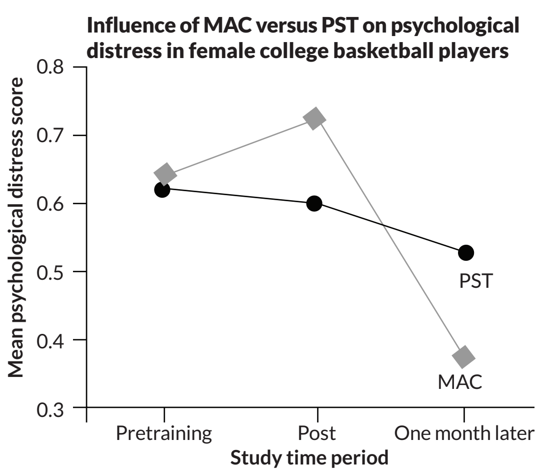
Researchers using these techniques say they've seen similar off-the-field benefits for their student-athletes, including improved focus on readings for class and better communication with friends and family. With those results in mind, Jha say she'd like to test how mindfulness and ACT training might work for Olympic teams.

She has, in fact, had several briefings with U.S. and Australian Olympic team representatives about her mindfulness training. Ideally, she says, she would train Olympic coaches to work with their athletes, and then track the competitors' performance and psychological health and attention. That kind of study is even more relevant after last year's very public experiences of athletes such as Biles and Osaka, she says.

"These people we see as pillars of excellence [are experiencing] extremely dysfunctional mental states," Jha says. "How do we have the mental fitness match the physical excellence?" Studies on mindfulness and ACT hint that a match-up is achievable, and the training might benefit not only elite athletes but every one of us.

"Athletes at the elite level are aspirational," Jha says. They show us that physical training is necessary for physical health, and they've reminded us more recently that the mind, like the body, "needs training to stay fit," she says, "and we can train it." ■

Drop in distress One month after training, the mindfulness-acceptance-commitment approach, or MAC, eased behavioral difficulties and emotional distress more than traditional psychological training, PST, among a group of female collegiate basketball players. SOURCE: M. GROSS *ET AL*/*INTL. J. SPORT EXERC. PSYCHOL.* 2018



Explore more

■ Amishi P. Jha. *Peak Mind*. HarperOne, 2021.

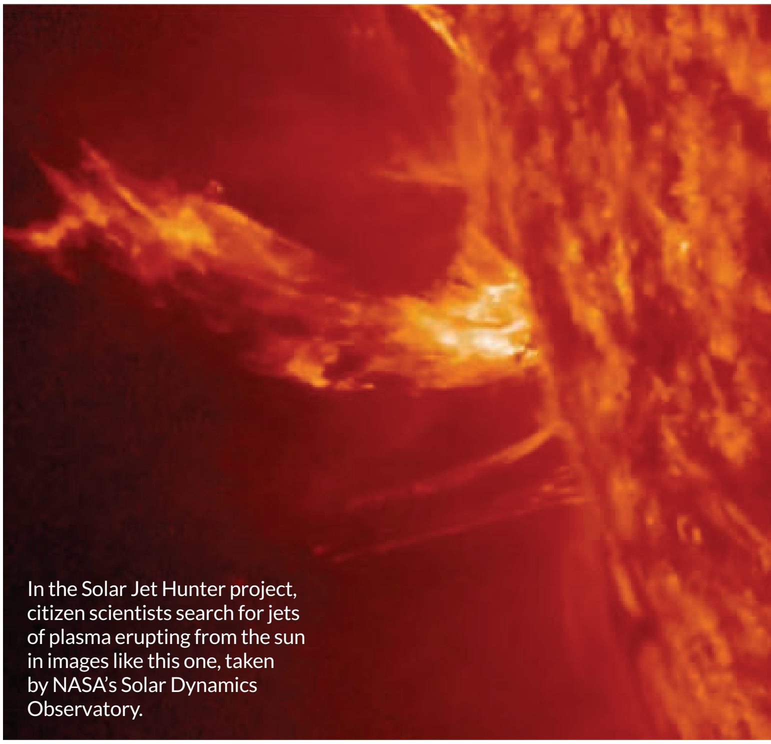
T. TIBBITTS

EXPERIENCES

Stuck at home? Give one of these citizen science projects a try

For many of us, it's the height of winter, with harsh weather and the pandemic keeping us inside. If you're looking for a new way to pass the time, why not help science?

Researchers from a range of disciplines rely on the power of crowdsourcing to collect and analyze data. From transcribing weather logs dating back to the Victorian era to classifying African animals caught by camera traps, here are just a few ways to put your free time to good use. *—Erin Wayman*



In the Solar Jet Hunter project, citizen scientists search for jets of plasma erupting from the sun in images like this one, taken by NASA's Solar Dynamics Observatory.

NASA

Solar Jet Hunter

AIM: Build a database of solar jets

HOW TO HELP: NASA's Solar Dynamics Observatory, or SDO, has been monitoring the sun's activity for more than a decade. Studying the sun's outbursts, including the narrow jets of plasma that erupt from the surface, will help scientists better understand space weather and crack solar mysteries (see Page 10). But first, researchers need to find those jets. That's where you and other armchair astronomers come in. Just go online, review sequences of SDO images, determine if solar jets are visible and document details about the events. In addition to helping scientists study the sun, the dataset could help create a computer program that could speed up future solar jet identifications.

Start hunting at **bit.ly/SolarJetHunter**

Weather Rescue At Sea

AIM: Extend the climate record further back in time

HOW TO HELP: To put today's climate change into perspective, scientists need a long-running record of global temperatures. That record is pretty good for the 20th century, but becomes spottier in the 19th century. To fill in the gaps, researchers are digitizing weather logbooks from ships that sailed in the mid-1800s. Anyone with an internet connection (and willing to read old-timey cursive handwriting) can help transcribe the wealth of data locked away in these books.

Transcribe observations at **bit.ly/WeatherRescueAtSea**

Community Collaborative Rain, Hail & Snow Network

AIM: Improve the quality of precipitation data

HOW TO HELP: Because rain and snowfall are so variable over even short distances, the best way to accurately assess precipitation is to get as many on-the-ground measurements as possible. That's the aim of this network of volunteers across the United States, Canada and the Bahamas who make daily precipitation measurements in their backyards. With a project-approved rain gauge and some online training, you can collect data that's useful to everyone from farmers and city managers to the National Weather Service.

Set up a weather station at **www.cocorahs.org**

Frog Find

AIM: Monitor threatened frogs

HOW TO HELP: To keep tabs on frog species vulnerable to extinction, scientists in Australia have deployed acoustic monitoring devices in several of the country's national parks. Researchers are seeking volunteers to listen in on hours of recordings. Just hop online, review a field guide of frog calls and start identifying amphibians in audio clips.

Categorize croaks at **bit.ly/FrogFind**

Prickly Pear Project Kenya

AIM: Assess the impacts of an invasive plant

HOW TO HELP: Invasive prickly pear cacti are spreading throughout East Africa. To learn how the plants may be altering the behavior of native wildlife, ecologists set up camera traps in Kenya. Citizen scientists can help document what's present in more than 100,000 photos. After taking an online tutorial, you can catalog everything from the aardvarks to the zebras that you see.

ID animals at **bit.ly/PricklyPearProject**

Finding Rico

AIM: Identify genius dogs

HOW TO HELP: In 2004, researchers introduced the world to Rico, a border collie that recognized about 200 spoken words (*SN: 6/12/04, p. 371*). Now, scientists are looking for more high-vocabulary dogs to study canine intelligence and language skills. If your pooch seems to know at least 20 objects by name, the team wants to hear from you.

Get in touch at **bit.ly/FindingRico**

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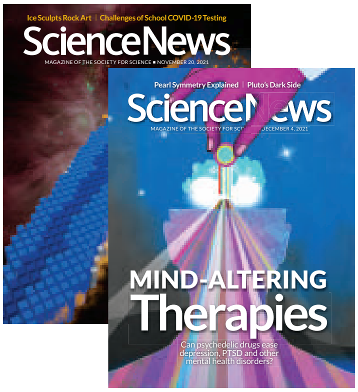
CONGRATULATIONS TO THE TOP 300 SCHOLARS OF 2022

Society for Science is proud to announce this year's Top 300 scholars in the Regeneron Science Talent Search, the oldest and most prestigious science and math competition in the United States for high school seniors. The scholars were selected from 1,804 entrants and come from 185 American and international high schools in 37 U.S. states, China, Singapore and Switzerland. Each scholar receives a $2,000 award with an additional $2,000 going to their respective schools.

Naisha Agarwal • Ayush Agrawal • Armaan Ahmed • Julie Alan • Claire Andreasen • Derek Araki-Kurdyla • Jacqueline Atchley • Neha Ayyalapu • Edith Bachmann • Anjana Balachandar • Sohini Banerjee • Seyun Bang • Maggie Bao • Ayaan Bargeer • Max Bee-Lindgren • Ryan Belkin • Harshal Bharatia • Aurrel Bhatia • Disha Bhattacharya • Pratiksha Bhattacharyya • Atreyus Bhavsar • Steven Blank • Mai Blaustein • Yanna Bravewolf • Michelle Brown • Elijah Burks • Daniel Cai • Victor Cai • Natalie Calman • Eric Cao • Madison Carson • Lawrence Chai • Karly Chan • Sara Chan • Varun Chandrashekhar • David Chang • Samantha Chavira-Prieto • Eileen Chen • Jeffrey Chen • Sabrina Chen • Caitlin Chheda • Nathan Chi • Ethan Chiu • Benjamin Choi • Jaiyoun Choi • Lauren Choi • Neil Chowdhury • Andrew Chu • Jonathan Chung • Rose Cioffi • Ryan Clairmont • Kevin Cong • Levi Cruz • Jason Cui • Srihitha Dasari • Riju Dey • Emily Dodd • Ryan Doherty • Brooke Dunefsky • Efe Eroz • Lindsay Fabricant • Alice Feng • Amy Feng • Aliya Fisher • Orion Foo • Abraham Franchetti • Harrish Ganesh • Rithvik Ganesh • Shyam Ganesh Babu • Andrew Gao • Wilson Gao • Dimple Amitha Garuadapuri • Lara Gastelumendi-Franco • Arko Ghosh • Shaurnav Ghosh • Prabuddha Ghosh Dastidar • Rohan Ghotra • Emi Gilmer • Aanya Goel • Ram Goel • Siya Goel • Maggie Graseck • Maya Groothuis • Audrey Gruian • Richard Gu • Bella Guerra • Joshua Guo • Karen Guo • Phillip Guo • Riya Gupta • Reem Hamdan • Vivien He • Garrett Heller • Heloise Hoffmann • Sheryl Hsu • Alexander Hu • Mulin Huan • Eric Huang • Grace Huang • Ryan Huang • William Huang • Haedam Im • Samuel Iskhakov • Michael Jacob • Fiona Jiang • Theodore Jiang • Yanan Jiang • Sonya Jin • Samuel Jung • Arjan Kahlon • Shreyas Kar • Su Kara • Mithra Karamchedu • Riley Keating • Andrew Kelly • Cyrus Kenkare • Jui Khankari • Selin Kocalar • Vivek Kogilathota • Nikitha Kota • Jeremy Kotlyar • Sophie Krajmalnik • Emma Kratcha • Kaivalya Kulkarni • Rishi Kumar • Ethan Labelson • Enrique Labre • Zoe Lakkis • Henry Lane • Daniel Larsen • Paridhi Latawa • Sachi Laumas • Kathryn Le • Aaron Lee • Rachel Lee • Abigail Lev • Sydney Levy • Jennifer Lew • Bangzheng Li • Eric Li • Jennifer Li • Jerry Li • Krystal Li • Victoria Li • Julianna Lian • Jessica Liang • Brandon Lin • Ann Liu • Francis Liu • Frank Liu • Seton Liu • Steven Liu • Donald Liveoak • Ricardo Lopez • Roberto Lopez • David Lu • Christopher Luisi • Amber Luo • Larissa Ma • Varun Madan • Atulya Mandyam • Rohit Mantena • Gilbert Mao • Evelyn McCreery • Ada Metaxas • Eli Meyers • Benjamin Miao • Vaibhav Mishra • Ashini Modi • Dheepthi Mohanraj • Soyoun Moon • Ella Moore • Genevieve Morange • Benjamin Nachod • Ron Nachum • Varsha Naga • Alexa Nakanishi • Yash Narayan • Kento Nishi • Nyasha Nyoni • Comfort Ohajunwa • Gabrielle Oliva • Jerry Orans • Amara Orth • Suraj Oruganti • Dhruv Pai • Katherine Panebianco • Khushi Parikh • Hannah Park • Ryan Park • Nithin Parthasarathy • Rishab Parthasarathy • Roshni Patel • Shivani Patel • Sidhya Peddinti • Katherine Pflieger • Kannammai Pichappan • Rachel Pizzolato • Emily Pizzorusso • Christopher Prainito • Jacqueline Prawira • Anika Puri • Pravalika Putalapattu • Sasvath Ramachandran • Navya Ramakrishnan • Vale Rasmussen • Janice Rateshwar • Neil Rathi • Aseel Rawashdeh • Brandon Recce • Desiree Rigaud • Luke Robitaille • Ashlyn Roice • Samuel Rossberg • Hrishika Roychoudhury • Varsha Saravanan • Olivia Schmidt • Sarah Schubel • Harshita Sehgal • Maxwell Selver • Arnav Shah • Cameron Sharma • Maya Sharma • Natalie Shell • Daniel Shen • Isabel Shi • Sophia Shi • Eiki Shido • Nina Shin • David Shon • Ankit Singhal • Savar Sinha • Arnab Sircar • Ashwin Sivakumar • Aaron Song • Kevin Song • Lucas Sosnick • Vivek Sreejithkumar • Robert Strauss • Shannon Su • Mark Takken • Cameron Takmil • Wanli Tan • Siddharth Tiwari • Ava Tsapatsaris • Waris Tuchinda • Nishi Uppuluri • Annika Vaidyanathan • Pratik Vangal • Keelan Vaswani • Sophie Vaughan • Alexandra Vesselinov • Jay Vogel • Alexandra Volkova • Oliver Walsh Fuchs • Aimee Wang • Atticus Wang • Ella Wang • Ethan Wang • Ethan Wang • Franklin Wang • Isabel Wang • Lucia Wang • Sunny Wang • Susan Wang • Winnie Wang • Gene Weng • Anthony Wong • Ethan Wong • Leo Wylonis • Zoe Xi • Daniel Xia • Vivian Xiao • Katherine Xie • Nathan Xiong • Jessica Yan • Ali Yang • Heran Yang • Margaret Yang • Christine Ye • Olivia Yeroushalmi • Han Youn • Xinkai Yu • Zara Yu • William Yue • Renee Zbizika • Michael Zeng • Gary Zhan • Alexander Zhang • Allison Zhang • Anya Zhang • William Zhang • Kevin Zhao • Luke Zhao • Andrew Zhou • Emily Zhou • Leon Lee Zhou • Zachary Zitzewitz • Yuqiao Zou • Ethan Zuo



NOVEMBER 20, 2021 & DECEMBER 4, 2021

Nuclear wonders

*A new particle accelerator at the Facility for Rare Isotope Beams will help scientists unlock the inner workings of atomic nuclei and explore how elements form in the cosmos, **Emily Conover** reported in "In search of extreme nuclei"* (SN: 11/20/21, p. 20). **Conover** reported that a rare variety of lithium, called lithium-11, has two extra neutrons that form a wide halo around the nucleus, expanding the nucleus' size.

Reader **Bob Conover**, no relation to **Emily Conover**, asked how lithium-11's halo neutrons can expand the nucleus.

In quantum physics, a neutron isn't localized to one spot within a nucleus, **Emily Conover** says. Instead, it is described by a wave function, which gives the probability of finding a neutron in a given place. Each halo neutron in lithium-11 has a wave function that is spread out much more than a normal neutron in a nucleus, she says. That makes the nucleus large, in the sense that it can collide with another nucleus even when the two nuclei are separated by a relatively large distance. While the halo neutrons are weakly bound to the nucleus, they are indeed bound.

Ticktock

*An atomic clock detected how general relativity warps time across a millimeter, revealing the extreme precision achievable by such clocks, **Emily Conover** reported in "Gravity warps time on tiny scale"* (SN: 11/20/21, p. 10).

Reader **Richard Boyer** wondered if the accuracy of a wristwatch changes as a person swings the watch-wearing arm.

"As you swing your arm, your watch could tick very, very slightly faster or slower," **Conover** says. "That's because each point in Earth's gravitational field will have a specific rate of time determined by the gravitational potential at that point." But the slight changes aren't enough to throw off your daily schedule.

Oldie but a goodie

*Lithium-ion batteries with recycled cathodes can last longer than batteries with new cathodes, **Carolyn Wilke** reported in "Recycled materials can make long-lasting batteries"* (SN: 12/4/21, p. 4).

Reader **Ann Hoffenberg** wanted to know how the recycled batteries outperformed the new ones.

The researchers don't know exactly why the recycled batteries' cathodes perform better, but they think it's because the recycling process used in the study made the material's microstructure more porous, **Wilke** says. When a battery is discharged and recharged, it goes through stages of shrinking and expanding. The more porous material seems to endure that process better, which is important for battery performance, she says.

Signal senders

*Cells called neuroids crawl around sponges' digestive chambers and send messages, a communication system that offers hints about how nervous systems evolved, **Laura Sanders** reported in "Brainless sponges may have echoes of a nervous system"* (SN: 12/4/21, p. 32). **Sanders** reported that in the studied sponges, some hairlike cilia — which help keep the animals fed by moving nutrients through feeding chambers — near neuroids were bent at angles that suggested the cilia were no longer moving. Reader **James Wilcox** wondered why the cilia get bent.

The researchers suspect that the bent shape indicates a sort of freeze, **Sanders** says. Neuroids might send small packages of chemical signals that stop the cilia's normal movement, putting the brakes on the sponge's meal.

Join the conversation

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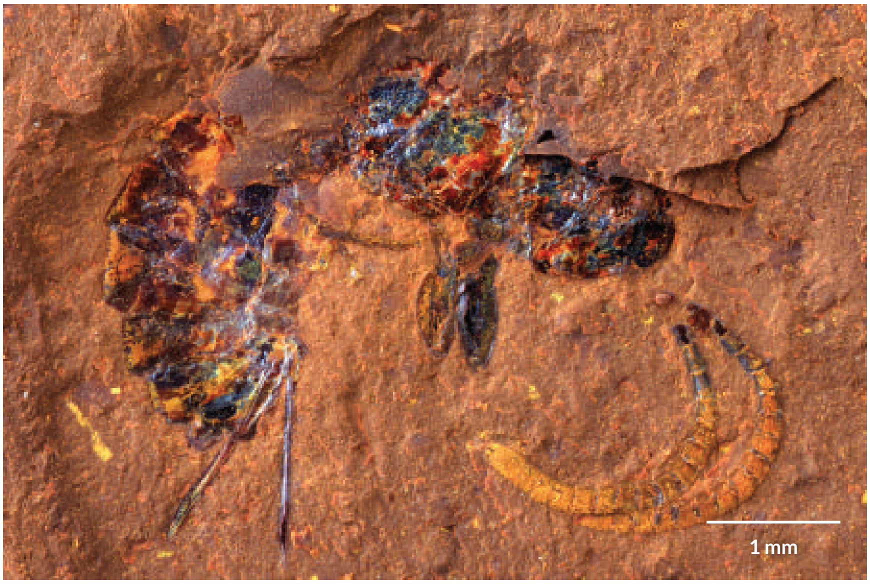


Rare fossils preserve Australia's wet history

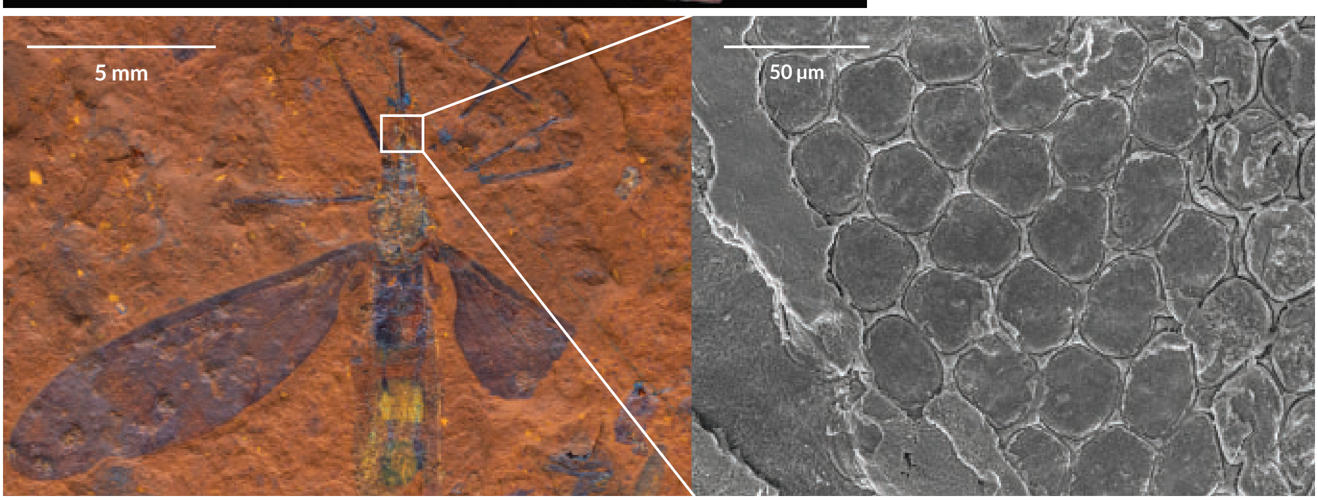
A new trove of thousands of insect, plant and other fossils offers an unprecedented snapshot of Australia's wetter, forest-dominated past.

The fossils were found at a site called McGraths Flat in southeastern Australia, vertebrate paleontologist Matthew McCurry and colleagues report January 7 in *Science Advances*.

Long ago, much of Australia was carpeted with rainforests. Then, during the Miocene Epoch, about 23 million to 5 million years ago, Earth underwent a climatic upheaval. For Australia, that meant drying out, with shrubs, grasses and deserts expanding into once-lush territory.

McGraths Flat, which is located in New South Wales, formed during that transition, between 16 million and 11 million years ago. Now shrubland, the site was part of a temperate forest around a small lake, says McCurry, of the Australian Museum Research Institute in Sydney.

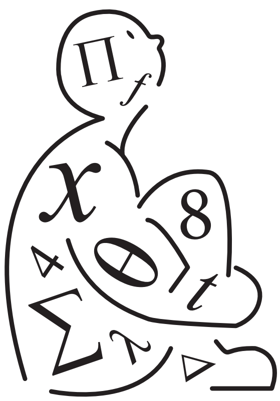
The fossils, including of a parasitoid wasp (top) and fern leaf (middle), were encased within layers of an iron-rich mineral called goethite, preserving the remains in astonishing detail. Scanning electron microscopy let the team zoom in on some fossils, including of a crane fly (bottom left), revealing the units, or ommatidia, of its compound eye (bottom right). — *Carolyn Gramling*



ALL: M.R. MCCURRY *ET AL*/*SCIENCE ADVANCES* 2022

See fossils from Australia's McGraths Flat at **bit.ly/SN_McGrathsFlat**

mens et manus



mind and hand

Admissions

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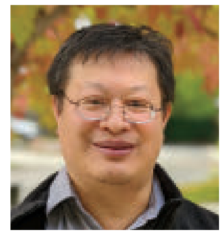
BENNET YEE DOES



According to Bennet, in lieu of becoming a science teacher, donating to Society for Science is one of the best ways to help cultivate scientific thinking in future generations. Through science, we can understand the world and improve lives. That is why Bennet gives to the Society through his donor advised fund at Vanguard Charitable.

> "*Science News* is wonderful because it allows me to stay broadly informed about advances in many scientific fields."

BENNET YEE

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