Crickets Pump Up the Volume | A New Quantum Supremacy Claim

ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ JANUARY 16, 2021

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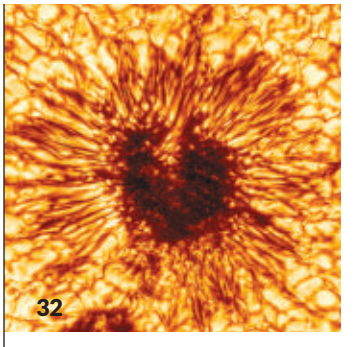
Features

News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Departments

COVER Volcanoes around the globe, Hawaii's Kilauea shown, still hold plenty of surprises. *RGB Ventures/SuperStock/Alamy Stock Photo*

For 100 years, bringing you the latest in science

In 1921, the world was still struggling to recover from the ravages of World War I and the influenza pandemic that had killed 50 million people. The global economy slid into a brief depression. The media magnate E.W. Scripps was contemplating the parallel goals he saw in science and journalism: to discover how the world works, and to explain it truthfully and in a way that people can understand. An informed, educated public, he believed, was essential to a democratic society.

Scripps had become an avid student of science in his later years, thanks in part to his friendship with zoologist William E. Ritter. Scripps was appalled by the media's willingness to promote fake cures and dangerous theories, writing in 1919 that "there is a vast quantity of misinformation being constantly spread abroad by our newspapers."

To combat that misinformation and to help people learn how to "think like a scientist," in 1921 Scripps and Ritter founded Science Service, an independent news service that covered the latest scientific research for publication in newspapers. Those weekly bulletins became so popular that starting in 1922, they were bundled into *Science News-Letter*, a stand-alone publication for the general public. That later morphed into *Science News* magazine.

Over the decades, we have stayed true to our founders' mission. *Science News* reporters covered the discovery of insulin as a treatment for diabetes in 1922 and traveled to Tennessee in 1925 to cover the Scopes "monkey trial" that challenged the teaching of evolution. We were on the scene at Bikini Atoll to witness the 1946 atomic weapons tests, and in 1959, first reported on data showing that Earth is warming. We covered the revolution in computing that has transformed science and society from the era of vacuum tubes. And we've tirelessly covered the coronavirus pandemic, both the extraordinary scientific efforts to combat the virus and its toll on society.

Of course, we're not going to let our 100th anniversary pass without notice. We'll be looking back at transformative moments in science over the last century, starting in this issue with the emergence of the theory of plate tectonics in the 1960s (Page 16). Earth and climate writer Carolyn Gramling chronicles the insights and technological advances that made it possible to reimagine the forces shaping our planet, and to discover that Earth's surface is divided into giant chunks that collide and split apart atop a churning mantle. She also illuminates how this crust on the go informs other big questions in science, including the possibility of life on other worlds.

We have big plans to explore other epochal achievements in science in the coming months, both here in the magazine and on our new Century of Science site (www.sciencenews.org/century). The site is designed to encourage exploration, revealing unexpected connections across fields of science. It will also include additional features, such as timelines and links to the original coverage in our archive. We'll be publishing new material through March 2021. I'm greatly looking forward to this journey of rediscovery and insight, and I'm glad you're along for the ride. —*Nancy Shute, Editor in Chief*

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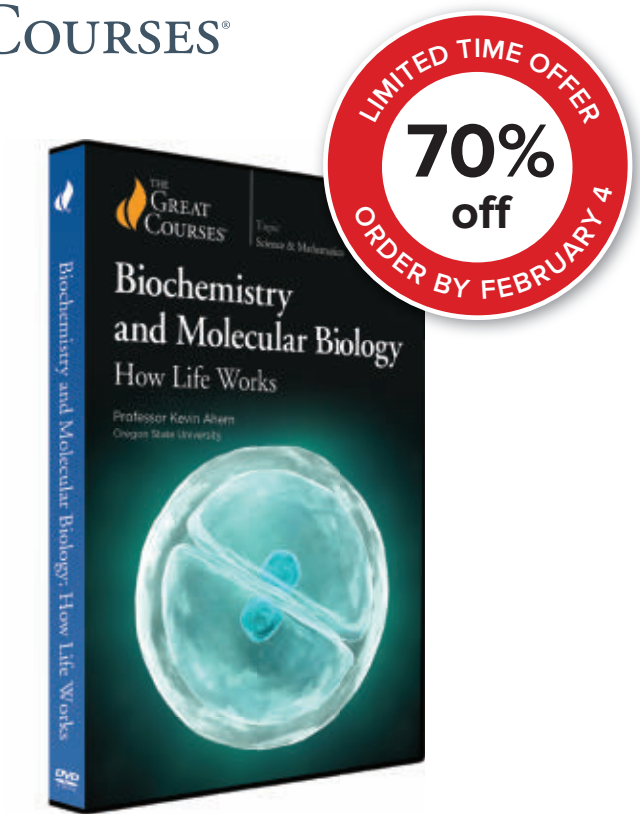

Understand the Science of Us

Biochemistry and its allied field of molecular biology are the fundamental sciences of life and the cornerstones of today's biotechnology revolution. But despite being about a subject that concerns us all—life—they are considered almost unapproachably difficult by non-scientists. Not anymore.

Biochemistry and Molecular Biology: How Life Works is an accessible and entertaining introduction to this vital discipline in 36 half-hour lectures. With lavish visuals, it is tailored to viewers with no more of a science background than high school chemistry. Using innovative teaching methods, Professor Kevin Ahern of Oregon State University introduces viewers to amino acids, proteins, enzymes, genes, and topics dealing with the intricate workings of living cells. Together, biochemistry and molecular biology have sparked a scientific revolution every bit as momentous as Einstein's relativity or Hubble's discovery of the expanding universe, but at the core, this remarkable field of study, says Professor Ahern in **Biochemistry and Molecular Biology**, is truly just "the science of us."

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Excerpt from the January 23, 1971 issue of *Science News*

50 YEARS AGO

By the sweat of their brow

Polywater, or anomalous water, has provoked a continuing controversy among chemists. It is hard enough to believe that water can assume a form as viscous as molasses and have an atomic weight several times that of an ordinary molecule of water.... From the beginning, however, there were doubters, and as proponents of polywater failed more and more ... in their attempts to produce convincingly large quantities of it, the doubters began to have their innings.

UPDATE: Polywater evaporated when scientists confirmed that impurities in ordinary water were responsible for the strange properties (*SN: 9/1/73, p. 133*). In the decades since that debunking, physicists have continued puzzling over other H_2O quirks. For instance, hot water appears to sometimes freeze faster than cold water — a phenomenon known as the Mpemba effect. A study of glass beads suggests that warm objects can take thermal shortcuts to reach the frozen finish line first (*SN: 9/12/20, p. 16*). The jury is still out on whether water, with all its complexity, behaves the same.

IT'S ALIVE

Face masks may turn up the sex appeal of male wrinkle-faced bats

A movable white fur mask seems to help male wrinkle-faced bats woo females in a rainforest in Costa Rica.

For tips on how to flirt while wearing a mask, take notes from nature's experts: male wrinkle-faced bats. The first video of a wrinkle-faced sexual encounter shows a male covering his face with a masklike flap of skin while wooing a female and then, at a dramatic moment, dropping the mask.

Even the basics of how bats mate — whether a male stakes out territory and advertises, or females just shop among a crowd of show-offs — remain a mystery in more than 90 percent of the world's 1,400 bat species, says mammalogist Bernal Rodríguez-Herrera of the University of Costa Rica in San José. So it was a stroke of luck when a tip from nature guides

RETHINK

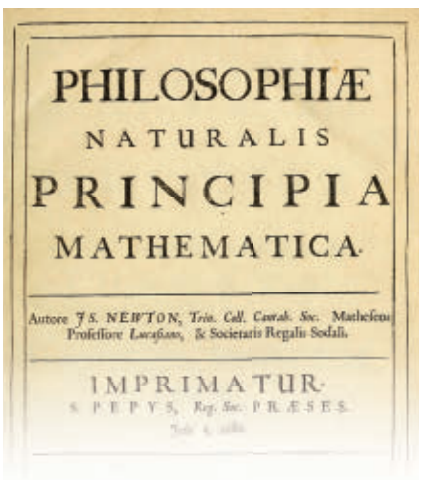
Newton's *Principia* gets a popularity boost

Isaac Newton's 17th century book the *Principia* gave the English scientist a reputation: "[T]here goes the man that writt a book that neither he nor any body else understands," a University of Cambridge student is said to have remarked as Newton passed by.

Likewise, historians have assumed that only a select few mathematicians and scientists were able to comprehend the highly technical book, which introduced game-changing physics concepts such as the law of universal gravitation.

But a new census of the remaining copies of the book's first edition, described online September 2 in *Annals of Science*, suggests that the student's quip was misleading. "An anecdote only tells you part of the story," says study coauthor and historian of science Mordechai Feingold of Caltech.

A census has more than doubled the number of known original copies of one of the most famous books in the history of science: Isaac Newton's *Principia*.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A 1950s search found only 189 copies of the first edition, published in 1687 under the full title *Philosophiae Naturalis Principia Mathematica* (*SN: 7/4/87, p. 11*). But Feingold and his former student Andrej Svorenčík, now at the University of Mannheim in Germany, unearthed 386 copies, suggesting a more substantial readership. By tracking down original owners and studying the annotations that readers made, the researchers conclude that well-educated laypeople were reading the book as well as scientists. — *Emily Conover*

FROM TOP: MARCO TSCHAPKA; SMITHSONIAN LIBRARIES

in 2018 led him to the first scientific observations of courtship in one of the more elusive bats in the Western Hemisphere's tropics, the wrinkle-faced bat, *Centurio senex*.

Males, but not females, grow loose folds of mostly white fur below the chin that look like a pulled-down neck gaiter. A male can use his skinny thumbs to tug the fur flap up over his chin and mouth.

It doesn't seem likely that only males would need covers for chilly chins. Single-sex excesses often are for showing off, like peacock feathers fanned out in competition for female favor. A lucky first look at wrinkle-faced courtship suggests that the masks play into a wooing competition, Rodríguez-Herrera and colleagues report November 11 in *PLOS ONE*.

For weeks, the researchers watched male bats convene in the Costa Rican forest from about 6 p.m. until midnight, hanging upside down in particular spots with their masks raised. Other bats occasionally flew close, very briefly, but researchers couldn't tell why.

Scientists filmed a male wrinkle-faced bat (one shown) dropping his furry mask before mating.

The dangling males, it turned out, were singing. Human hearing picks up lots of tropical night sounds, such as the calls of frogs and owls, but hardly ever the bats. Bat-recording instruments, however, revealed great roaring ultrasonic bat songs. The sounds dipped into the range of human hearing only when a flyby visitor made a quick intrusion. The males also "move the tips of the wings, constantly," Rodríguez-Herrera says. He can't tell if the wing rustling contributes any sound, but "we think it's part of the courtship display."

Males gathering in a specific place to sing suggests to Rodríguez-Herrera that the wrinkle-faced species takes a singles bar approach to mating, so far rarely reported among bats. The strategy, known as lekking, sees males cluster and display while females shop for a mate. Help raising the resulting offspring is not on offer.

For weeks, these male bats in Costa Rica spent evenings rubbing wings and singing upside down. The pale mask might work as a visual lure in dim light or might play a role in wafting scents, a romantic feature in some other bats' courtships. Or maybe the flap "helps sound resonance," Rodríguez-Herrera muses. "We do not know."

What the team finally saw, and got on film, was one wrinkle-faced mating. A female landed on a male's perch. The two faced each other briefly. As he repositioned himself for intimate contact, down went his mask. — *Susan Milius*

THE –EST

Microplastics reach new heights

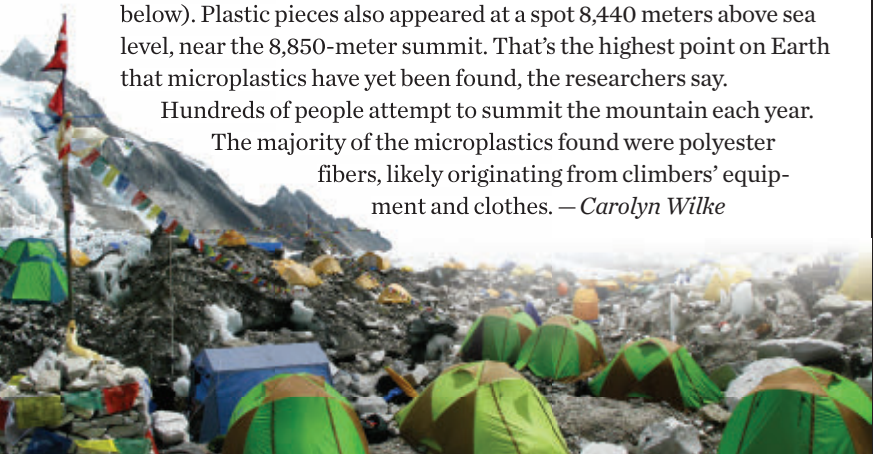
Minuscule shreds and threads of plastic are turning up all over, including in the snow on Mount Everest.

"We've known that plastic is in the deep sea, and now it's on the tallest mountain on Earth," says marine scientist Imogen Napper of the University of Plymouth in England. "It's ubiquitous through our whole environment."

All of the 11 snow samples that Napper's team analyzed from Mount Everest contained microscopic bits of plastic, the researchers report in the Nov. 20 *One Earth*. "That really took me aback," Napper says. Microplastics also turned up in three of eight stream water samples from the mountain.

The highest concentration of microplastics that the team detected — 119,000 pieces per cubic meter — was in snow from Everest Base Camp, where climbers congregate (a campsite is shown below). Plastic pieces also appeared at a spot 8,440 meters above sea level, near the 8,850-meter summit. That's the highest point on Earth that microplastics have yet been found, the researchers say.

Hundreds of people attempt to summit the mountain each year. The majority of the microplastics found were polyester fibers, likely originating from climbers' equipment and clothes. — *Carolyn Wilke*



FROM TOP: MARCO TSCHAPKA; R.M. NUNES/ISTOCK/GETTY IMAGES PLUS

THE EVERYDAY EXPLAINED

Lonely brains crave people like hungry brains crave food

After spending a day in complete isolation, people's brains perked up at the sight of social gatherings, like a hungry person's brain seeing food, scientists report November 23 in *Nature Neuroscience*.

Cognitive neuroscientist Livia Tomova of the University of Cambridge and colleagues at MIT asked 40 participants to fast for 10 hours. Afterward, certain nerve cells in the midbrain — which plays an important role in motivation to seek food and friends — fired up in response to pictures of pizza and chocolate cake. Those cells produced a chemical messenger associated with reward.

On a different day, the same people underwent 10 hours of social isolation. That evening, nerve cells in the same spot activated in response to pictures of groups of people chatting or playing team sports. The more hunger or isolation a person reported, the stronger the effect.

The findings "speak to our current state," Tomova says. COVID-19 has left many people socially isolated, putting mental as well as physical health at stake and leaving people with cravings for more than food. — *Bethany Brookshire*

MATTER & ENERGY

Quantum supremacy claimed again

A light-based device reaches a computing milestone

BY EMILY CONOVER

A new type of quantum computer has proved that it can reign supreme, too.

A photonic quantum computer, which harnesses particles of light, or photons, performed a calculation that's impossible for a conventional computer, researchers in China report online December 3 in *Science*. That milestone, known as quantum supremacy, has been met only once before, in 2019 by Google's quantum computer (*SN: 12/21/19 & 1/4/20, p. 29*). Google's computer, however, is based on superconducting materials, not photons.

"This is the first independent confirmation of Google's claim that you really can achieve quantum supremacy," says Scott Aaronson, a theoretical computer scientist at the University of Texas at Austin. "That's exciting."

Named Jiuzhang after an ancient Chinese mathematical text, the new quantum computer can perform a calculation in 200 seconds that would take more than half a billion years on the fastest nonquantum, or classical, computer.

Google's device, called Sycamore, is based on tiny quantum bits made of superconducting materials, which conduct electricity without resistance. In contrast, Jiuzhang consists of a complex array of optical devices that shuttle photons around. Those devices include light sources, hundreds of beam splitters, dozens of mirrors and 100 photon detectors.

Employing a process called Gaussian boson sampling, Jiuzhang generates a distribution of numbers that is exceedingly difficult for a classical computer to replicate. Here's how it works: Photons are first sent into a network of channels. There, each photon encounters a series of beam splitters, each of which sends the photon down two paths simultaneously in what's called quantum superposition. Paths also merge together, and the repeated splitting and merging causes the photons to interfere with one another according to quantum rules.

Finally, the number of photons in each of the network's output channels is measured at the end. When repeated many times, this process produces a distribution of numbers based on how many photons were found in each output.

If operated with large numbers of photons and many channels, the quantum computer will produce a distribution of numbers that is too complex for a classical computer to calculate. In the new experiment, up to 76 photons traversed a network of 100 channels. For one of the world's most powerful classical computers, the Chinese supercomputer Sunway TaihuLight, predicting the results that Jiuzhang would get for anything beyond about 40 photons was impractical.

While Google was the first to break the quantum supremacy barrier, the milestone is "not a single-shot achievement," says study coauthor Chao-Yang Lu, a quantum physicist at the University of Science and Technology of China in Hefei. "It's a continuous competition between constantly improved quantum hardware and constantly improved classical simulation." After Google's quantum supremacy claim, IBM proposed a type of calculation that might allow a supercomputer to perform the task Google's computer completed, at least theoretically.

And achieving quantum supremacy doesn't necessarily indicate that the quantum computers are yet very useful, because the calculations are esoteric ones designed to be difficult for classical computers.

The result does boost the profile of photonic quantum computers, which haven't always received as much attention as other technologies, says quantum physicist Christian Weedbrook, CEO of Xanadu, a Toronto-based company focused on building photonic quantum computers. "Historically, photonics has been the dark horse."

One limitation, Weedbrook notes, is that Jiuzhang can perform only boson sampling. In contrast, Google's quantum computer could be programmed to execute a variety of algorithms. But other types of photonic quantum computers, including Xanadu's, are programmable.

Demonstrating quantum supremacy with a different type of device reveals how rapidly quantum computing is progressing, says quantum physicist Fabio Sciarrino of Sapienza University of Rome. "The fact that now the two different platforms are able to achieve this regime ... shows that the whole field is advancing in a very mature way." ■

A new quantum computer manipulates light via an array of optical devices (shown on a table).

HANSEN ZHONG

ATOM & COSMOS

New moon rocks brought to Earth

The Chang'e-5 mission sampled a previously unexplored region

BY LISA GROSSMAN

Early in the morning on December 17, 2020, the Chang'e-5 return capsule (shown) landed in Inner Mongolia. The Chinese mission brought the first lunar samples to Earth since 1976.

CHINA DAILY VIA REUTERS

For the first time in almost half a century, scientists are going to get their hands on new moon rocks.

On December 17, 2020, the return capsule of China's Chang'e-5 mission landed in Inner Mongolia at 1:59 a.m. local time, carrying lunar material from a previously never-before-visited region of the moon. Those samples could provide details about a period of lunar geologic history not touched on by other moon missions.

"We've been talking since the Apollo era about going back and collecting more samples from a different region," says planetary scientist Jessica Barnes of the University of Arizona in Tucson, who works with lunar samples from the American and Soviet missions of the 1960s and 1970s.

Chang'e-5, the latest in a series of missions named for the Chinese moon goddess (*SN: 11/24/18, p. 14*), landed on the northwestern region of the moon's nearside on December 1.

The mission's lander, equipped with a scoop and a drill, set out to collect about two kilograms of soil and small rocks, possibly from as deep as two meters below the moon's surface, says planetary scientist Long Xiao of China University of Geosciences in Wuhan. After landing in Inner Mongolia, the return capsule was sent to Beijing, where scientists will determine exactly how much lunar material was collected, and then catalog and store the samples.

The Chang'e-5 lander had to work fast. With no internal heating mechanism, it had no defenses against the extremely cold lunar night, which can reach about –170° Celsius. So the entire mission had to happen while the sun was up, a period of 14 Earth days. The lander is now dead.

The lander stored collected material in an ascent vehicle that lifted off from the moon on December 3 to meet up with the Chang'e-5 orbiter, where the ascent vehicle's cargo was transferred to the return capsule.

The last time new lunar samples were sent back to Earth was 1976, with the end of the Soviet Union's Luna program. Between those missions and NASA's Apollo missions, scientists on Earth have about 380 kilograms of moon material to study (*SN: 7/6/19 & 7/20/19, p. 18*). "Perhaps for a long time people thought, been there, done that, when it comes to the moon," Barnes says.

A couple kilograms of new stuff might not sound like much next to what's already in hand. But the new samples come from an entirely unexplored region. Chang'e-5's landing site was in the volcanic flatlands of the Mons Rümker region on the nearside of the moon. Like the Apollo and Luna landing sites, the Rümker region is flat. "The engineering consideration is first, to be safe," Xiao says.

All the Apollo and Luna missions visited ancient volcanic plains, where the rocks are between 3 billion and 4 billion years old. Rümker's volcanic rocks are much younger, around 1.3 billion years old. In the 1960s, scientists didn't think the moon was still volcanically active that late. More recent studies from lunar orbit and from telescopes have suggested a more complicated volcanic past.

"With these new samples, we potentially add another pinpoint in our geologic history of the moon," Barnes says. "We'll get an idea of, what was the volcanic history like on the moon a billion years ago? That's something we don't have access to in the returned samples we already have."

The Rümker region is also rich in potassium, rare-earth elements and phosphorus, together known as KREEP elements. Those elements were some of the last to crystallize out of the magma ocean that covered the young moon and can help reveal details of how that process happened. "It's a really different area, geochemically, to the rest of the moon," Barnes says.

One of the biggest challenges for the mission was drilling that material. The drill couldn't change direction once deployed, so it had to drill through anything directly below it. Had it hit a large rock, the drill could have failed.

The Chinese National Space Administration plans to share the recovered samples with international scientists. A 2011 congressional rule makes it difficult for U.S. scientists to collaborate directly with China, so it's unclear who will get to work with the rocks. But the discoveries that the new lunar material will enable go beyond international borders.

"It doesn't matter who's doing it," Barnes says. "The whole world should be behind this mission and this endeavor. It's a piece of history." ■

Some of the volcanoes in Alaska's Islands of the Four Mountains (shown in a photo taken from the International Space Station) may be part of one big caldera.

EARTH & ENVIRONMENT

Alaska may be hiding a supervolcano

A geologic game of connect the dots hints at a giant crater

BY BETH GEIGER

A mysterious, previously undiscovered supervolcano may be lurking beneath Alaska's Aleutian Islands.

A new study suggests that a wide crater, created when the supervolcano exploded, connects at least five existing volcanoes. The supervolcano is so big that if it erupted during the last few thousand years, it could have disrupted civilizations around the world, says John Power, a geophysicist at the U.S. Geological Survey's Alaska Volcano Observatory in Anchorage. Power presented the findings December 7 at the virtual meeting of the American Geophysical Union.

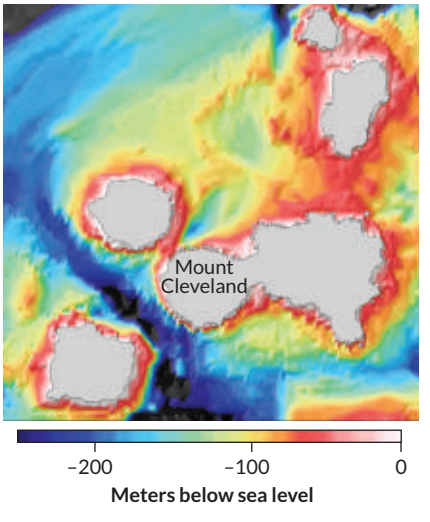
The discovery, not yet confirmed, emerged from several pieces of evidence that at first glance seem unrelated, says Diana Roman, a volcanologist at the Carnegie Institution for Science in Washington, D.C., and one of Power's collaborators. "There's no one smoking gun," she says. And in fact, the mythical-sounding Islands of the Four Mountains, actually six volcanoes located near the center of the Aleutians, look like an ordinary volcanic cluster.

But taken together, the data point to the existence of a caldera about 20 kilometers across. The volcanoes' peaks are arranged in a partial circle, and seafloor mapping shows arc-shaped ridges and a 130-meter-deep depression in the center of the partial circle. Both are clues that the volcanoes are connected by one big caldera, a massive crater that forms when a very large magma chamber in a volcano explodes and empties.

Gravity data collected by satellites look similar to data gathered from other calderas. An analysis of volcanic gases such as sulfur dioxide, as well as patterns of microearthquakes in the area, further suggest the presence of a caldera.

"We weren't surprised there were microearthquakes," Roman says. After all, one of the volcanoes, Mount Cleveland, is one of the most active volcanoes in the Aleutians. But, she says, those microearthquakes extended farther east and north than expected based on the volcanoes seen at the surface. "That makes more sense in the context of the caldera."

In search of a supervolcano Seafloor mapping suggests that some Aleutian Island volcanoes (gray, excluding bottom left) may be joined to one larger caldera (red-orange shows apparent connections beneath the sea surface).



One hallmark of many calderas is still-active volcanoes on the caldera rim that tap into the same magma chamber, even long after the caldera itself formed. Mount Cleveland fits that scenario. It has "erupted 60 or 70 times since 2001," Power says. Besides blasting out sky-high ash plumes that disrupt air travel, this level of constant activity is typical of volcanoes rimming calderas, he says. One such volcano is Indonesia's Rinjani, whose eruption around the year 1257 dumped enough sulfur particles into the atmosphere to cool the entire planet.

Piecing the evidence together has been challenging, thanks to the remote location, a largely underwater setting and newer volcanic deposits that obscure older ones. Previous studies provided different lines of evidence for a caldera, but until now, none had connected the dots. Roman likens the team's approach to "looking under the couch cushions."

"It's a neat example of how lots of threads come together to make a bigger story," says volcanologist Michael Poland of the USGS Yellowstone Volcano Observatory, who is based in Vancouver, Wash., and was not involved in the study. "We're starting to get the datasets we need to make these sorts of discoveries."

The Aleutians site is accessible for only a short time each year, Poland says, so "it's a mad rush to collect data." But that's what Power's team hopes to do to confirm the caldera's existence. The team also wants to search for ash in ice cores collected in other parts of the world to determine when the supervolcano erupted. "These very large calderas have very large impacts globally," Power says. "This potential identification helps us understand what we might expect, why Cleveland is so active, and understand the hazards." ■

FROM TOP: NASA; HÉLÈNE LE MÉVEL

EARTH & ENVIRONMENT

Warming has transformed the Arctic

In the last 15 years, the region has changed faster than expected

BY CURTIS SEGARRA

Fifteen years of grading the impact of warming on the Arctic has made one thing abundantly clear: Climate change has drastically altered the region in that short time period.

There have been so many unfortunate records, it feels "like whack-a-mole," says climate scientist Jackie Richter-Menge, an editor of the 2020 Arctic Report Card, released December 8 at the virtual meeting of the American Geophysical Union. From sea ice lows to temperature highs, records keep popping up all over the place in the Arctic. For instance, in June, a record-high temperature of 38° Celsius (about 100° Fahrenheit) was set in the Arctic Circle. In 2018, winter ice on the Bering Sea shrank to a 5,500-year low.

"But quite honestly, the biggest headline is the persistence and robustness of the warming," says Richter-Menge, of the University of Alaska Fairbanks. In 2007, only a year after the first Arctic Report Card, summer sea ice reached a record low, shrinking to an area of 4.2 million square kilometers, about 1.6 million square kilometers smaller than the previous year. Only five years later, there was a new low: 3.4 million square kilometers. In 2020, the sea ice extent didn't set a record but came close, becoming the second lowest on record in the last 42 years, the extent of the satellite record.

"The transformation of the Arctic to a warmer, less frozen and biologically changed region is well under way," the report states. And the Arctic is changing faster than was expected when researchers launched the report card in 2006. The annual average air temperature in the region is rising two to three times faster than the rest of the globe, Richter-Menge says. Over the last 20 years, the Arctic has warmed at a rate of 0.77 degrees C per decade, compared with the global average of 0.29 degrees C per decade.

Improvements in research techniques over the last 15 years have helped scientists more thoroughly observe the warming's impact and how different aspects of Arctic climate change are linked to one another, she says. These improvements include the ability to measure ice mass via gravity measurements taken by satellites, as well as more on-the-ground measurements, including observations by the Arctic's Indigenous people, who experience these changes directly.

The recorded changes have revealed few bright spots, but one is the rebound of bowhead whales (*Balaena mysticetus*), which were hunted almost to extinction around the turn of the 20th century. Researchers suggest that the rebound is due, at least in part, to the warming that has occurred over the last 30 years. Earlier sea ice melting during the year means more light and warmer surface water, resulting in more food for these filter-feeding whales.

But don't be fooled. This potential good news is overshadowed by the bad news. There's been "this accumulation of knowledge and insights that we've gained over 15 years," says Mark Serreze, a climate scientist at the National Snow and Ice Data Center in Boulder, Colo., who wasn't involved in this year's report. The 2020 report card is "an exclamation point on the changes that have been unfolding," he says. "The bowhead whales are doing OK, but that's about it." ■

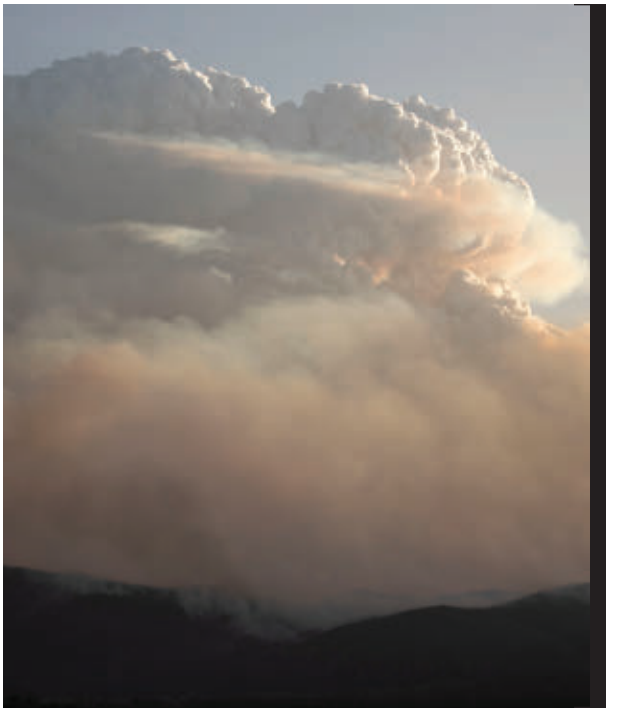
EARTH & ENVIRONMENT

Australian fires sent smoke high

Intense Australian wildfires in late 2019 spawned storms that created the loftiest and largest cloud of smoke ever measured, scientists said in a news conference December 11 at the virtual meeting of the American Geophysical Union.

The fires produced 32 pyrocumulonimbus, or pyroCb, events from December 29 to December 31, 2019, ultimately generating a plume of smoke that rose up to 35 kilometers into the atmosphere. This plume, along with a second large plume on January 4, 2020, in total injected three times as many aerosols into the stratosphere as any previously recorded pyroCb event (a pyroCb event in southeastern Australia's Orroral Valley on January 31, 2020, is shown at right).

In terms of number of aerosols sent into the stratosphere, these plumes were on par with the strongest volcanic eruptions in the last 25 years. What impact these particles have on weather patterns is still unclear. Scientists detected traces of a 2017 plume for up to 10 months; particles from the 2019–20 plumes are still lingering, researchers said. — *Carolyn Gramling*



BROOK MITCHELL/GETTY IMAGES

A male *Oecanthus henryi* tree cricket peeks through a hole it cut in a leaf. Males can increase the volume of their mating song and attract more females by calling from such self-made tools.

R. DEB

LIFE & EVOLUTION

Quiet crickets find a way to be heard

Leafy 'megaphones' can double the volume of mating songs

BY JONATHAN LAMBERT

The rules of the tree cricket world, sexually speaking, are simple.

Perched on a leaf's edge, males call out into the night by rhythmically rubbing their wings. Females survey the soundscape, gravitating toward the loudest and largest males. Small, quiet types get drowned out.

Unless they cheat the system.

Some male crickets make their own megaphones by cutting wing-sized holes into the center of a leaf. With their bodies stuck halfway through this vegetative speaker, male *Oecanthus henryi* crickets can more than double the volume of their calls, allowing naturally quiet males to attract as many females as loud males, researchers report in the Dec. 23 *Proceedings of the Royal Society B*.

It's a rare example of insect tool use that "really challenges you to think about what it takes to produce complex behavior," says Marlene Zuk, an evolutionary biologist at the University of Minnesota in St. Paul who wasn't involved in the study.

Biologists first reported crickets creating leaf-speakers, called baffles, and singing from them, or baffling, in 1975. Since then, the baffling behavior has been reported in several other species, but scientists weren't sure exactly how the behavior benefits individual crickets.

Rittik Deb, an evolutionary ecologist now at the National Centre for Biological Sciences in Bangalore, India, was stunned when he first witnessed an *O. henryi* male baffling in 2008. "It was mind-bogglingly beautiful," he says. "I had to understand why it was happening."

Deb, then at the Indian Institute of Science in Bangalore, and colleagues first looked for any commonalities among crickets that use baffles. Only 25 out of 463, or 5 percent, of crickets observed and individually marked at field sites outside Bangalore were seen baffling. On average, baffling males were smaller and called more quietly when not baffling. In the field, Deb found that baffling approximately doubles the volume of a quiet male's call, raising him to the level of the most attractive males.

Cricket wings are essentially resonance structures, reverberating with the vibration caused by rubbing, sort of like the body of a violin. When bafflers crawl through a hole in a leaf, align their wings with the leaf and start to sing, the crickets are expanding this resonance structure, using the leaf "a bit like a loudspeaker or a megaphone," Deb says.

Do females fall for the inflated calls? Yes, according to lab experiments. When given a choice, females overwhelmingly prefer louder calls, even when these come from baffling males. Baffling evens the playing field, allowing quiet males to attract just as many females as louder males.

The benefits of baffling don't stop there.

The climax of cricket mating is the transfer of the spermatophore, a protein ball packed with sperm. Females dictate how much sperm they accept by how long they retain the spermatophore. With larger males, it's about 40 minutes, compared with only 10 minutes for small males. But when Deb artificially boosted the calls of small and quiet males, females treated them like large males, retaining their spermatophores for longer. "It's as though the females are in some sense being deceived," Deb says.

It's unclear why females don't seem to notice that they're mating with a smaller male, though it's not necessarily surprising. "They're not wrapping their little arms around males to see whether they're big or small," Zuk says. "Maybe there's something in the song that signals 'go ahead and have more of this guy's babies.'"

Whatever the mechanism, *O. henryi* males have evolved a remarkably effective mating strategy, Zuk says. The behavior appears to be innate, not learned, as lab-raised crickets of all sizes can make and use baffles when given leaves. "It makes me really want to know why such a small portion of males actually do this," Zuk says.

Baffling might not be worth the extra work for larger males that can already attract plenty of females. But there are many small and quiet males who could presumably reap huge rewards by baffling, but don't. Perhaps the crickets face a shortage of big enough leaves, or maybe baffling males face a trade-off: With their antennae blocked by the leaf, baffling could make crickets sitting ducks for predators such as geckos and spiders to attack from behind.

Despite potential costs, it's clear these crickets have evolved a clever way of bending the natural world to their interests. Such tool use among animals is varied, from primates cracking nuts with stones (*SN: 8/3/19, p. 13*) to puffins scratching themselves with sticks (*SN: 2/1/20, p. 5*). While some biologists may quibble with designating a baffle as a bona fide tool, these crickets show that sophisticated behaviors aren't just for big, complex brains. "It really turns that idea on its head," Deb says. ■

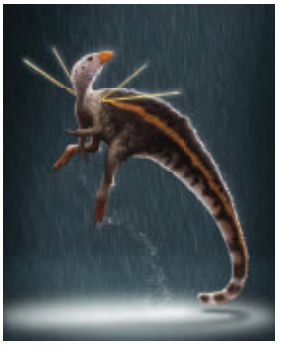
LIFE & EVOLUTION

A newfound dinosaur had a flashy look

Elaborate feathers may have helped the animal woo mates

BY JOHN PICKRELL

The fossil of a chicken-sized meat eater from Brazil that had a mane of fluffy filaments and a pair of stiff streamers emerging from the shoulders is the first dinosaur fossil with feathers discovered in the Southern Hemisphere.



Ubirajara jubatus, illustrated above, had shoulder streamers and a feathery mane.

The predator, named *Ubirajara jubatus*, lived 110 million years ago and probably used its plumage to attract mates and ward off rivals, researchers report online December 13 in *Cretaceous Research*.

"These structures are really elaborate," says study coauthor David Martill, a paleontologist at the University of Portsmouth in England. "When birds have these sorts of feathers, they do all sorts of posh dances and displays, so this dinosaur looks like it was a little show-off."

U. jubatus was a type of compsognathid, a lineage that branched off from other carnivorous dinosaurs fairly early in the group's history, Martill says. That suggests that the use of feathers for complex display purposes may have a very ancient history within the carnivorous dinosaurs.

The fossil was discovered in the limestones of northeast Brazil's Crato Formation, probably by local quarry workers extracting paving slabs, says study coauthor Eberhard Frey, a geoscientist at the State Museum of Natural History Karlsruhe in Germany.

In the early 1990s, the fossil arrived at a Brazilian paleontological museum, where it came to the attention of Frey and Martill. The two sought permission to export the fossil to Germany in 1995, where they have studied it in the intervening years and where it remains today.

Max Langer, a paleontologist at the University of São Paulo, says it was only a matter of time until a feathered dinosaur was discovered in the Crato Formation or the surrounding rocks of the Araripe Plateau. Here, "the fossilization is pristine," he says, with many specimens recording such details as muscle fibers and blood vessels.

But it's a shame, he says, that the fossil didn't remain in Brazil, and that Brazilian scientists were not involved in this research. "The fossils found here are part of the Brazilian paleontological heritage, so it is not good that this material is out of the country," he argues. ■

HUMANS & SOCIETY

Lava tubes alleviated ancient droughts

For centuries, Ancestral Puebloans mined ice from the caves

BY RACHEL FRITTS

During a parched summer almost 2,000 years ago, people in what is now New Mexico crawled into the dark belly of a volcanically formed cave to melt the frozen water at its heart. The ice preserved in these naturally cool formations may have helped Ancestral Puebloans in the area persevere through five such drought events over the course of 800 years.

Charcoal embedded in ice in this lava tube suggests Ancestral Puebloans visited the cave to melt water in times of drought.

New analysis of charcoal particles from around A.D. 150 provides the earliest dated evidence that Ancestral Puebloans used fire to melt ice trapped in lava tubes when liquid water was scarce, researchers report November 18 in *Scientific Reports*. The findings show that these people went to remarkable lengths to survive in an often hostile environment.

"This study demonstrates the ingenuity of Indigenous people who used the area," says Barbara Mills, an anthropological archaeologist at the University of Arizona in Tucson who was not involved in the study. "It also shows how knowledge about the trails, caves and harvesting practices was passed down over many centuries, even millennia."

Ancestral Puebloans, builders of Mesa Verde's famous cliff dwellings, survived in the arid southwestern United States for at least 2,000 years. A key to that survival was finding creative ways to extract water from an unforgiving environment.

In 2017, a team led by Bogdan Onac, a paleoclimatologist at the University of South Florida in Tampa, traveled to El Malpais National Monument in New Mexico to collect ice cores from the park's lava tubes to extract ancient climate data. Lava tubes are an empty space left behind by flowing lava, a relic of the area's volcanically active past. Far removed from their fiery beginnings, the caves can maintain a temperature of at or below 0° Celsius that can preserve accumulating ice — and anything trapped inside the ice — for hundreds of years. The layout of the tubes causes cooler, denser air to sink toward the ground and push warmer, lighter air up and out.

Onac and his team planned only to extract paleoclimate data from the ice, but they found much more when they reached Cave 29. The interior of the 171-meter-long lava tube was covered with charcoal deposits concentrated around what was once a roughly 1,000-cubic-meter block of ice.

The team recovered a 59-centimeter-long core sample from what remains of the ice block, and noticed five distinct black bands that broke up its length. The

LIFE & EVOLUTION

Baikal seals are like baleen whales

With its comblike teeth, the species eats crustaceans

BY JAKE BUEHLER

Baikal seals are fans of bite-size portions, a dietary quirk that may explain why the seals are thriving.

Found in Russia's Lake Baikal, the mammals devour tiny crustaceans, likely using comblike teeth in a manner similar to how baleen whales feed, a study finds.

The research suggests that Baikal seals (*Pusa sibirica*) use a combination of special teeth, speed and skill to gobble up dozens of inch-long critters called amphipods on a single dive, scientists report in the Dec. 8 *Proceedings of the National Academy of Sciences*.

Typically, seals eat fish and mollusks. For Baikal seals, there may be big benefits to hunting amphipods. They "are very predictable," says marine biologist Yuuki Watanabe of the National Institute of Polar Research in Tokyo. "They form big aggregations, and they come to the surface in the nighttime."

Exploiting such a dependable food source low in the food chain, Watanabe says, may make Baikal seals more resilient than other lake seals to environmental impacts such as climate change.

Watanabe has studied Baikal seals since 2003. Back then, he had evidence from depth-measuring devices mounted on the seals that showed they reliably shift their diving depths through the night, suggesting the animals follow a particular food source. Amphipods are known to make daily migrations from the depths to the shallows and back again.

In 2018, Watanabe returned to Lake Baikal to see if he could gather direct evidence that the seals feed on swarms of amphipods. He and colleagues caught eight seals and attached cameras and accelerometers to their backs, recording what the seals ate, how fast they swam and how deep they dove. On night dives, seals rapidly snatched up amphipods one at a time, as many as 154 in one descent (an amphipod every 2.5 seconds).

Over a single day, Baikal seals probably make thousands of catches. Based on estimates by Watanabe and colleagues, the seals may get about 20 percent of their daily calorie needs from amphipods.

Mia Wege, a marine ecologist at the University of Pretoria in South Africa, says she is surprised such small prey could form a major part of a seal's diet.

When Watanabe examined Baikal

B. ONAC

presence of charcoal suggested fire, and the presence of fire deep in an icy cavern suggested human activity. Even more exciting, the charcoal in the ice allowed the researchers to date the periods of human activity. "When we got the core out and we saw the charcoal, obviously we were just jumping all over because that meant that we would have a chronology," Onac says.

The team melted the core down and radiocarbon-dated the charcoal pieces. Resulting dates — ranging from around A.D. 150 to A.D. 950 — corresponded to drought events recorded in tree rings in the surrounding area. The charcoal bands' chronological alignment with drought events suggests that hunters and travelers kept track of accessible water for survival and ceremonial practices over hundreds of years, the researchers say.

Researchers had already suspected that Ancestral Puebloans exploited the area's lava tubes for freshwater. Ancient trail networks crisscross the lava flows' treacherous terrain, and pottery pieces and charcoal have been found in and around caves. But evidence until now has been largely circumstantial. ■

seal skulls in museum collections and compared the skulls with those of other seals, he noticed the cheek teeth of the Baikal animals have folded margins that give the teeth a comblike shape. Baikal seals use these teeth to efficiently sieve amphipods from the lake, expelling excess water with every gulp, the researchers suspect.

In the future, Watanabe wants to conduct feeding experiments to confirm how the seals use their comblike chompers. He also wants to study the animals' winter diet, since he thinks amphipods may be gathering underneath the lake's winter ice, potentially providing a reliable, dense feast for hungry seals. Determining how seasonal ice cover influences the seals' food sources is of increasing importance, Watanabe says, since the lake's winter ice is waning due to climate change. ■

In 2019, a group traveled over 200 kilometers from Taiwan to Japan's Ryukyu Islands in a dugout canoe (shown) crafted using stone axes that were modeled off of ancient artifacts.

Y. KAIFU

HUMANS & SOCIETY

Early sea trip was probably no accident

A cruise to remote Pacific islands was deliberate, researchers say

BY CHARLES Q. CHOI

Ancient mariners successfully navigated a perilous journey to arrive at Japan's Ryukyu Islands, a new study suggests.

Archaeological sites on six of the isles, part of a 1,200-kilometer-long chain, indicate that migrations to the islands occurred 35,000 to 30,000 years ago, both from the south via Taiwan and from the north via the Japanese island of Kyushu.

Whether ancient humans navigated there on purpose or drifted there by accident on the Kuroshio ocean current, one of the world's largest and strongest currents, has been unclear. Now, satellite-tracked buoys that simulated wayward rafts suggest there's little chance that the seafarers reached the isles by accident.

Researchers analyzed 138 buoys that were released near or passed by Taiwan and the Philippine island of Luzon from 1989 to 2017. Only four of the buoys came within 20 kilometers of any of the Ryukyu Islands, and did so only as a result of typhoons and other adverse weather, the team reports December 3 in *Scientific Reports*.

It's unlikely ancient mariners would have set out on a voyage with a major storm on the horizon, say paleoanthropologist Yousuke Kaifu of the University of Tokyo and colleagues. And geologic records show that the region's currents have remained stable for at least the last 100,000 years. So the findings indicate that the Kuroshio current would have forced drifters away from, not toward, the Ryukyu Islands, suggesting that anyone who made the crossing did so intentionally, Kaifu says.

"From a navigation perspective, crossing to the Ryukyus was so challenging that accidental-drift models are unlikely to provide an effective explanation," agrees archaeologist Thomas Leppard of Florida State University in Tallahassee. This new work "is, of course, not conclusive, but it is suggestive."

Archaeological evidence hints that hominid lineages such as *Homo erectus* crossed seas at least 709,000 years ago. And artifacts in Australia suggest *Homo sapiens* began voyaging across the ocean at least 65,000 years ago (*SN: 8/19/17, p. 10*). But it remains hotly debated whether ocean trips during the Paleolithic, about 2.6 million years to about 11,700 years ago, were intentional or an accident.

Other evidence suggests that ancient humans could have deliberately made the voyage to the Ryukyu Islands. In 2019, a team of adventurers paddled more than 200 kilometers from Taiwan to one of the islands in a dugout canoe that Kaifu and colleagues made using stone axes modeled off Paleolithic artifacts.

Although Paleolithic people are often perceived as primitive and conservative in their goals, Kaifu says, "I felt something very different from the evidence of human presence on these remote islands." ■

LIFE & EVOLUTION

Pandas may roll in poop to stay warm

Chemicals in horse manure can inhibit a cold-sensing protein

BY JONATHAN LAMBERT

It was a strange sight: In the winter of 2007, scientists in China spotted a wild giant panda romping about in horse manure, smearing itself with excrement until its fur became a poop-muddled mess. It wasn't the last time the researchers would spot this behavior.

But figuring out why pandas do this would take the team 12 years and a scientific trek through the fields of animal behavior, chemical ecology and neurophysiology. Now, the researchers think they have an answer.

Pandas may roll in manure to feel warm: Chemicals present in horse droppings confer cold resistance to lab mice and could inhibit a cold-sensing protein present in giant pandas (*Ailuropoda melanoleuca*), the researchers report online December 7 in the *Proceedings of the National Academy of Sciences*.

"I'm a panda expert, and this is one of the strangest panda papers I've ever read," says Bill McShea, a biologist at the Smithsonian Conservation Biology Institute in Front Royal, Va. "There's still a lot of work to be done, but these researchers deserve a lot of credit."

Students of ecologist Fuwen Wei of the Chinese Academy of Sciences in Beijing first glimpsed the bizarre behavior in the Qinling mountains of central China. The region is crisscrossed by ancient trade routes well-trod by horses today.

Rolling around in dung isn't unheard of among animals — consider the dog. But many mammals actively avoid the fecal matter of other individuals and species, as it can harbor pathogens and parasites, says Cécile Sarabian, a cognitive ecologist at Kyoto University in Japan.

"Behavior is a story of compromises," she says. "In this case, the benefits of getting in contact with fresh horse manure may override the [potential] risks."

To understand what those benefits might be, Wei and colleagues first had to catch more manure maneuvers. The team set up motion-sensitive cameras along roads in the Foping National Nature Reserve. The cameras captured 38 panda-poop interactions from July 2016 to June 2017. The camera setup also recorded time and air temperature, revealing a pattern: Pandas rolled in manure only in colder weather, usually when temperatures were between –5° Celsius and 5° C.

Pandas were picky about poop too, largely ignoring manure more than a few days old. Chemical analysis revealed that two volatile compounds were abundant in fresh manure but scarce in older samples: beta-caryophyllene, or BCP, and beta-caryophyllene oxide, or BCPO.

Given the preference for fresh manure, the researchers figured pandas might be attracted to a combination of BCP/BCPO. At the Beijing Zoo, the team presented six pandas with hay piles suffused with the combination or with other substances. The pandas spent more time investigating hay covered in BCP/BCPO. One panda spent six minutes covering itself with the treated hay.

A camera trap in China captured this image of a wild giant panda covered in horse manure.

F. WEI

Armed with these clues, the researchers tested whether BCP/BCPO somehow affects temperature sensation. Pandas aren't exactly amenable to lab experiments, so the team applied BCP/BCPO to lab mice and subjected them to cold tolerance tests. Compared with saline-treated mice that shivered in the cold, mice with BCP/BCPO seemed unfazed.

Further experiments revealed more clues. BCP/BCPO interacts with the panda version of a cold-sensing protein called TRPM8. Found in the skin of many mammals, TRPM8 alerts the rest of the body to cold and also gets activated by menthol, the chemical behind peppermint's cooling sensation. In cells in the lab, BCP/BCPO inhibited TRPM8, making the protein less able to detect cold.

From camera trap to petri dish, the evidence suggests pandas have stumbled onto an environmental resource that acts as a sort of analgesic against the cold, perhaps helping them acclimate to winter, the researchers conclude.

"It's a really remarkable study," says Elena Gracheva, a neurobiologist at Yale University. "It shows the value in exploring behaviors out in the wild and looking for their molecular mechanisms."

But, she says, it will take more direct evidence to truly demonstrate that pandas roll in manure to resist the cold. Extrapolating the effects of BCP/BCPO on mice to pandas "isn't a totally fair comparison," she says. There may be other reasons for donning a coat of dung. Pandas are known to cover themselves in natural scents, which may ward off parasites or act as a territorial signal.

Also unclear is whether horse poop actually prevents pandas from feeling cold temporarily, or if it just makes feeling cold less unpleasant, Gracheva says.

If BCP/BCPO does confer cold resistance, McShea wonders if other animals may also roll around in the occasional pile of dung. "Everyone likes some relief from the cold every once in a while." ■

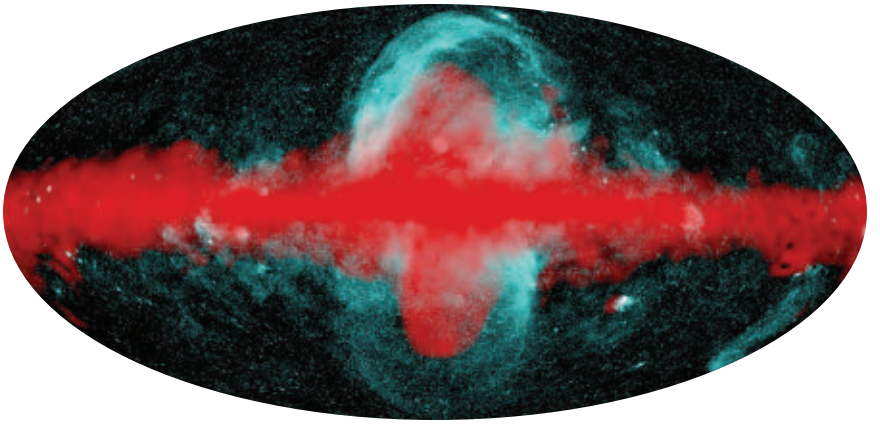
ATOM & COSMOS

Enormous X-ray bubbles balloon from the center of the Milky Way

Scientists have known for a decade that two bubbles of charged particles, or plasma, flank the plane of the Milky Way. Known as Fermi bubbles, the structures are visible in high-energy light called gamma rays (*SN: 12/4/10, p. 18*). But now, the eROSITA X-ray telescope has revealed larger bubbles, seen in X-rays. Those bubbles extend about 45,000 light-years above and below the galaxy's center, researchers report in the Dec. 10 *Nature*.

The gamma-ray bubbles are nested inside the X-ray bubbles, suggesting the two features are connected, says study coauthor Andrea Merloni, an astronomer at the Max Planck Institute for Extraterrestrial Physics in Garching, Germany.

Studying these bubbles could help reveal violent events that may have taken place in the past. The supermassive black hole at the center of the Milky Way is currently fairly quiet, as far as black holes go. But a past feeding frenzy might have spewed its leftovers outward, forming the structures. Or the bubbles could have been the result of a period when many stars formed and exploded in the galaxy's heart. — *Emily Conover*



Bubbles spill from the center of the Milky Way, seen in both gamma rays (red) and now X-rays (blue). Both sets of bubbles extend above and below the galaxy's plane (central horizontal line).

EARTH & ENVIRONMENT

Plastic waste threatens camels

A survey of dromedary camels in the United Arab Emirates hints that plastic may contribute to about 1 percent of those camels' deaths.

"We hear about marine mammals, sea lions, whales, turtles and seabirds impacted" by plastic waste, says Marcus Eriksen, an environmental scientist at the 5 Gyres Institute, a plastic pollution research and education organization in Santa Monica, Calif. But "this is not just an ocean issue. It's a land issue too. It's everywhere."

About 390,000 dromedary camels (*Camelus dromedarius*) live in the UAE. Of 30,000 dead camels examined since 2008, 300 had guts packed with masses of plastic, Eriksen and colleagues report in the February 2021 *Journal of Arid Environments*. The team suspects plastic contributed to those deaths. In a subset of five camels, plastic masses weighed up to 64 kilograms.

As camels roam the desert for food, they munch on plastic bags and other trash that drift into trees and pile up along roadsides. "From the camel's perspective … if it's not sand, it's food," says Eriksen. With a stomach full of plastic, camels may not eat because they don't feel hungry, and they can starve to death. Plastic can also leach toxicants and introduce harmful bacteria, says coauthor Ulrich Wernery, a veterinary microbiologist at the Central Veterinary Research Laboratory in Dubai. — *Asher Jones*

LIFE & EVOLUTION

A contagious face cancer may not eliminate Tasmanian devils after all

Tasmanian devils were supposed to be extinct by now. With a deadly, highly contagious cancer plaguing devils, forecasts over the last decade have spelled imminent doom for the marsupial.

But devil facial tumor disease has become far less transmissible over time, suggesting it won't wipe out the species, researchers report in the Dec. 11 *Science*.

Instead, the disease may stick around at lower levels, or "the tumor itself might eventually go extinct," says Andrew Storfer, an evolutionary geneticist at Washington State University in Pullman.

Storfer and colleagues reconstructed the history of the disease's spread by analyzing changes in tumor genes that evolve in a regular, clocklike manner.

Though discovered in 1996, the disease probably originated in the 1980s, the study finds. At the peak in the late 1990s, each afflicted devil (*Sarcophilus harrisii*) infected 3.5 other devils, on average. That number has fallen to one, suggesting the epidemic may peter out.

The slowdown may stem from population decline — fewer devils means fewer transmission opportunities. The disease also appears to be less transmissible, and the devils seem to have evolved some resistance (*SN: 10/1/16, p. 8*).

With only about 25,000 or so devils left in the wild, some experts want to introduce captive-bred animals to boost numbers. That could backfire, Storfer says, by letting the disease take off again. — *Jonathan Lambert*

ATOM & COSMOS

Asteroid dirt arrives on Earth

For the first time, scientists can study asteroid dirt so old it may hold clues to how our solar system formed.

A capsule with two smidgens of dirt from asteroid Ryugu arrived in Japan December 7 after landing in Australia. Ryugu is an old, carbon-rich asteroid that scientists think contains some of the earliest solids to form in the solar system.

The spacecraft Hayabusa2 explored Ryugu from June 2018 to November 2019, grabbing two samples of the asteroid. Hayabusa2 is the second mission to bring an asteroid sample to Earth. The first Hayabusa mission visited the stony asteroid Itokawa and returned less than 2,000 dirt grains in 2010. Hayabusa2's goal was to collect at least 100 milligrams (*SN: 1/19/19, p. 20*). On December 14, scientists opened the capsule and saw dark grains with the texture of instant coffee, though did not report how much had been collected. — *Lisa Grossman*

P. PREDEHL *ET AL*/*NATURE* 2020

Scientists have peppered the planet with seismometers that can detect the rumble of moving magma within a volcano, and GPS stations can spot changes in land elevation as magma swells below. But anticipating eruptions remains tricky — more of an art than a science.

ScienceNews 100

To celebrate our upcoming 100th anniversary, we're launching a series that highlights some of the biggest advances in science over the last century. For more on the story of plate tectonics, and to see the rest of the series as it appears, visit our new Century of Science site at www.sciencenews.org/century

Shaking Up Earth

Plate tectonics has upended how we understand our planet — and has sparked new questions about life in the cosmos **By Carolyn Gramling**

Some great ideas shake up the world. For centuries, the outermost layer of Earth was thought to be static, rigid, locked in place. But the theory of plate tectonics has rocked this picture of the planet to its core. Plate tectonics reveals how Earth's surface is constantly in motion, and how its features — volcanoes, earthquakes, ocean basins and mountains — are intrinsically linked to its hot interior. The planet's familiar landscapes, we now know, are products of an eons-long cycle in which the planet constantly remakes itself.

When plate tectonics emerged in the 1960s, it became a unifying theory, "the first global theory ever to be generally accepted in the entire history of earth science," writes Harvard University science historian Naomi Oreskes, in the introduction to *Plate Tectonics: An Insider's History of the Modern Theory of the Earth*. In 1969, geophysicist J. Tuzo Wilson compared the impact of this intellectual revolution in earth science to Einstein's general theory of relativity (*SN: 11/8/69, p. 430*), which had produced a similar upending of thought about the nature of the universe.

1989
Loma Prieta earthquake
A slip of the San Andreas Fault (top), where the Pacific Plate and North American Plate meet, triggered a magnitude 6.9 earthquake that rocked the San Francisco Bay area, causing 63 deaths and billions of dollars in damage (bottom).

Plate tectonics describes how Earth's entire, 100-kilometer-thick outermost layer, called the lithosphere, is broken into a jigsaw puzzle of plates — slabs of rock bearing both continents and seafloor — that slide atop a hot, slowly swirling inner layer. Moving at rates between 2 and 10 centimeters each year, some plates collide, some diverge and some grind past one another. New seafloor is created at the center of the oceans and lost as plates sink back into the planet's interior. This cycle gives rise to many of Earth's geologic wonders, as well as its natural hazards.

"It's amazing how it tied the pieces together: seafloor spreading, magnetic stripes on the seafloor ... where earthquakes form, where mountain ranges form," says Bradford Foley, a geodynamicist at Penn State. "Pretty much everything falls into place."

With so many lines of evidence now known, the theory feels obvious, almost inevitable. But the conceptual journey from fixed landmasses to a churning, restless Earth was long and circuitous, punctuated by moments of pure insight and guided by decades of dogged data collection.

Continents adrift

In 1912, German meteorologist Alfred Wegener proposed at a meeting of Frankfurt's Geological Association that Earth's landmasses might be on the move. At the time, the prevailing idea held that mountains formed like wrinkles on the planet as it slowly lost the heat of formation and its surface contracted. Instead, Wegener suggested, mountains form when continents collide as they drift across the planet's surface. Although now far-flung, the continents were once joined together as a supercontinent Wegener dubbed Pangaea, or "all-Earth." This would explain why rocks of the same type and age, as well as identical fossils, are found on either side of the Atlantic Ocean, for example.

This idea of drifting continents intrigued some scientists. Many others, particularly geologists, were unimpressed, hostile, even horrified. The idea Wegener put forth, detractors thought, was too speculative, not grounded enough in leading

PREVIOUS SPREAD: BRUCE DAVIDSON/NATURE PICTURE LIBRARY/ALAMY; THIS PAGE, FROM TOP: KEVIN SCHAFER/ALAMY; DAVID WEINTRAUB/SCIENCE SOURCE

geologic principles such as uniformitarianism, which holds that the same slow-moving geologic forces at work on Earth today must also have been at work in the past. The principle was thought to demand that the continents be fixed in place.

German geologist Max Semper disdainfully wrote in 1917 that Wegener's idea "was established with a superficial use of scientific methods, ignoring the various fields of geology," adding that he hoped Wegener would turn his attention to other fields of science and leave geology alone. "O holy Saint Florian, protect this house but burn down the others!" he wrote sardonically.

The debate between "mobilists" and "fixists" raged on through the 1920s, picking up steam as it percolated into English-speaking circles. In 1926, at a meeting in New York City of the American Association of Petroleum Geologists, geologist Rollin T. Chamberlin dismissed Wegener's hypothesis as a mishmash of unrelated observations. The idea, Chamberlin said, "is of the foot-loose type, in that it takes considerable liberty with our globe, and is less bound by restrictions or tied down by awkward, ugly facts than most of its rival theories."

One of the most persistent sticking points for Wegener's idea, now called continental drift, was that it couldn't explain how the continents moved. In 1928, English geologist Arthur Holmes came up with a potential explanation for that movement. He proposed that the continents might be floating like rafts atop a layer of viscous, partially molten rocks deep inside Earth. Heat from the decay of radioactive materials, he suggested, sets this layer to a slow boil, creating large circulating currents within the molten rock that in turn slowly shift the continents about.

> "It was quite clear, at this conference in New York, that everything was going to change."
>
> **DAN MCKENZIE**

Holmes admitted he had no data to back up the idea, and the geology community remained largely unconvinced of continental drift. Geologists turned to other matters, such as developing a magnitude scale for earthquake strength and devising a method to precisely date organic materials using the radioactive form of carbon, carbon-14.

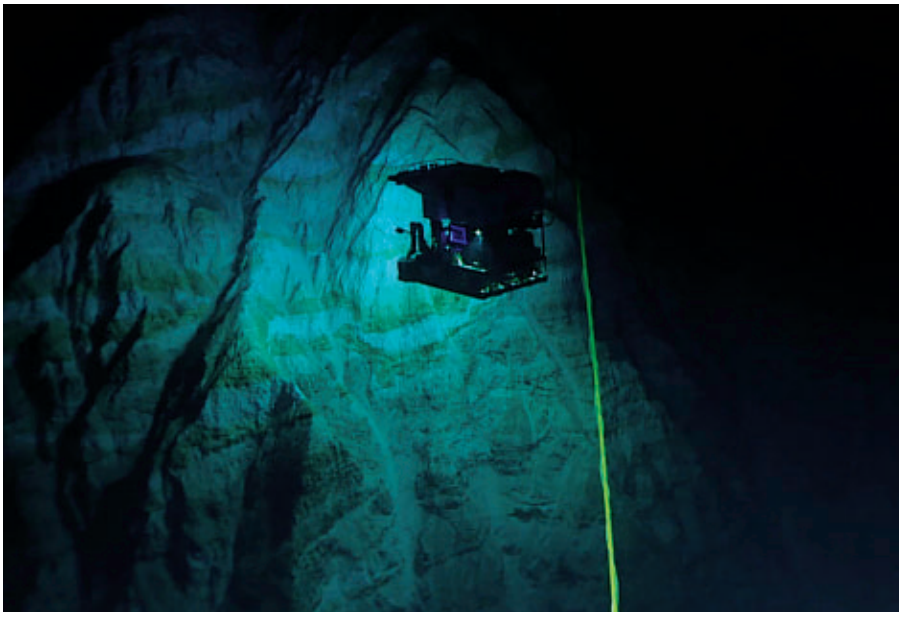
Data flood in

Rekindled interest in continental drift came in the 1950s from evidence from an unexpected source — the ocean bottom. World War II had brought the rapid development of submarines and sonar, and scientists soon put the new technologies to work studying the seafloor. Using sonar, which pings the seafloor with sound waves and listens for a return pulse, researchers mapped out the extent of a continuous and branching underwater mountain chain with a long crack running right down its center. This worldwide rift system snakes for over 72,000 kilometers around the globe, cutting through the centers of the world's oceans.

Armed with magnetometers for measuring magnetic fields, researchers also mapped out the magnetic orientation of seafloor rocks — how their iron-bearing minerals are oriented relative to Earth's field. Teams discovered that the seafloor rocks have a peculiar "zebra stripe" pattern: Bands of normal polarity, whose magnetic orientation corresponds to Earth's current magnetic field, alternate with bands of reversed polarity. This finding suggests that each of the bands formed at different times.

Meanwhile, growing support for the detection and banning of underground nuclear testing also led to an opportunity for seismologists: the chance to create a global, standardized network of seismograph stations. By the end of the 1960s, about 120 different stations were installed in 60 different countries, from the mountains of Ethiopia's Addis Ababa to the halls of Georgetown University in Washington, D.C., to the frozen South Pole.

Thanks to the resulting flood of high-quality seismic data, scientists discovered and mapped rumbles along the mid-ocean rift system, now called mid-ocean ridges, and beneath the trenches.



NOAA OFFICE OF OCEAN EXPLORATION AND RESEARCH

1960
Descent into the Mariana Trench
U.S. Navy Lt. Don Walsh and Swiss oceanographer Jacques Piccard became the first to ride to the bottom of the Pacific Ocean's Mariana Trench, the deepest known subduction zone. Here, an ROV, the *Deep Discoverer*, explores the trench at a depth of 6,000 meters in 2016.

1963
Hot spots proposed
Geophysicist J. Tuzo Wilson suggested that volcanic island chains form as plates move over upwellings of magma. To this day, the origins of the Hawaiian Islands (Kilauea volcano shown) and other similar chains remain a geologic puzzle.

The quakes near very deep ocean trenches were particularly curious: They originated much deeper underground than scientists had thought possible. And the ridges were very hot compared with the surrounding seafloor, scientists learned by using thin steel probes inserted into cores drilled from shipboard into the seafloor.

In the early 1960s, two researchers working independently, geologist Harry Hess and geophysicist Robert S. Dietz, put the disparate clues together — and added in Holmes' old idea of an underlying layer of circulating currents within the hot rock. The mid-ocean ridges, each asserted, might be where circulation pushes hot rock toward the surface. The powerful forces drive pieces of Earth's lithosphere apart. Into the gap, lava burbles up — and new seafloor is born. As the pieces of lithosphere move apart, new seafloor continues to form between them, called "seafloor spreading."

The momentum culminated in a two-day gathering of perhaps just 100 earth scientists in 1966, held at the Goddard Institute for Space Studies in New York. "It was quite clear, at this conference in New York, that everything was going to change," University of Cambridge geophysicist Dan McKenzie told the Geological Society of London in 2017 in a reflection on the meeting.

But going in, "no one had any idea" that this meeting would become a pivotal moment for the earth sciences, says seismologist Lynn Sykes of Columbia University. Sykes, then a newly minted Ph.D., was one of the invitees; he had just discovered a distinct pattern in the earthquakes

Crucible of life

Earth is the only known world with plate tectonics. It's also the only one known to harbor life.

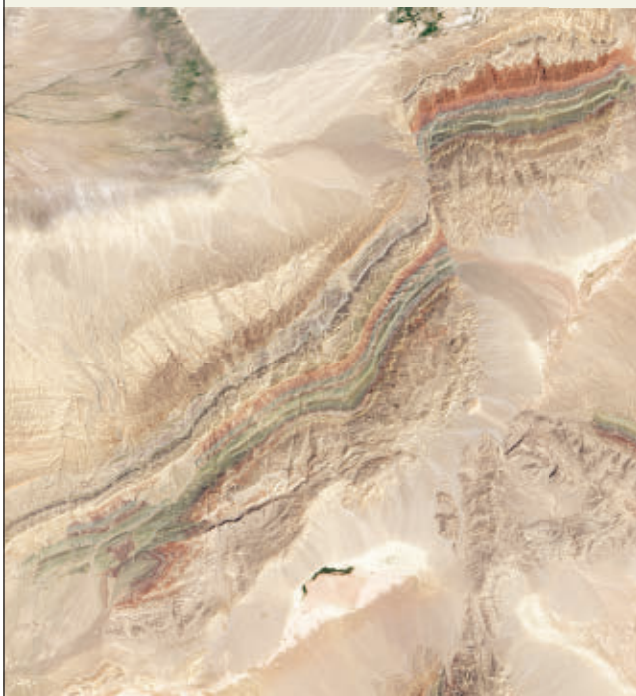
Planetary scientists puzzle over whether and how these two facts might be related — and what it means for just how unusual Earth really is, says Lindy Elkins-Tanton, a planetary scientist at Arizona State University in Tempe. "Nobody knows how plate tectonics began on Earth, and why it didn't begin elsewhere," she adds. "It's a mystery that connects to a lot of other mysteries, and one of those is habitability."

We know plate tectonics plays a powerful role in keeping Earth habitable, primarily by moving carbon around. "It's responsible for mediating the climate on long geological time scales, making sure the climate is more or less temperate for life," says Roger Fu, a geophysicist at Harvard University.

When two tectonic plates collide, one can slide beneath the other, carrying rocks bearing carbon deep into the planet's interior. The subducting plate begins to melt, and volcanoes bloom on the overlying plate, belching carbon dioxide and other gases into the atmosphere. As carbon dioxide builds up, it warms the planet through the greenhouse effect.

This warmer atmosphere then speeds up weathering of rocks on Earth's surface, by boosting the chemical reaction between carbon dioxide–rich rainwater and the rocks. Those reactions draw the gas out of the atmosphere to form new carbon minerals. The minerals wash into the ocean, where tiny ocean creatures use the carbon to build their calcium carbonate shells. Ultimately those creatures die, their shells sinking to the ocean floor and becoming carbonate rocks themselves. As more carbon dioxide gets sequestered away from the

FROM TOP: ART WOLFE/GETTY IMAGES; NASA EARTH OBSERVATORY IMAGES BY ROBERT SIMMON AND JESSE ALLEN



atmosphere in this way, the planet cools — until, eventually, the slow grind of plate tectonics carries the carbonate into the planet's interior with a subducting plate.

This cycle, playing out over many millions of years, doesn't just keep temperatures mild. It also keeps oxygen, nitrogen, phosphorus and other nutrients cycling through the atmosphere, oceans and rocks — and chemically transforms them into forms that living organisms can use. "That's not to say that life wouldn't happen without plate tectonics," Fu says. "But it would be very different."

In fact, the first life on Earth may predate the onset of plate tectonics. The planet's ancient rocks bear traces of life dating to at least 3.4 billion years ago, several hundred million years before the earliest known evidence for any plate motions, in the form of fossilized stromatolites, layered structures made of microbes and minerals. Similar microbial communities exist today at hot springs, such as those of Yellowstone National Park. Some scientists speculate that hot springs — which contain the biochemical recipe for life, including chemical elements, water and energy — may have set the stage for Earth's earliest life.

It's certainly theoretically possible for planets without plate tectonics, like the early Earth, to have livable atmospheres and liquid water, as well as abundant heat, says Bradford Foley, a geodynamicist at Penn State. Foley has simulated how much carbon dioxide could seep out from the interior of "stagnant lid" planets. Such planets, like Mars and Mercury, have a single, continuous piece of lithosphere that sits like a cold, heavy lid over the hot interior. Even on these planets, Foley says, "we still have volcanism," because there's still hot rock circulating beneath. Eruptions release carbon dioxide to the atmosphere and produce fresh new rock for weathering.

Climate-altering volcanism might not last as long as it does when plate tectonics keeps things churning along. But it theoretically could persist for 1 billion or 2 billion years, Foley says. That means that some stagnant lid planets could create an atmosphere and even have temperate climates with liquid water, at least for a time.

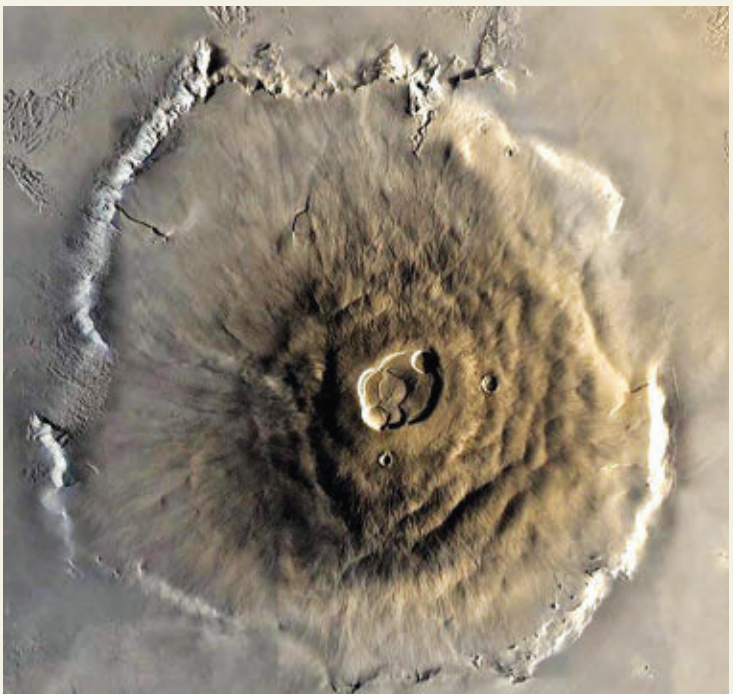
Then there's Europa, Jupiter's icy moon. The surface of the moon is broken into a mosaic of plates of ice that slide past and over and under one another, much like those on Earth. "Instead of subduction, it's referred to as subsumption," Fu says. The result of this icy cycle may be similar to the hard-rock recycling on Earth, moving nutrients between surface ice and liquid ocean below, which could help support life.

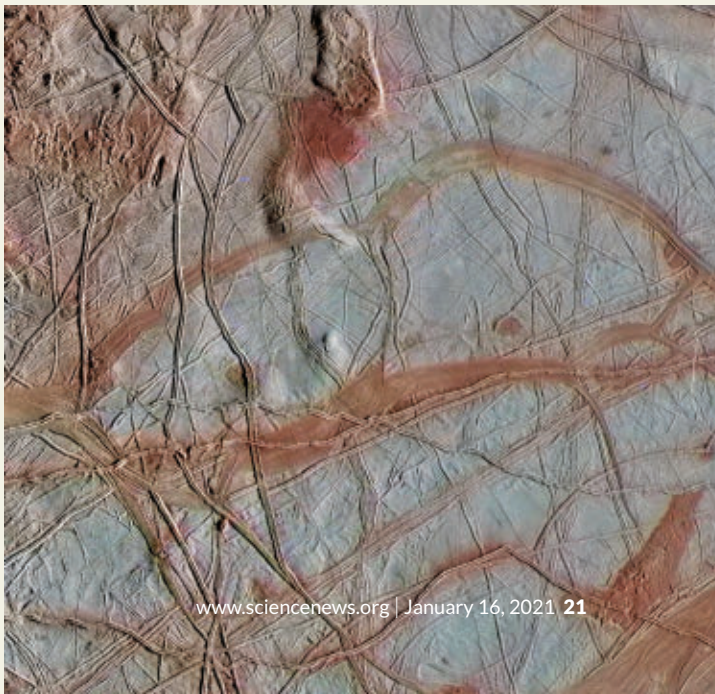
"What exactly plate tectonics is isn't an answered question," Fu says. The term, he says, has become a catchall that encompasses numerous physical features on Earth — mid-ocean ridges, subduction, moving continents — as well as processes like nutrient cycling. "But there's no guarantee they always have to happen together."

Scientists instinctively turn to Earth as a template for studying other worlds, and as an example of what to look for in the search for habitability, Elkins-Tanton says. "If it turns out we're unusual, we're a bit of an outlier, then explaining things is much harder." It may be that each world has its own eclectic history, she says. Earth's happens to include the powerful cycle of plate tectonics. But life elsewhere might have found another way.

— Carolyn Gramling

FROM LEFT: JPL-CALTECH/NASA; JPL-CALTECH/NASA, SETI INSTITUTE





Surface textures
Signs of landmasses colliding are visible on Earth's surface (Piqiang Fault in China's Xinjiang Province shown, left). Mars has signs of volcanic activity (Olympus Mons, center) but no known plate tectonics. Jupiter's frozen moon Europa (right) has its own form of icy plate tectonics.

at mid-ocean ridges. This pattern showed that the seafloor on either side of the ridges was pulling apart, a pivotal piece of evidence for plate tectonics.

At the meeting, talk after talk piled data on top of data to support seafloor spreading, including Sykes' earthquake data and those symmetrical patterns of zebra stripes. It soon became clear that these findings were building toward one unified narrative: Mid-ocean ridges were the birthplaces of new seafloor, and deep ocean trenches were graves where old lithosphere was reabsorbed into the interior. This cycle of birth and death had opened and closed the oceans over and over again, bringing the continents together and then splitting them apart.

The evidence was overwhelming, and it was during this conference "that the victory of mobilism was clearly established," geophysicist Xavier Le Pichon, previously a skeptic of seafloor spreading, wrote in 2001 in his retrospective essay "My conversion to plate tectonics," included in Oreskes' book.

1987
Great ocean conveyor belt described
Geochemist Wallace Broecker described a global system of ocean currents that transports heat and salt. Shifting landmasses — such as the opening of the Drake Passage between South America and Antarctica (icebergs around Elephant Island shown) — can alter currents, and so climates.

A theory is born

The whole earth science community became aware of these findings the following spring, at the American Geophysical Union's annual meeting. Wilson laid out the various lines of evidence for this new view of the world to a much larger audience in Washington, D.C. By then, there was remarkably little pushback from the community, Sykes says: "Right away, they accepted it, which was surprising."

Scientists now knew that Earth's seafloor and continents were in motion, and that ridges and trenches marked the edges of large blocks of lithosphere. But how were these blocks moving, all in concert, around the planet?

To plot out the choreography of this complex dance, two separate groups seized upon a theorem devised by mathematician Leonhard Euler way back in the 18th century. The theorem showed that a rigid body moves around a sphere as though it is rotating around an axis. McKenzie and geophysicist Robert Parker used this theorem to calculate the dance of the lithospheric blocks — the plates. Unbeknownst to them, geophysicist W. Jason Morgan independently came up with a similar solution.

With this last piece, the unifying theory of plate tectonics was born. The hoary wrangling over continental drift now seemed not only antiquated, but also "a sobering antidote to human self-confidence," physicist Egon Orowan told *Science News* in 1970 (*SN: 7/25/70, p. 25*).

People have benefited greatly from this clearer vision of Earth's workings, including being able to better prepare for earthquakes, tsunamis and volcanoes. Plate tectonics has also shaped new research across the sciences, offering crucial information about how the climate changes and about the evolution of life on Earth (see "Crucible of life," Page 20).

And yet there's still so much we don't understand, such as when and how the restless shifting of Earth's surface began — and when it might end. Equally puzzling is why plate tectonics doesn't appear to happen elsewhere in the solar system, says Lindy Elkins-Tanton, a planetary scientist at Arizona State University in Tempe. "How can something be a complete intellectual revolution and also inexplicable at the same time?" ■

Explore more

■ Naomi Oreskes. *Plate Tectonics: An Insider's History of the Modern Theory of the Earth.* Westview Press, 2003.

NASA IMAGE BY JEFF SCHMALTZ, LANCE/EOSDIS RAPID RESPONSE

U.S. educators punish Black students more frequently and severely than white students. Experts call the disproportionate discipline of Black schoolchildren a civil rights violation.

SUSPENDED EDUCATION

How to reduce harsh discipline for Black students

By Sujata Gupta

Anne Gregory remembers the child's fondness for the Dewey decimal system. He would write down a combination of numbers and letters on a scrap of paper and hunt down the desired book in the library. Details were his thing. He once wrote several pages outlining the sequence of moves needed to beat a video game, she says.

But at the elementary school where Gregory worked as a counselor, educators saw a different child. A troublemaker. One teacher told Gregory that the boy frequently wandered about mid-lesson. So the teacher moved his desk to the far corner of the room, and sometimes sent him to the principal's office.

Outside the principal's door, the boy joined a queue of almost all Black boys. But Black and Latino students together made up just over half of the school's student population. Gregory brought up her concerns with the principal. Why was that little boy always in trouble? Why did that line of supposed trouble-makers skew Black and male?

This was the mid-1990s, a time when educators and researchers knew Black students, on average, scored lower on standardized tests than white students. This "achievement gap" was, by then, a cause for concern. But how educators treated Black children was rarely part of the discussions. The principal told Gregory that her concerns, while potentially valid, were "too hot" to tackle.

"I could just see how much the school structure itself was squelching this African-American boy's potential and all his strengths," Gregory says. "That, accompanied with the silence around this at his school, demonstrated to me the absolute urgency, the need, to point this out."

Gregory, now a psychologist at Rutgers University in Piscataway, N.J., has devoted her career to pointing out the problem. In the January 2010 *Educational Researcher*, she used the term "discipline gap" to characterize what she'd observed: Black students, particularly boys, were punished more frequently and severely than their white peers — despite a lack of evidence that the Black kids were committing more offenses. Those punishments ranged from teachers sending students to the principal's office to expulsion. Black students' disproportionate removal from school may well underlie the achievement gap, Gregory and others contend.

In 2015, President Barack Obama signed into law the Every Student Succeeds Act, in part to curtail practices that pull students from class. The act required each state to collect and report data on discipline, and school districts had to formulate alternatives to suspensions and expulsions. A handful of states and districts have banned suspensions for minor offenses, such as talking back to a teacher.

But President Donald Trump's administration rolled back key requirements. And as of July 2020, no states were fully reporting disciplinary data, according to an October 11 report by the Civil Rights Project, a UCLA group that promotes social justice research. In addition, Black students in middle and high school were four times as likely to be suspended as white students, based on federal data from the 2015–16 academic year.

Policy changes alone cannot close the gap, says Russell Skiba, a psychologist at Indiana University Bloomington who focuses on equity in education. Educators must also transform how they view Black students. "What we need are interventions that look at both a reduction in overall use of exclusionary discipline, but also focus on issues of implicit bias [and] structural racism," Skiba says.

Removing Black students from the classroom robs them of a lifetime of opportunity, adds Daniel Losen, director of UCLA's Center for Civil Rights Remedies and a coauthor of the October report. Compared with other students, punished students are more likely to fall behind academically, often by years, have lower test scores, drop out of school, earn less and end up in prison. "This is a massive civil rights violation," Losen says.

Punishing customs

Punitive practices in U.S. schools are nothing new. Teachers commonly paddled or whipped students into the early 1900s. Corporal, or physical, punishment remains legal in many states to this day. By the 1960s, teachers and other educational leaders also began suspending students for misbehavior.

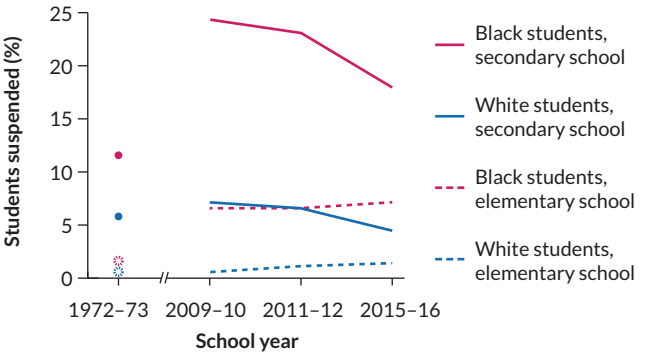
Harsh discipline in all forms was falling out of favor until the crack cocaine epidemic began ravaging Black communities in the 1980s. Politicians launched "a war on drugs" to wipe out that scourge. Violent crime also peaked in the early 1990s. Those twin forces led to policy changes in the 1980s and '90s that made prison sentences for drug and violent crimes harsher, including mandatory minimum sentences for certain offenses. At the time, people believed that criminals thrive in chaotic, lawless environments, Losen says. So law enforcement began giving citations for even minor violations.

Those draconian practices reached the classroom. President Bill Clinton signed the Gun-Free Schools Act of 1994 mandating expulsion for a minimum of one year of any student who brought a weapon to school, no hearing necessary. States soon passed zero-tolerance laws that led to suspensions or expulsions for even minor offenses. Students have been removed from school for wielding "weapons," such as nail clippers or rubber bands, or distributing "contraband" cough drops. Today, zero-tolerance policies account for about 10 percent of the racial discipline gap, educational policy expert Chris Curran of the University of Florida in Gainesville reported in the December 2016 *Educational Evaluation and Policy Analysis*.

Educators' explicit or implicit biases against Black children also keep the gap wide, research suggests. Those biases are present even in preschools. In one study, researchers fit 132 early education teachers with eye trackers and asked the teachers to watch video clips of four children — a Black girl, a Black boy, a white girl and a white boy — seated around a table. The researchers told the teachers to look for misbehaviors.

In truth, none of the children misbehaved, but the eye trackers revealed that the teachers spent more time gazing at the Black boy. And in an accompanying questionnaire that asked which child required the most attention, 42 percent of respondents chose the Black boy, 34 percent chose the white boy, 13 percent chose the white girl and 10 percent chose the Black girl, researchers from Yale University wrote in a report to federal and state officials in September 2016.

U.S. school suspension rates by race, 1972–2016



Unequal burden Although U.S. middle and high school suspension rates have been dropping, the gap between Black and white students has remained relatively unchanged, federal data show. Elementary rates are lower, but rising for Black children. SOURCE: D.J. LOSEN AND P. MARTINEZ/UCLA CIVIL RIGHTS PROJECT 2020

Another study shows how such biases contribute to teachers disciplining Black students more harshly than white students. Researchers asked 191 teachers of K–12 students to imagine teaching at a middle school depicted in a photograph. The teachers then read a series of vignettes about a student who got in trouble twice, once for insubordination and again for disrupting class. Researchers told half the teachers that the student's name was Darnell or Deshawn, stereotypically Black male names; for the other half, the boy was named Greg or Jake, stereotypically white male names.

After each incident, the teachers answered questions on a seven-point scale. Questions included, "How severe was the student's misbehavior?" and "How severely should the student be disciplined?" After the first bad behavior, the teachers were equally lenient toward the Black and white boys. But after the second bad behavior, the teachers rated Black boys as 25 percent more troublesome than white boys and recommended 30 percent harsher disciplinary responses, reported social psychologists Jason Okonofua and Jennifer L. Eberhardt of Stanford University in 2015 in *Psychological Science*. The researchers called this finding the "two-strikes" paradigm.

That study shows how bias can manifest in institutions, says Sean Darling-Hammond, a graduate student in education policy at the University of California, Berkeley, who collaborates with Okonofua, also now at UC Berkeley, to continue that line of research. After repeated misbehaviors, teachers were more lenient with white students, but penalized Black students.

Color-blind corrections

The October report provides the most up-to-date snapshot of the discipline gap. Data for the report come from the U.S. Department of Education Civil Rights Data Collection and

C. CHANG

include information on student enrollment, demographics and discipline for every public school in the country.

Overall suspension rates were declining under the Obama administration, probably in part because 15 states adopted laws discouraging suspensions. California, for instance, flags districts that suspend more than 6 percent of their students and assists in bringing those districts' rates down.

When grades K–12 were lumped together, suspension rates fell from 4 percent to 3 percent for white students and 16 percent to 13 percent for Black students, between the 2009–10 to 2015–16 school years.

But with Black students still suspended at four times the rate of white students, the report also spotlights the shortcomings of relying solely on policy changes to close the gap. No policy can capture the myriad interactions that happen in a school, says educational policy researcher Kenneth Shores of the University of Delaware in Newark. Consider common scenarios — teachers praising white students while criticizing Black students, or calling mostly on white students.

Yet many current interventions aim to improve school climate while sidestepping issues of race. For instance, several programs rely on restorative justice. That concept is applied frequently in criminal justice settings, and brings victims and offenders together to discuss an incident and give all involved parties a voice.

Restorative justice practices can help teachers change how they handle discipline problems. Such approaches can also create school cultures based on trust and open communication, often in lieu of discipline. For instance, many schools use a multitiered system of support for students and staff. Tier one is preventive: Students come together in so-called community-building circles to discuss a prompt or question and listen to one another's perspectives. At tier two, students involved in a minor dispute work together in "responsive circles" to solve the problem. And at tier three, everyone involved in a serious dispute participates in a "restorative conference" where a trained facilitator guides the dialog. If a student is still suspended, educators later welcome the student back to school and gauge his or her need for additional support to get caught up.

In 2006, the suspension gap between Black and white students in the large urban district of Denver was 12 percentage points: About 6 percent of white students had been suspended compared with 18 percent of Black students. By 2013, the gap had narrowed to 8 percentage points, researchers reported in *Closing the School Discipline Gap*, a 2015 book Losen coedited. Some of the drop may have been due to restorative justice training, which launched in the early 2000s.

Nonetheless, educators were still suspending more Black students — at a rate of 10.42 percent versus 2.28 percent for white students. In effect, the color-blind approach worsened the racial suspension gap from a threefold difference between Black and white students to more than fivefold.

"Interventions for reducing disparities in ... discipline cannot be race neutral," says Indiana's Skiba.

Racial discipline differences in police departments

Differences in how Black and white people are disciplined exists in at least one type of workplace, new research suggests. Researchers don't always have easy access to data on how companies discipline employees. But disciplinary records from several police departments have become available to researchers and the public.

Between 1991 and 2015, Black police officers in the Chicago and Philadelphia police departments were formally disciplined more than white officers, despite having similar numbers of misconduct allegations — including things like use of excessive force and verbal assault — filed against them by the public or coworkers, researchers reported online last April in *Organizational Behavior and Human Decision Processes*.

Reviewing records from over 8,000 officers — women and men of various races — Sheri Walter, a management researcher at Indiana University Bloomington, and coauthors tallied the disciplinary actions taken against officers in the two police departments. In Chicago, Black officers were about twice as likely to have been disciplined than white officers. In Philadelphia, Black officers were almost 1.5 times as likely to have been disciplined.

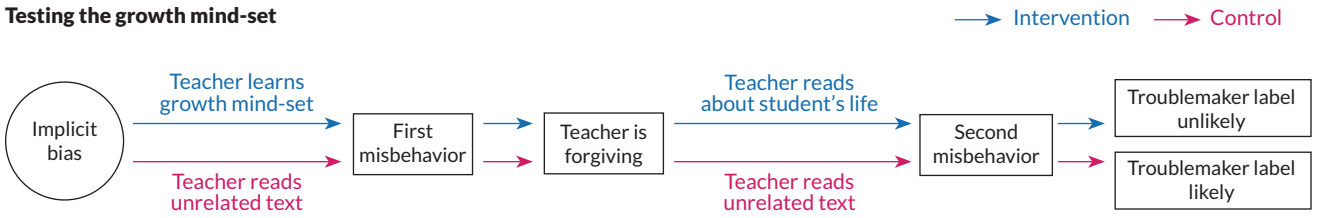
It's not entirely clear what's causing the disparity, mainly because disciplinary decisions made in reaction to misconduct allegations often happen out of the public eye, says Bryan Stroube, a management researcher at the London Business School. His analysis of discipline disparities within the Chicago Police Department was published online September 1 in the same journal. "There's just not a lot of visibility to this process," he says. — *Curtis Segarra*

Addressing race

Decades have passed since Gregory observed that elementary school boy waiting outside the principal's office. Yet she is still grappling with how to help children like him.

Two years ago, for instance, Gregory and her colleagues piloted a program at one elementary, one middle and one high school in New York City to confront racism in schools. That program combines a race-conscious version of restorative justice with socioemotional learning. The latter helps children regulate their emotions by teaching self- and social awareness and responsible decision making. During 25 hours of training, teachers come together in circles similar to those used in Denver. The prompt, however, asks teachers to consider how structural racism hurts children. After that initial training, coaches also work with the teachers one-on-one.

This facilitated dialog around race has helped teachers speak freely about their worries, Gregory noted in 2018 in the trade publication *The Learning Professional*. For instance, during the training circles, teachers often express concern that



Course correct Research suggests teachers are more lenient with white than Black students — a sign of implicit bias. Rather than tackle bias, a new study taught teachers how students and relationships can improve. The teachers also learned about the student. Those teachers were less likely than teachers who read unrelated text to label Black students as troublemakers. SOURCE: J.A. OKONOFUA, A.D. PEREZ AND S. DARLING-HAMMOND/*SCIENCE ADVANCES* 2020

nonpunitive approaches are too soft or unstructured. When that happens, Gregory and her colleagues walk teachers through scenarios of alternative responses to students misbehaving.

Data collection is also key to the success of a new program, Gregory says. Crunching the numbers can illuminate disparities that might otherwise go unnoticed. For example, the pilot middle school in Gregory's study had a predominantly Black student population, making racial gaps in discipline less of a problem to begin with. School officials knew, however, that girls there had more behavioral problems than boys. Yet an examination of discipline data showed that teachers were punishing boys more frequently and more severely than girls.

In 2019, the team began scaling up the program to eventually reach 18 schools in Queens and Brooklyn. The researchers are also monitoring how school leaders are providing support, such as space for restorative circles and freeing up time for students to learn socioemotional skills. The pandemic, however, interrupted the expansion effort and the release of preliminary results, Gregory says.

But research in education and other fields shows that efforts to eradicate people's biases rarely stick. So rather than targeting the bias itself, Darling-Hammond, Okonofua and UC Berkeley psychology graduate student Amanda Perez recently tried addressing its downstream consequences. That is, if harsh discipline is seen as the culmination of a process that begins with bias and ends with, say, expulsion, then what targets between those two points might be easier to change? The team identified activities that changed teachers' thinking or helped them understand a misbehaving student's perspective.

The two-strikes work from 2015 showed that educators were quick to label Black students as troublemakers. So the trio wondered if teachers could be convinced to adopt a "growth mind-set" — the belief that students and relationships could change. The team also theorized that once teachers adopted a growth mind-set, they would need time and space to get to know their students.

Okonofua and colleagues knew from the 2015 study that teachers recommended 30 percent harsher discipline for Black students than white students. So in a follow-up study, the team asked a different group of U.S. teachers to read vignettes about hypothetical students named Deshawn or Greg.

But this time teachers had extra vignettes to read. First, about half of the 243 teachers read a passage on the growth mind-set, specifically how teachers can change a student's life. Second, the teachers read about how their relationship to students could grow. Third, they read about the student's initial misbehavior. Fourth, they read about the student's love of music and struggles outside school. And finally, the teachers read about the student's second misbehavior, then answered a set of questions.

Teachers in a control group, meanwhile, read only the misbehavior vignettes interspersed with unrelated or subversive readings, such as a passage on how relationships cannot change.

The intervention made responses to both Black and white students more positive. Compared with teachers in the control groups, those who read the additional vignettes about Deshawn were less likely to label him as a troublemaker or expect him to get suspended in the future, and were more likely to feel they could build a strong relationship with him, the team reported October 16 in *Science Advances*. Though those teachers were also less willing to see Deshawn receive harsh discipline, that finding did not reach statistical significance. Darling-Hammond now hopes to see these interventions tested outside of the lab.

The virtual classroom

Meanwhile, Losen and others worry that the ongoing COVID-19 pandemic could make shrinking the discipline gap even harder. Data collected during the pandemic are not yet available, but anecdotes of teachers punishing Black students for misbehaving during online classes have recently surfaced. Police arrived at the home of a 12-year-old in Colorado after his art teacher saw him playing with a neon green toy gun. The school later suspended the boy for five days. Police also visited a boy in New Jersey after a teacher saw him playing with a Nerf gun. School officials in Louisiana suspended a 9-year-old boy for having an unloaded BB gun visible in his bedroom.

During this pandemic, teachers have even less time and space to get to know what's going on in their students' lives. And everyone's stress levels are at an all-time high, Losen says. "Unless we do something very different and really address needs in a way that we never have, we're going to see a train wreck." ■

Explore more

- Daniel J. Losen and Paul Martinez. "Lost opportunities." Learning Policy Institute; Center for Civil Rights Remedies at the Civil Rights Project, UCLA. October 11, 2020.

C. CHANG

The Light Ages
Seb Falk
W.W. NORTON & CO., $30

BOOKSHELF

Science in the 'Dark Ages'

A long-standing myth about medieval history is that the Middle Ages were intellectually dark. Science supposedly took a hiatus between the demise of Rome and the rise of Copernican astronomy and Galileo's physics, some superficial accounts suggest.

"The medieval reality, however, is a Light Age of scientific interest and inquiry," historian Seb Falk writes in *The Light Ages*. Historians have long known that medieval monasteries and universities hosted many deep thinkers engaged in sophisticated intellectual enterprises. In particular, Falk emphasizes, the medieval era produced high-level technical achievements in the realm of scientific instrument making.

Falk tells his story from the perspective of John Westwyk, a monk at St. Albans Abbey in England in the 14th century. Little is known about Westwyk, but Falk re-creates his life through an account of the life events and duties of monks at that time. Westwyk is known to have produced two important astronomical manuscripts, both about scientific instruments.

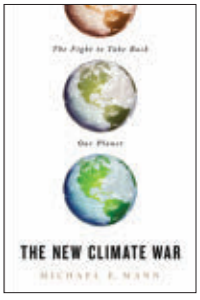
Most noteworthy among the instruments of the day was the astrolabe, a contraption containing movable disks to measure and represent the positions of astronomical objects. If you ever wondered how astrolabes worked, down to the last detail, this is the book for you. And if you're curious about the medieval obsession with astrology — a prime motivation for building astrolabes — your appetite will be sufficiently satisfied.

If you desire more detail about medieval science, though, other books offer more. Falk mentions only in passing the accomplishments of some of the era's many serious science-minded scholars, such as Robert Grosseteste, Roger Bacon, Albert the Great and Nicole Oresme. There is virtually no discussion about the science of mechanics during the Middle Ages, which, while falling short of modern understanding, still provided a foundation for later achievements.

Nonetheless, Falk's book offers an illuminating antidote to the "Dark Ages" myth. It's thoroughly documented, richly illustrated and engagingly written (although with occasional slower sledding through the details of some of those astronomical mechanisms and the casting of horoscopes).

Falk says he "sought to tell the story of medieval science ... as an integral part of medieval life and culture," and he succeeds in embedding scientific pursuits within the culture of medieval religious life. Science and religion were not generally at odds, as sometimes assumed, but rather were dual attempts to grasp the workings of God's creation. True, theologians sometimes clashed with natural philosophers, but everyone operated within the understanding that the study of nature was the study of God's work.

Falk's account is not the whole story of all the ways that medieval science was light rather than dark. But it is still an important part of that story. — *Tom Siegfried*



The New Climate War
Michael E. Mann
PUBLIC AFFAIRS, $29

BOOKSHELF

The art of climate war

Sometime around the fifth century B.C., the Chinese general and military strategist Sun Tzu wrote in his highly quotable treatise *The Art of War*, "If you know the enemy and know yourself, you need not fear the result of a hundred battles."

In *The New Climate War*, climate scientist Michael Mann channels Sun Tzu to demystify the myriad tactics of "the enemy" — in this case, "the fossil fuel companies, right-wing plutocrats and oil-funded governments" and other forces standing in the way of large-scale action to combat climate change. "Any plan for victory requires recognizing and defeating the tactics now being used by inactivists as they continue to wage war," he writes.

Mann is a veteran of the climate wars of the 1990s and early 2000s, when the scientific evidence that the climate is changing due to human emissions of greenhouse gases was under attack. Now, with the effects of climate change all around us, we are in a new phase of those wars, he argues. Outright denial has morphed into "deception, distraction and delay."

Such tactics, he says, are direct descendants of earlier public relations battles over whether producers or consumers must bear ultimate responsibility for, say, smoking-related deaths. When it comes to the climate, Mann warns, an overemphasis on individual actions could eclipse efforts to achieve the real prize: industrial-scale emissions reductions.

He pulls no punches, calling out sources of "friendly fire" from climate advocates who he says divide the climate community and play into the "enemy's" hands. These advocates include climate purists who lambaste scientists for flying or eating meat; science communicators who push fatalistic visions of catastrophic futures; and idealistic technocrats who advocate for risky, pie-in-the-sky geoengineering ideas. All, Mann says, distract from what we can do in the here and now: regulate emissions and invest in renewable energy.

The New Climate War's main focus is to combat psychological warfare, and on this front, the book is fascinating and often entertaining. It's an engrossing mix of footnoted history, acerbic political commentary and personal anecdotes. As far as what readers can do to assist in the battle, Mann advocates four strategies: Disregard the doomsayers; get inspired by youth activists like Greta Thunberg; focus on educating the people who will listen; and don't be fooled into thinking it's too late to take action to change the political system. — *Carolyn Gramling*

NOVEMBER 7, 2020

SOCIAL MEDIA

Rhythm of the night

Music created from telescope data helps people with visual impairments experience the wonders of astronomy, such as the Pillars of Creation (shown below), and could aid research, **Maria Temming** reported in "How music can amplify astronomy" (*SN: 11/7/20, p. 4*). On Facebook, reader **Alexander Micheal Carter** praised the effort with a pun: "Love it!!! Great algor-rhythms."

X-RAY: CXC/NASA, INAF, M. GUARCELLO *ET AL.*; OPTICAL: NASA, STSCI

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Waiting to exhale

Cuvier's beaked whales may rely on large stores of oxygen, a slow metabolism and the ability to tolerate lactic acid to dive for hours without surfacing for air, ***Erin Garcia de Jesus*** *reported in "Whale's breathtaking dive impresses"* (SN: 11/7/20, p. 5*).*

"Your report on Cuvier's beaked whales' long dives begins: 'To break the record for longest dive by a marine mammal, take a deep breath and jump in the water,'" reader **John Hoskins** wrote. "Do these whales inhale or exhale before diving?" he asked. **Hoskins** noted that northern elephant seals exhale before diving deep. That, along with flexible rib cages, helps those mammals' lungs collapse as water pressure increases.

Cuvier's beaked whales exhale most of the air from their lungs before diving, **Garcia de Jesus** says, and the whales also have flexible rib cages. "It seems that Cuvier's beaked whales have very similar diving methods to northern elephant seals," she says.

Swept away

Bacteria and other microbes that get swept into the atmosphere can end up in clouds and influence weather, ***Cassie Martin*** *reported* (SN: 11/7/20, p. 4*) in an update to a 1970 article "Clouds may be ecosystems"* (SN: 11/14/70, p. 384*).*

Reader **Mike Sevilla** wondered if clouds could spread the algae responsible for harmful red tides. "Can the clouds pick up and carry [the algae]?" he asked. "Great food for thought over toast and tea."

It's possible that some algae could get swept into the atmosphere where they might seed clouds, **Martin** says. "But those species haven't been documented in samples of cloud water to my knowledge." It's also unclear if the organisms would survive the trip. "Microbial meteorology is a relatively new field," **Martin** says. "While researchers don't yet have an answer for whether clouds disperse algae that go on to form red tides, the question is definitely worth discussing during your next teatime chat."

It's a small world after all

A photo of a zebrafish's lymphatic system took top honors in the 2020 Nikon Small World photography contest, ***Erin Garcia de Jesus*** *reported in "Glowing fish gives up its anatomical secret"* (SN: 11/7/20, p. 32*).*

The third-place winner, featured in an online version of the story, was a magnified image of a snail tongue. Reader **Orlando Saint-Sebastien** was surprised to learn that snails have tongues and asked how sticky they are.

Snail tongues come in various shapes, sizes and textures. **Igor Siwanowicz**, a photographer and neurobiologist at Howard Hughes Medical Institute's Janelia Research Campus in Ashburn, Va., doesn't think the tongue of the freshwater snail he photographed was sticky. **Siwanowicz** admits that he's never been licked by a snail, but he imagines the tongue would feel like fine sandpaper. "More like a cat's than a chameleon's tongue," he says.

Serendipity with a dash of salt

Passion and happy chance encounters connect botanists studying rare plants and a physicist trying to replicate supernova explosions in the lab, ***Nancy Shute*** *wrote in "In praise of serendipity — and scientific obsession"* (SN: 11/7/20, p. 2*).*

"That's only the half of it," reader **Thomas Nied** wrote. In "Bringing supernova physics down to Earth" (*SN: 11/7/20, p. 20*), Emily Conover "writes that as a graduate student in the 1980s, the physicist Hye-Sook Park worked on 'an experiment 600 meters underground in a working salt mine beneath Lake Erie.' Although the story doesn't say, that salt mine under Lake Erie was owned and operated by Morton Salt, with its headquarters in Chicago," **Nied** wrote. Meanwhile, part of "Rare plants and the people who love them" (*SN: 11/7/20, p. 14*) is set in Morton Arboretum in Lisle, Ill. "The same Morton who funded the arboretum founded the salt mine.... But, at this point, to paraphrase [journalist and author] Walter Lippmann, 'the facts have far exceeded my curiosity,'" **Nied** wrote.

CONVERSATIONS WITH MAYA

MONIKA SCHLEIER-SMITH
Associate Professor of Physics, Stanford University

Maya Ajmera, President & CEO of the Society for Science and Publisher of *Science News*, chatted with Monika Schleier-Smith, an alumna of the 2001 Science Talent Search who was named to the SN 10, *Science News*' list of 10 scientists to watch, in 2019. Schleier-Smith is an Associate Professor of Physics at Stanford University and recently received a MacArthur Fellowship. We are thrilled to share an edited summary of their conversation.

What was it like to conduct science research when you were a high school student, and how did it impact your life? Are there any particular moments that still stand out to you?

In high school I had the unique opportunity to conduct cutting-edge nanotechnology research at a nearby company, the MITRE Corporation. It was tremendously empowering to have that type of experience at such an early age. I was given an open-ended research problem and had a mentor who gave me the confidence that even I—a 16-year-old—could tackle this problem. I got to spend my summer reading scientific literature, learning new techniques like computational chemistry. I had the freedom to come up with my own ideas, which ultimately led to a couple of patents, a paper and my first scientific collaboration. It was really an amazing experience to be fully engaged in the world of scientific research at such an early age.

When you spoke at the Virtual Regeneron International Science and Engineering Fair 2020, you shared a bit about your childhood. Where did you grow up and who were your role models?

I grew up outside Washington, D.C., in northern Virginia and went to Thomas Jefferson High School. It's difficult to identify just one role model, although my older brother was a big influence on me. I started to learn how physicists think from him. He would take a physicist's attitude, writing down an equation on the back of an envelope to solve a problem from first principles.

I also had a fantastic experience at Thomas Jefferson High School, with an amazing group of friends with whom it was normal to be on the math team and also run track. It was possible to have this kind of well-rounded life. We motivated each other in math and science and that was really wonderful.

What advice do you have for students who would like to progress in their research at the high school or college level, but are confined to their homes because of the COVID-19 pandemic?

It's possible that being confined at home might give you a little bit more time to be creative and do what you want to do without all the extracurricular things that might otherwise keep you busy. One of my fond memories from high school was a project that was driven by my own curiosity. I had been reading a book about fractals and learned that fractals appear in music. As an amateur violinist, I was fascinated by this idea and started investigating what I could learn by analyzing the fractal patterns in music. I conducted a mathematical analysis to determine whether I could identify which era a particular piece was written in. That actually turned into a science fair project.

What are you currently working on?

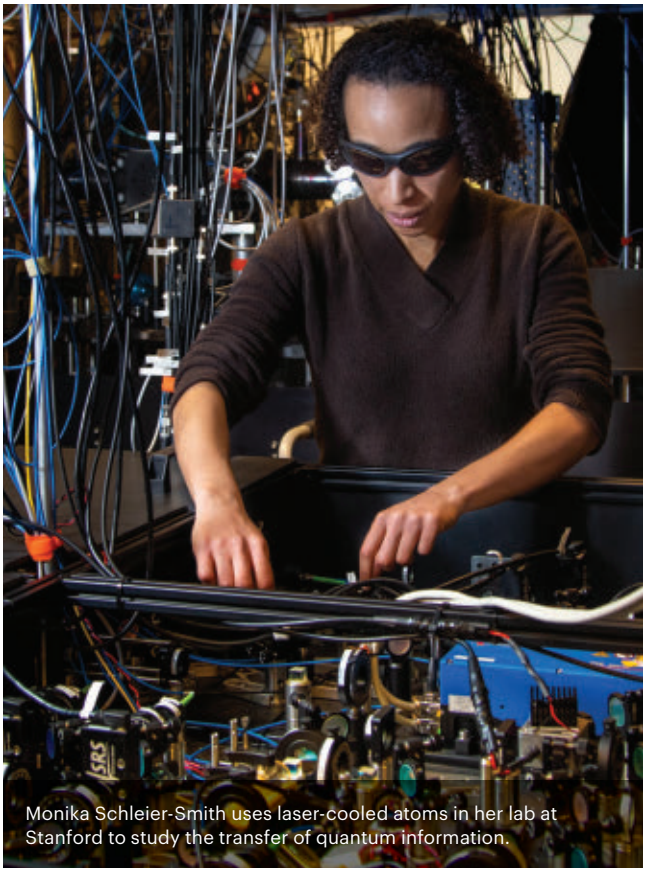
My research group does experiments with laser-cooled atoms, which is something I started working with in graduate school. I think of it as a wonderful model system for studying quantum mechanics and advancing the control we have over quantum systems to the point where they ultimately will have some technological impact. The application you are most likely to

read about in the news is quantum computation—and that is one area I am interested in—but there are also applications such as precise sensors used in medical imaging that may stand to benefit from advances in quantum control.

The key phenomenon that quantum technologies aim to exploit is known as entanglement, which essentially says that one can encode information in a way that's not in one particle but that can be delocalized, hidden in correlations among many particles. Generating those correlations between specified particles requires controlling which particles interact and which do not—it's almost like sharing a secret between specified people by whispering or sending text messages. In my lab, we use laser light to control the interactions between atoms with an eye towards expanding the kinds of entanglement that we can create. We are also working on quantum simulation, which is where we use these atoms as model systems to answer questions from other areas of physics, ranging from materials science to quantum gravity.

Congratulations on being named a 2020 MacArthur Fellow. What do you hope to do with the grant?

I am still trying to figure out how I am going to leverage the grant. So far, being named a fellow has given me an opportunity to share quantum physics with a broader audience. That's something that I appreciate.



Monika Schleier-Smith uses laser-cooled atoms in her lab at Stanford to study the transfer of quantum information.

As a leading Black female physicist, do you feel you've had any unique obstacles in your path? How were you able to overcome them?

I don't think that I've had challenges that are unique. Everybody, in any career, faces some challenges along the way. That said, I think as a woman in physics, I had to adjust to feeling comfortable within the sometimes assertive culture of communicating in physics.

Physicists often ask a question by making a statement and then seeing whether anybody disagrees with it. My natural method for pointing out that somebody is wrong would be to ask a question. But sometimes that's not heard. I don't like to overgeneralize, but I think this is more of a female communication style.

It can be frustrating when everybody else is more assertive and seems more confident. It also can take some time to not be intimidated, and it took me time to learn how to say things in a way that would be heard. I recently told one of my graduate students that this was something I had to learn and she was shocked. She said she couldn't imagine me not being assertive.

What strategies and actions do you think are critical for scientific leaders and policy makers to take in order to combat scientific illiteracy and disinformation?

I'm certainly not an expert in this, but my main instinct is that the best thing we can do is to create an awareness of science and encourage a sense of curiosity about the world at an early age. That's something where I feel I was lucky; although my mother doesn't have a background in science, it was important to her to do simple science experiments at home to instill that sense of curiosity.

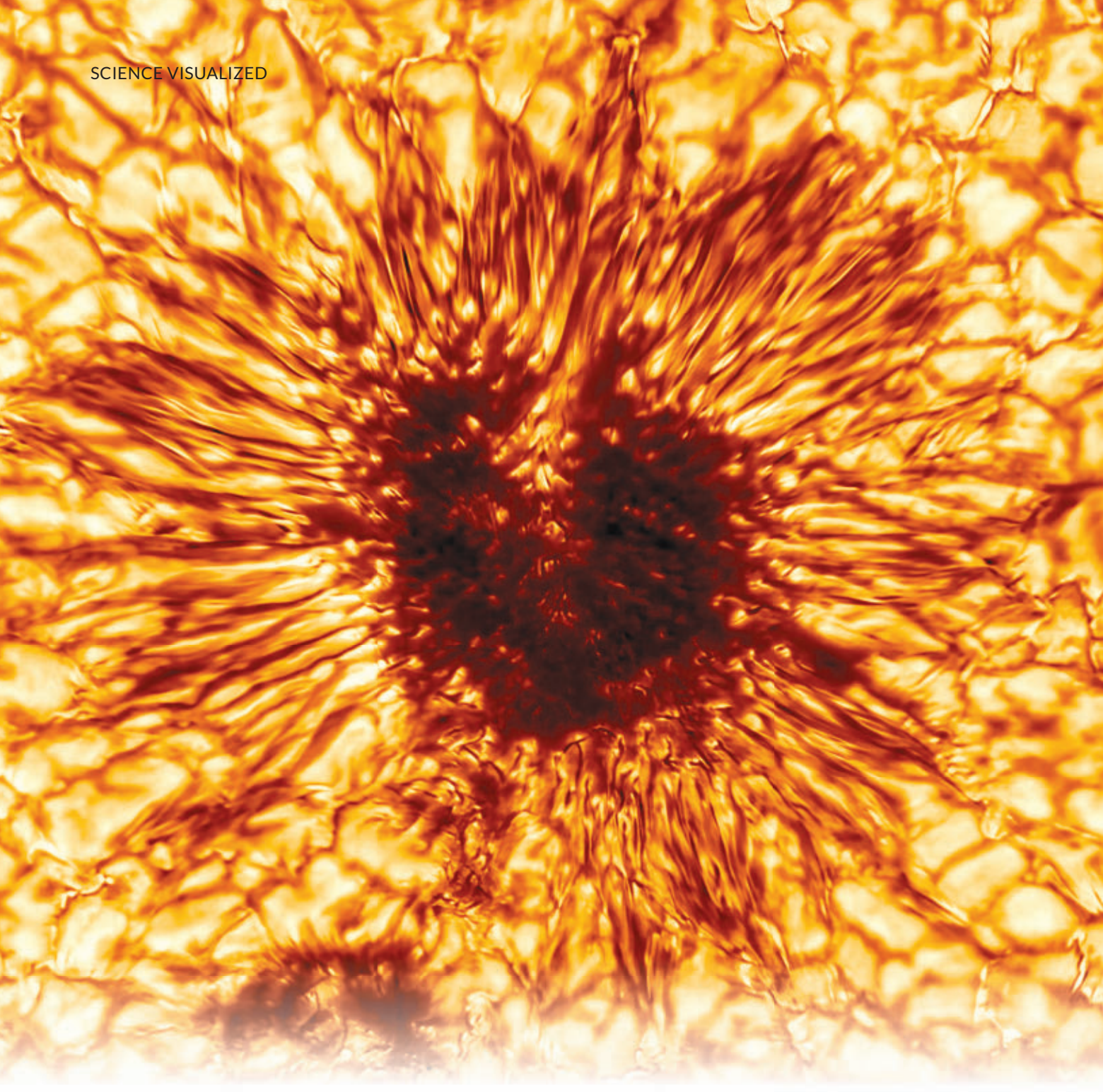
I think the more our society emphasizes scientific inquiry and gives those opportunities to everybody, the better off we will be.

What advice do you have for young people just starting college or their professional careers?

Find a subject that you are passionate about and find an environment with people who you love to work with. I find it's always important to have fun in what I'm doing. It's great to have goals and vision, but also if I'm doing something every day, I want to do it with people I love to work with.

What keeps you up at night right now?

I have to say that I am not a worrier. I tend to be an optimist. I know that issues like climate change are out there, but I also see people working to solve those problems. I get to spend a lot of my time interacting with students, which is the best thing about my job. Some of them are worriers, and that's a good thing. They also bring a lot of positive energy to wanting to improve the world around them. So that's perhaps what keeps me an optimist—I'm always around young people who are committed to solving all the world's problems.



A sunspot's moment in the spotlight

The largest solar telescope on Earth has captured the best glimpse ever of a sunspot.

Vaguely resembling a sunflower — or the Eye of Sauron from *The Lord of the Rings* — the spot appears as a dark blemish surrounded by ribbons of plasma that have been sculpted by magnetic fields sprouting from the spot's center. That dark spot spans roughly 6,000 kilometers, while the wreath of puckered plasma is about 15,000 kilometers across, a distance that could engulf the Earth with some room to spare.

The image was captured using the nearly constructed Daniel K. Inouye Solar Telescope in Hawaii, project director Thomas Rimmele and colleagues report in the December *Solar Physics*. With its 4-meter-wide mirror, the telescope is starting to provide the highest-resolution views of the sun ever seen. Such images will help researchers get at the root of enduring mysteries about the sun, such as why its outer atmosphere is millions of degrees hotter than its surface.
— *Christopher Crockett*

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