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Science News

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ APRIL 10, 2021

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Breakthroughs that revealed the nature of matter also unleashed the nuclear bomb

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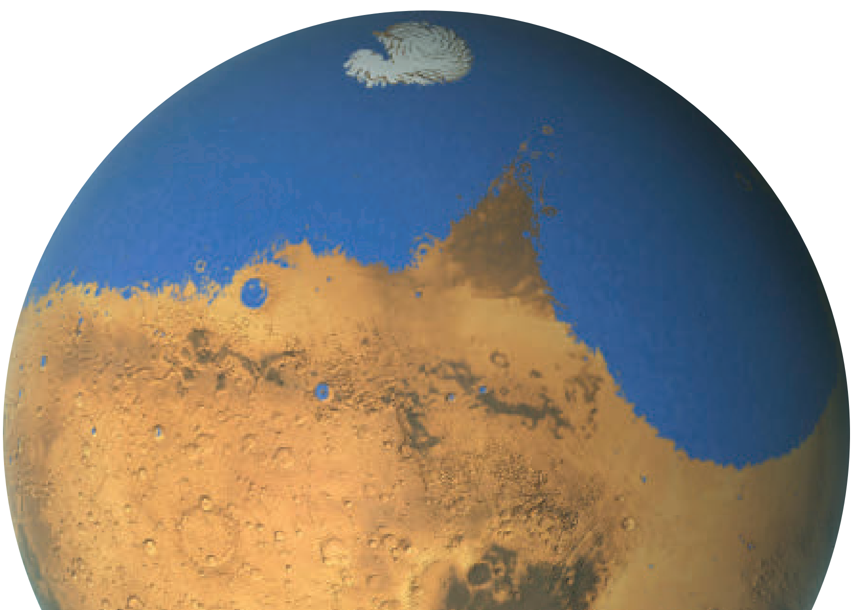
COVER After bombing Japan in 1945, the U.S. military continued nuclear weapons tests, shown in 1946 at Bikini Atoll. *Library of Congress*



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FROM TOP: L. KOBZIAR; S. MITOH; GSFC/NASA

Celebrating 100 years of unbiased journalism

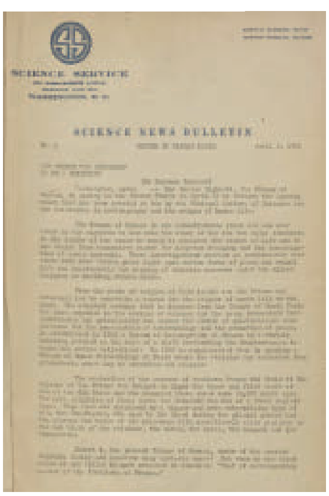
Growing up as the daughter of a physicist and an entrepreneur, I was exposed to *Science News* at a young age. I enjoyed reading the latest discoveries in astronomy, medicine and neuroscience, while delving through pages lined with photographs of the stars, animals and natural world.

Seven years ago, when I began my tenure as the publisher of *Science News*, I was faced with a staggering task. I was told to either sell the magazine, shut it down or make it sustainable. I mulled the options and realized there was only one choice: I had to turn things around to ensure that *Science News* would survive. I just could not imagine this magazine no longer existing.

I believe that journalism is a cornerstone of our democracy, and a science-literate public is crucial to our future. When I started, we were also one of the few newsrooms left in the United States with science beat journalists. Since I have taken the helm, we have ensured a bright future for *Science News* by making a capital investment in modernizing our digital newsroom and bringing the magazine into high schools across the country. Today, we are in over 5,000 high schools nationwide, providing high-quality content for students and teachers.

Since its founding in 1921 as *Science News Bulletin* (first issue below), *Science News* has been covering timely and controversial scientific topics to democratize access to knowledge. It was the vision of newspaper magnate E.W. Scripps and zoologist W.E. Ritter to build a scientifically literate society through evidence-based, unbiased science journalism. In 1925, our reporters extensively covered the Scopes Trial, which debated whether evolution should be taught in schools. In 1922, we covered news much like today's: testing of new pneumonia vaccines.

We are now dealing with a deadly pandemic. Rampant misinformation about the potential of vaccinations, masking and social distancing efforts persist. It is notable that *Science News* survived the Great Depression because it is precisely in these moments of crisis that society most depends on science. Our newsroom is working around the clock to keep the public informed with objective, accurate scientific news and public health guidance.


SCIENCE SERVICE

SCIENCE NEWS BULLETIN

As we celebrate our centennial, I want to thank our editor in chief, Nancy Shute, for her visionary leadership and our newsroom of talented journalists for their phenomenal reporting. Thank you to our readers, subscribers and members for sticking with us. Many of you have become donors, giving above and beyond — I am grateful to you for your support. When I first came on board, you made a bet on my leadership. Thank you for taking a chance on me.

We look forward to our continued reporting of scientific discoveries for the next 100 years!
— Maya Ajmera, Publisher

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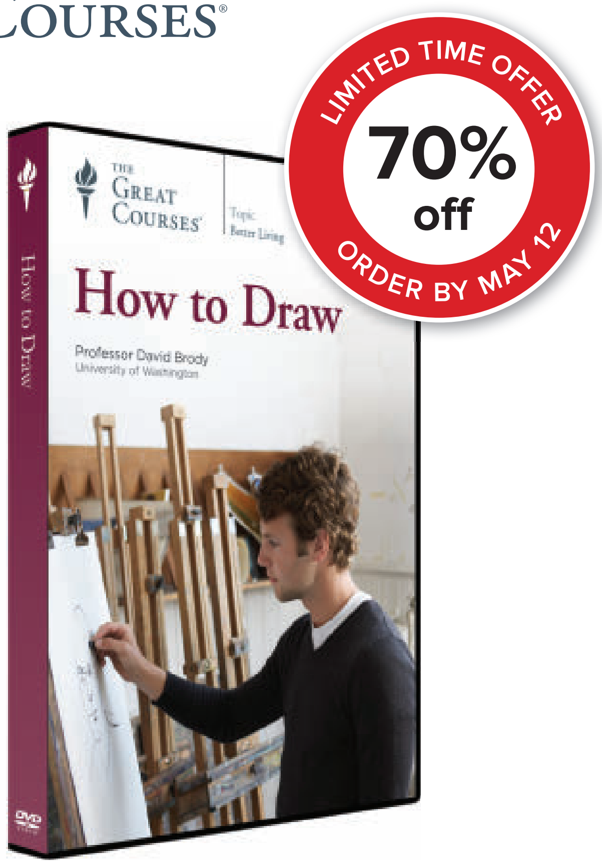

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Excerpt from the April 17, 1971 issue of *Science News*

50 YEARS AGO

Helium: Should it be conserved?

To avoid some of the loss and provide a stockpile against future needs, the United States Government, in the late 1950s, established a helium conservation program.... Under the program the Bureau of Mines contracts with certain natural gas producers to extract helium and store it in underground chambers. Now the users and extractors of helium are fighting a decision to end that program.

UPDATE: To the relief of balloons everywhere, the Federal Helium Reserve survived. Arguments to shutter the facility, located in Texas, centered around declining use. But the element is often used in scientific research and is now crucial for smartphone manufacturing and MRI machines. Global demand is high, and users have faced numerous shortages. In 2016, the discovery of a helium gas deposit under Tanzania temporarily eased concerns of the world's supply running dry (*SN: 7/23/16, p. 14*). Still, the U.S. government has long wanted to float away from the helium game and plans to close the reserve later this year.

The detached head of a sea slug glides by its still-living body soon after separation. While the abandoned body will die, the head will grow a new one — heart and all.

S. MITOH

HOW BIZARRE

No body is no problem for detached sea slug heads

Losing your body from the neck down can be just another one of life's annoying but temporary setbacks — at least for two kinds of rippling, green-tinged sea slugs.

Heads of young *Elysia* cf. *marginata* sea slugs can pull themselves free from their bodies and crawl around while growing a new body, report ecologists at Nara Women's University in Japan. Within a few hours, some heads can start nibbling on algae, Sayaka Mitoh and Yoichi Yusa report in the March 8 *Current Biology*. And within about 20 days, three out of five of the heads had fully regrown bodies, heart and all.

That's perhaps the first time anyone has reported such dramatic "whole-body" regeneration in any sea slug, Yusa says.

Other creatures regenerate. In one sense, planarian flatworms are better at it, Yusa says. They can regenerate from multiple cut pieces. Yet their body plan is simpler, and they don't have hearts.

A group of tubelike sea squirts called ascidians might be the most complex whole-body regenerators, that is, the most closely related to us. Vertebrate regenerators such as salamanders don't regrow a whole body from a severed head.

Mitoh first noticed the sea slugs' extreme regeneration by chance in some *Elysia* slugs in the lab. "We were really surprised to see the head crawling," Yusa says.

Just which *Elysia* species can turn into crawling heads isn't yet clear. Marine biologist Sónia Cruz at the University of Aveiro in Portugal works with two other *Elysia* species but hasn't seen anything like it. She does caution, though, that she hasn't done systematic tests.

A sea slug head can take several hours to rip itself loose from its body, so Mitoh and Yusa doubt that deheading helps when predators attack. Instead, a detachable body may be the sea slug's way of dealing with parasites. In a batch of wild-caught *E. atroviridis* sea slugs, copepods parasitized the few that ditched their bodies.

On close inspection, the researchers found that sea slugs have a slight groove looped on the back of the head region that seems to work as a break-here zone. An abandoned body can move for days or even months, but won't regrow its head. The leaf-shaped remnant instead turns pale and weak and eventually dies.

Perhaps *Elysia* slugs manage extreme regrowth by stealing plants' energy factories, called chloroplasts, the scientists muse. Grazing slugs "pierce the cell walls of sea algae and sip the contents," Yusa says, and can keep chloroplasts alive inside them for weeks.

Biologists debate what the stolen chloroplasts do for their kidnappers besides provide a green tinge. But Yusa suspects the looted plant booty improves sea slug regeneration. If chloroplasts are more than cosmetic, maybe that energy boost is just what a severed head needs to get (more than) ahead.
— *Susan Milius*

Watch a video of sea slugs regenerating at **bit.ly/SN_SeaSlug**

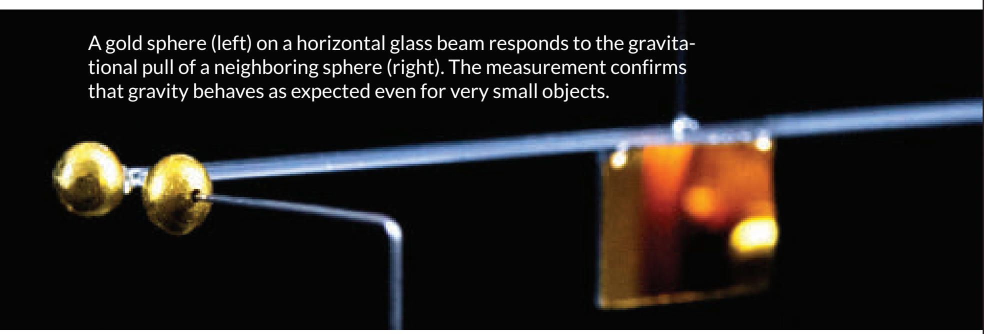
THE –EST

Newton's law of gravity holds up in miniature

Even teeny objects obey the law of gravity. A gold ball just 2 millimeters wide, with a mass of about 90 milligrams, is now the smallest object to have its gravitational pull measured. Observations of that sphere tugging on another similarly sized sphere confirm that gravity behaves as expected even for extremely weak gravitational fields, physicists report in the March 11 *Nature*.

Newton's law of universal gravitation states that the gravitational force between two masses is inversely proportional to the square of the distance between them. Physicists in Austria tested whether that law applies to tiny masses by attaching a gold sphere to a horizontally suspended beam. The sphere was free to rotate in response to the gravitational pull of another gold sphere a few millimeters away. Measurements of the motions of the first sphere as the second sphere moved closer and farther away matched predictions of Newton's law and Einstein's general theory of relativity, two theories of gravity that are equivalent under most everyday conditions.

Researchers want to test how gravity behaves on even smaller scales, and this test inches them closer to exploring gravity's quantum side. — *Emily Conover*



A gold sphere (left) on a horizontal glass beam responds to the gravitational pull of a neighboring sphere (right). The measurement confirms that gravity behaves as expected even for very small objects.

SCIENCE STATS

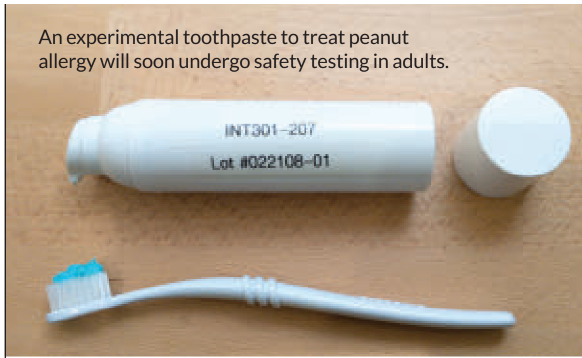
Global food waste nears 1 billion metric tons

The world wasted about 931 million metric tons of food in 2019 — an average of 121 kilograms per person. That's about 17 percent of all food that was available to the global human population that year, a new United Nations report estimates.

"Throwing away food de facto means throwing away the resources that went into its production," Martina Otto, who leads the U.N. Environment Programme's work on cities, said during a news conference on March 4. Food that ends up in landfills "does not feed people, but it does feed climate change," she said. Some 690 million people face hunger each year. Meanwhile, food waste accounts for up to 10 percent of global greenhouse gas emissions. Reducing food waste could ease both problems, according to the Food Waste Index Report 2021 published March 4 by the U.N. Environment Programme and WRAP, a U.K.-based environmental charity.

In the most comprehensive accounting of global food waste to date, researchers analyzed data from 54 countries. Most waste, 61 percent, came from homes. Restaurants and other food services accounted for 26 percent of global food waste while retail outlets such as supermarkets contributed 13 percent. Food waste was a substantial problem for nearly all countries regardless of income level. As a first step, Otto recommends that countries integrate food waste reduction into climate strategies and pandemic recovery plans. — *Rachel Fritts*

121
kilograms
Average amount of food wasted per person in 2019



An experimental toothpaste to treat peanut allergy will soon undergo safety testing in adults.

TEASER

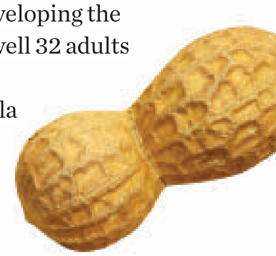
Toothpaste could brush away peanut allergy

Someday it may be possible for people to tackle their food allergies simply by brushing their teeth. A New York City–based company has launched a trial to test this concept in peanut allergy sufferers. The idea is to expose users to small doses of an allergen daily to build and maintain tolerance to it.

An existing treatment that delivers allergen doses through under-the-tongue liquid drops offers decent protection (*SN: 9/28/19, p. 8*). But it can be hard for users to keep up with this daily therapy. Plus, the immune cell targets are densest inside the cheeks.

Allergist William Reisacher of Weill Cornell Medicine in New York City came up with the toothpaste idea while brushing his teeth in front of a mirror several years ago. "I saw all the foam in my mouth going into all the areas I wanted it to go," he says. Delivering the allergen as a toothpaste would get the treatment to the right cells *and* embed it in a daily habit, he thought.

A trial launched by Intrommune Therapeutics, which is developing the toothpaste, will test how well 32 adults tolerate escalating doses.



Allergist Sakina Bajowala of Kaneland Allergy & Asthma Center in North Aurora, Ill., supports the concept. But she worries about safety. Unhealthy gums could give allergens access to the bloodstream, increasing the risk of allergic reactions, she says. — *Esther Landhuis*

FROM TOP: INTROMMUNE THERAPEUTICS; TOBIAS WESTPHAL/UNIV. OF VIENNA; NANCY C. ROSS/E+/GETTY IMAGES PLUS

News

ATOM & COSMOS

'Oumuamua gets a new origin story

A Pluto-like exoplanet may have spawned the interstellar object

The weird-looking interstellar object known as 'Oumuamua (illustrated), discovered in 2017, may be a piece of nitrogen ice broken off a Pluto-like planet in another solar system.

BY MARIA TEMMING

Since its discovery, the interstellar object known as 'Oumuamua has defied explanation. First spotted in 2017, it has been called an asteroid, a comet and an alien spaceship (*SN: 11/25/17, p. 14*). But researchers think they finally have the mystery object pegged: It could be a shard of nitrogen ice broken off a Pluto-like planet orbiting another star.

"The idea is pretty compelling," says Garrett Levine, an astronomer at Yale University who was not involved in the work. "It does a really good job of matching the observations."

'Oumuamua's origin has been a mystery because it looks sort of like a comet, but not quite (*SN Online: 12/18/17*). After whipping by the sun, 'Oumuamua zoomed away slightly faster than gravity alone would allow. That happens when ices on the sunlit sides of comets vaporize, giving them a little rocketlike boost in speed. But unlike comets, 'Oumuamua didn't appear to have a tail from typical cometary ices, such as carbon monoxide or carbon dioxide, streaming off it.

Alan Jackson and Steven Desch, planetary scientists at Arizona State University in Tempe, set out to discover what other kind of evaporating ice could give 'Oumuamua a big enough nudge to explain its movement. The pair reported their results March 17 at the virtual Lunar and Planetary Science Conference and in two studies published online March 16 in the *Journal of Geophysical Research: Planets*.

The amount of force that a vaporizing ice exerts on a comet depends on factors such as how much the ice heats up when it absorbs energy, the mass of its molecules and even the ice's crystal structure. By calculating the rocketlike push on 'Oumuamua if it were made of ices such as nitrogen, hydrogen and water, "we learned that nitrogen ice would work perfectly well," Desch says.

Because nitrogen ice covers outer solar system bodies such as Pluto and Neptune's moon Triton, but not smaller objects like comets, 'Oumuamua is probably a chip off a Pluto-like exoplanet, the researchers report.

To determine how realistic that scenario is, Jackson and Desch calculated how many chunks of nitrogen ice could have been knocked off Pluto-like bodies in the early solar system. Back then, the Kuiper Belt of objects beyond Neptune was much more crowded than it is today, including thousands of Pluto-like bodies iced with nitrogen. But some 4 billion years ago, Neptune's orbit expanded. That disruption caused many Kuiper Belt objects to collide with each other, and most sailed out of the solar system altogether.

Under such chaotic conditions, collisions could have broken trillions of nitrogen ice fragments off Pluto-like bodies, Jackson and Desch estimate. If other planetary systems throw out as many shards of ice, those objects could make up about 4 percent of the bodies in interstellar space. That would make seeing an object like 'Oumuamua mildly unusual but not exceptional, the researchers say.

"When I first started reading it, I was skeptical ... but it does tick a lot of the necessary boxes," says astronomer Scott Sheppard of the Carnegie Institution for Science in Washington, D.C., who was not involved in the work. "It's definitely plausible that this could be a fragment of an icy dwarf planet." But plausible, he notes, does not necessarily mean correct.

'Oumuamua is now too far away to confirm this idea with more observations. But the upcoming Vera C. Rubin Observatory and European Space Agency's Comet Interceptor mission could detect more interstellar objects, says Yun Zhang, a planetary scientist at Côte d'Azur Observatory in Nice, France, who was not involved in the research. The Vera C. Rubin Observatory is expected to spot, on average, one interstellar visitor per year, and the Comet Interceptor spacecraft may actually visit one.

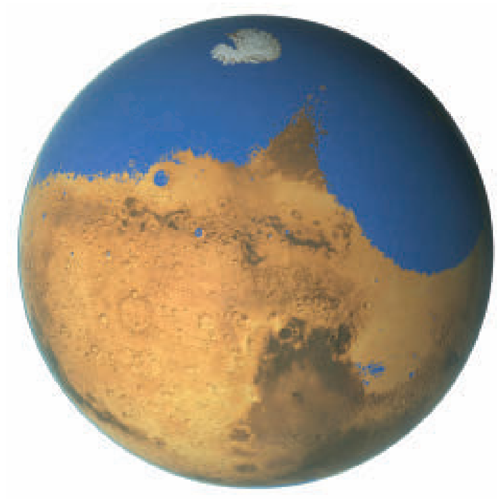
Getting a closer look at more of these objects could narrow down which possible explanations for 'Oumuamua are most reasonable, she says. ■

WILLIAM HARTMANN

ATOM & COSMOS

Mars' missing water may hide in crust

Simulations hint at why so little H_2O is seen escaping into space



Mars was a watery world (illustrated) billions of years ago. Much of that water, once thought to have been lost to space, may be trapped in the Red Planet's crust, a new study suggests.

BY MARIA TEMMING

An ocean's worth of water may be lurking in minerals below Mars' surface, which could help explain why the Red Planet dried up.

Once home to lakes and rivers, Mars is now a frigid desert. Scientists have typically blamed that on Mars' water wafting out of the planet's atmosphere into space (*SN: 12/5/20, p. 14*). But the levels of atmospheric water loss measured by spacecraft like NASA's MAVEN orbiter are not enough to account for all of Mars' missing water — which was once so abundant it could have covered the planet in a sea up to 1,500 meters deep. That's more than half of the Atlantic Ocean's volume.

Computer simulations of water moving through Mars' interior, surface and atmosphere now suggest that most of the planet's water molecules may have lodged inside minerals in the crust, scientists report online March 16 in *Science*.

The finding "helps bring focus to a really important mechanism for water loss on Mars," says Kirsten Siebach, a planetary geologist at Rice University in Houston who was not involved in the work. "Water getting locked up in crustal minerals may be equally important as water loss to space and could potentially be more important."

Planetary scientist Eva Scheller of Caltech and colleagues simulated scenarios for water loss on Mars based on spacecraft observations and laboratory analyses of Martian meteorites. The simulations accounted for possible water lost to space and locked into the planet's crust through bodies of water or groundwater interacting with rock.

For the simulations to match how much water was on Mars 4 billion years ago, how much is left in ice now and the observed abundance of hydrogen in Mars' atmosphere, 30 to 99 percent of Mars' ancient water must be stashed away inside its crust. The rest was lost to space.

Water on Earth also gets locked inside minerals, Scheller says. But unlike on Mars, volcanoes eventually belch out that underground water into the atmosphere. That difference is important for understanding why one rocky planet is habitable while another is a wasteland.

Future explorers could mine Mars' underground water, says planetary geologist Jack Mustard of Brown University in Providence, R.I. The most easily accessible water on Mars may be at the planet's polar ice caps, he says. But if water can be extracted from minerals, then humans could set up colonies at warmer climes. ■

EARTH & ENVIRONMENT

Lightning may have sparked life

Strikes could have produced phosphorus for DNA and RNA

BY MARIA TEMMING

One key ingredient for life thought to be delivered to Earth by meteorites may have been homemade after all.

The phosphorus that went into building the first DNA and RNA molecules is thought to have come from a mineral called schreibersite, which is typically found in meteorites. Now, an analysis of minerals forged by a lightning strike hints that lightning may have produced enough schreibersite on early Earth to help kick-start life, researchers report online March 16 in *Nature Communications*.

That means "emergence of life is not necessarily connected to meteorite impacts," says Sandra Piazolo, a geologist at the University of Leeds in England. A weather-fueled source for phosphorus could broaden the window of opportunity for life to arise on Earthlike planets.

Piazolo and colleagues analyzed a hunk of glassy material called fulgurite (*SN: 2/17/07, p. 101*) that formed when lightning zapped the ground in Illinois in 2016. By firing lasers, X-rays and electrons at the fulgurite and observing how those beams interacted with the material, the researchers were able to probe its composition. The team discovered that the fulgurite was studded with tiny kernels of schreibersite, which collectively made up about 100 grams, or about 0.4 percent, of the lightning-made material.

Using those observations, along with estimates of weather conditions on early Earth, Piazolo's team calculated that from about 4.5 billion to 3.5 billion years ago, lightning could have forged 110 to 11,000 kilograms of schreibersite each year to help seed life.

The main source of phosphorus for Earth's first life-forms depends on when life arose, says Matthew Pasek, a geochemist at the University of South Florida in Tampa who was not involved in the work. If life began by about 3.5 billion years ago, meteorites may have supplied about as much phosphorus as lightning strikes. But about 4.5 billion years ago, space rocks could have delivered some 100,000 to 10 million kilograms of phosphorus-containing compounds to Earth each year. "If life is a little bit younger, then lightning is a fantastic source of phosphorus," Pasek says. "If it's older, then meteorites were a much more abundant source." ■

GSFC/NASA

A health worker administers a vaccine in an attempt to slow an ongoing Ebola outbreak in Guinea. A person infected with Ebola at least five years ago may have sparked the outbreak.

CAROL VALADE/AFP VIA GETTY IMAGES

BODY & BRAIN

An old infection fueled Ebola outbreak

Virus may have laid low in a person for years before spreading

BY ERIN GARCIA DE JESÚS AND JONATHAN LAMBERT

The ongoing Ebola outbreak in Guinea was most likely sparked by someone infected during an outbreak five to seven years ago, a new study shows. Viruses from both outbreaks are almost genetically identical, hinting that the virus did not jump from an animal to people, as scientists expected, but that it had lurked hidden in a human body for years.

"With this news, I was really, really shocked," says Angela Rasmussen, a virologist at Georgetown University in Washington, D.C.

The first potential Ebola case emerged in the West African nation in late January, and Guinean health officials declared an outbreak on February 14 after three people tested positive for the virus. The region hadn't seen an outbreak since the one from 2013 to 2016, which claimed over 11,000 lives. A separate, unrelated outbreak in Congo was declared on February 7.

As of March 16, 30 cases and 15 deaths had been reported in both countries, according to the Africa Centres for Disease Control and Prevention. A genetic analysis found that four Ebola viruses from people infected in the Guinea outbreak are close relatives of viruses that had infected people in 2014, according to a trio of reports posted March 12 at virological.org that have not yet gone through peer review. Only about a dozen mutations separate these new cases from the 2014 cases. That's far fewer than the more than 100 mutations scientists expect would accumulate over that period if there were sustained transmission of the virus.

The lack of mutations also suggests that the new outbreak in Guinea did not get its start when a bat virus jumped into humans and began spreading. Rather, the most recent cases appear to be a resurgence of the same variant that caused the 2013–2016 Ebola outbreak, carried by someone who was infected back then.

Researchers have known that Ebola virus can stick around in the body after recovery. Some cases in West Africa during the 2013–2016 outbreak stemmed from individuals who had been infected and had recovered months, or even more than a year, earlier. But the new findings show the most recent outbreak began after a five-year lull in cases and suggest that the virus wasn't replicating during that time, meaning the virus may have gone dormant.

The finding "suggests some sort of weird mechanism that hasn't been seen before," Rasmussen says, but doesn't mean that Ebola outbreaks from dormant viruses in humans are going to become common. What might have happened is "a mystery. We'll probably solve [the mechanism], but right now, there's just not very much known about it," she says.

Other recent research backs up the idea that Ebola can lie low in the body for years. Levels of immune proteins that recognize the virus spiked in the blood in 39 out of 51 people months after those people recovered, molecular virologist Georgios Pollakis and colleagues reported in the Feb. 18 *Nature*. Though the team could not find evidence in the blood that the virus was replicating, the roused immune response hinted that the virus may have been hiding somewhere in the body. "We were quite surprised to see [that] data," says Pollakis, of the University of Liverpool in England.

For Pollakis, the new developments emphasize the need for continued surveillance and research on diseases that aren't top of mind. "Public health needs serious investment," he says. "We focus on what is [spreading] faster, on the biggest player. And then we leave the virus that doesn't seem to be a burden for the moment ... now it comes back to haunt us."

Though experts say transmission of the virus from people infected long ago appears to be rare, the outbreak raises fears that Ebola survivors could face new stigmas.

Health officials have sprung into action across the region to isolate potential contacts in the current outbreak and vaccinate them and their contacts, a strategy known as ring vaccination (*SN Online: 5/18/18*). In Guinea, at least 500 contacts have been identified and more than 3,300 people have been vaccinated as of March 16.

Still, public health officials may need to alter Ebola vaccination strategies, Rasmussen says. While ring vaccination is currently used to control outbreaks, "we need to think about maybe having a mass immunization campaign — not using vaccination as a control strategy but as a prevention strategy." ■

BODY & BRAIN

Hospital fungus is found in nature

Researchers locate deadly pathogen in coastal wetlands

BY AIMEE CUNNINGHAM

A deadly fungus that seemed to spring up out of nowhere in hospitals has been found in nature for the first time.

Researchers isolated the yeast *Candida auris* from two sites on the Andaman Islands in the Indian Ocean. The finding suggests that *C. auris* was an environmental fungus before it was identified as a human pathogen, researchers report online March 16 in *mBio*.

Where *C. auris* came from when it began appearing in patients and clinics was a real puzzle, says Christina Cuomo, who studies fungal pathogen evolution at the Broad Institute of MIT and Harvard and was not involved in the study. The new report is "the first clue as to where else [this fungus] might be."

C. auris emerged as a human pathogen on three continents in the early 2010s. The yeast has since been named a public health threat for its ability to cause dangerous, sometimes fatal infections that are resistant to many antifungal drugs (*SN: 12/7/19, p. 6*). *C. auris* spreads among patients — usually those already seriously ill — in hospitals and other health care facilities, causing infections of the bloodstream, gut or other organs. There have been more than 1,600 cases reported in the United States as of January 19, according to the U.S. Centers for Disease Control and Prevention.

The fact that *C. auris* can thrive inside the human body is unusual. Most fungi aren't able to grow in that toasty, 37° Celsius milieu. That has spurred scientists to hypothesize that *C. auris* gained the ability to infect people after becoming accustomed to warmer conditions in the environment as a result of climate change (*SN: 9/14/19, p. 4*). A possible location for the fungus: wetlands, which are very sensitive to the effects of warming.

The remote Andaman Islands, with coastal wetlands, swamps and beaches, fit the bill. Anuradha Chowdhary, a medical mycologist at the University of Delhi, and colleagues studied soil and seawater specimens from eight locations on the islands. The team struck gold at two sites, isolating *C. auris* from a coastal wetland and a beach. The isolates from the beach were resistant to antifungals and genetically similar to each other, a sign they are related. It's unclear at this point whether the beach isolates came from people, Chowdhary says.

But the two isolates from the coastal wetland — where there is no known human activity — were genetically different from each other and from the beach specimens. One of the two wetland isolates was still sensitive to antifungals, the researchers report, suggesting *C. auris* developed drug resistance after it adapted to people. And while all of the isolates grew at 37° C, the drug-susceptible one grew more slowly than the rest.

The new study should motivate wider sampling of *C. auris* to understand how extensive it is in nature, Cuomo says. Learning more about where *C. auris* comes from can provide insight into its tolerance for higher temperatures and its resistance to antifungal drugs. There's now a foot in the door, Cuomo says, "to really look more deeply." ■

HUMANS & SOCIETY

Grave riches may crown a Bronze Age queen

A lavish Bronze Age burial found in southeastern Spain may hold a queen's remains, researchers say. This unexpected discovery bolsters suspicions that women wielded political power in that region's El Argar society, which lasted from around 4,220 to 3,570 years ago. Researchers have typically assumed that men ran Bronze Age societies (*SN: 11/9/19, p. 8*).

In 2014, a team led by archaeologist Vicente Lull of the Autonomous University of Barcelona discovered the skeletons of a man and a woman in a large jar underneath what appears to be a royal structure at a site called La Almoloya. Radiocarbon dating indicates that both individuals died about 3,700 years ago.

Most of the 29 valuables in the grave lay on or next to the woman, Lull and colleagues report online March 11 in *Antiquity*. A circular silver headband, or diadem (shown below), was found on the woman's skull. Excavations at other El Argar sites in the 19th and 20th centuries yielded several females buried with diadems. Functions of the buildings under which those graves were located are unknown. But diadems signified power and social prominence, the researchers contend. If the La Almoloya woman was a queen, the team can't say if she was a ceremonial leader or made actual rulings. — *Bruce Bower*

GRUP ASOME/UAB

MATTER & ENERGY

Superconductors drop to new lows

Scientists look for ways to take the pressure off elusive materials

BY EMILY CONOVER

For decades, scientists quested after a room-temperature superconductor. Now that they've finally found one, the hunt is on for an even better material.

Until last year, all known superconductors — materials that conduct electricity without resistance — had to be cooled, many to extremely low temperatures, making them impractical for use in most electronic devices. In 2020, physicist Ranga Dias and colleagues reported that a compound of carbon, sulfur and hydrogen was superconducting at room temperature (*SN: 11/7/20, p. 6*). But the need for cooling had been swapped for another impractical requirement: The material had to be crushed to 267 gigapascals, more than 2 million times Earth's atmospheric pressure.

Now, scientists are devising strategies to ease the squeeze, perhaps even bringing pressures down to atmospheric levels. A superconductor that operates at room temperature and atmospheric pressure could be integrated into electronic devices, enabling improved computers and advanced levitating trains while saving vast amounts of energy. Dias, of the University of Rochester in New York, envisions a future where hardware store salespeople will ask, "You want a superconducting wire or you want normal wires?" he said March 18 at an online meeting of the American Physical Society. "We want it to get to that level."

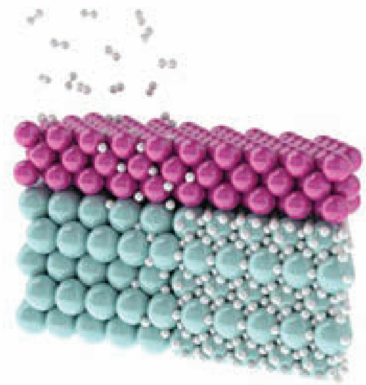
To find the next big superconductor, it helps to know where to start hunting. Scientists are using computer calculations to theoretically determine the structures and properties of materials and guide the search, theoretical chemist Eva Zurek of the University at Buffalo in New York said March 16 at the meeting. That strategy has paid off in the past. "Theory has played a very important role, in some cases predicting these structures before they were made," Zurek said. Such predictions led researchers to a compound of lanthanum and hydrogen that was found in 2018 to be superconducting at what was then a record high: up to about –13° Celsius (*SN: 10/13/18, p. 6*).

Now, predictions have guided Dias, Zurek and colleagues to a superconductor made of yttrium and hydrogen, Dias reported at the meeting. Superconducting at up to about –11° C, the material is one of the highest-temperature superconductors known. While Dias' carbon, sulfur and hydrogen superconductor is still the temperature record holder, the new material requires a significantly lower pressure — although at 182 gigapascals, it's no simple squeeze. Dias, Zurek and colleagues also reported the results March 19 in *Physical Review Letters*.

The list of high-temperature record holders is dominated by hydrogen-rich superconductors. Pure hydrogen is expected to become a room-temperature superconducting metal when squeezed (*SN: 8/20/16, p. 18*). But metallic hydrogen demands such extreme pressures that it's difficult to create. By adding in another element, such as lanthanum or yttrium, scientists have created superconductors that function similarly to metallic hydrogen, but at lower pressures.

Theoretical calculations have explored all combinations of hydrogen and any other single element, looking for likely superconductors. The new frontier is calculating combinations of two elements with hydrogen, such as the carbon-sulfur-hydrogen compound that Dias found experimentally. One study has already suggested this technique will find success in bringing down the pressure.

A combination of lanthanum, boron and hydrogen may be superconducting at lower pressures, physicist Lilia Boeri of the Sapienza University of Rome and colleagues reported at the meeting and in a study posted online February 22 at arXiv.org. The chemical structure is similar to that of the 2018 superconductor made of lanthanum and hydrogen, where a cage of hydrogen atoms surrounds a lanthanum atom. In the new compound, boron atoms fill some empty space around the cage, providing extra chemical pressure, Boeri said. If the material were created in the lab, it is predicted to retain its superconductivity even when the external pressure is as low as 40 gigapascals. The predicted temperature required for superconductivity is –147° C, still relatively warm compared with most superconductors.



Hydrogen (silver spheres) diffuses through palladium (pink spheres) to form a superconductor with yttrium (blue spheres) at high pressure, researchers report.

DEAN SMITH

"We were actually quite surprised that it would work this way," Boeri says. Normally, chemists would expect the boron to form bonds with the hydrogen, rather than simply acting to pen in the hydrogen cage. But chemistry under pressure breaks the normal rules.

That's why calculations are so important in the search for superconductors, Zurek says. Computational methods of searching for new materials under pressure can find structures that normal intuition wouldn't have conceived of.

At the meeting, Dias dropped hints about another new material his team has found that is superconducting at room temperature and at an external pressure of around 20 gigapascals. But he can't speak about it yet due to a pending patent application.

Scientists are enthusiastic about the new developments in superconductor research. "This is just the most exciting thing that's going on at the moment in science," said physicist Graeme Ackland of the University of Edinburgh, who moderated one of the sessions at the meeting. ■

ATOM & COSMOS

Supernova scrap looks superhuge

Debris cloud is by far the largest seen from Earth

BY KEN CROSWELL

A cloud of expanding gas in space is the largest supernova remnant ever seen in the sky, a new study confirms.

The Milky Way has some 300 known supernova remnants, each made of debris from an exploded star mixed with interstellar material swept up by the blast. This supersized one, located in the constellation Antlia, isn't necessarily the biggest physically. But thanks to the remnant's proximity to Earth, it *looks* the biggest to us. As seen from Earth, the remnant spans a region of sky more than 40 times the size of a full moon, astronomer Robert Fesen of Dartmouth College and colleagues report online February 25 at arXiv.org. The Antlia remnant appears about three times as large as the previous champion, the Vela supernova remnant.

The star that created the Antlia remnant exploded roughly 100,000 years ago. Estimates of the remnant's distance from Earth vary, so its physical size has yet to be nailed down. If the cloud is 1,000 light-years away, then it's about 390 light-years across. But if it's twice as far, then it's twice as big. Either way, the Antlia remnant is considerably larger than the Vela remnant, which is about 100 light-years wide.

The Antlia remnant isn't new to astronomers. In 2002, researchers discovered the cloud and proposed that it is the nearby remains of a supernova, based on the red glow of its hydrogen atoms as well as its X-ray emissions. But hardly anyone had observed the object since. "It wasn't really firmly established as a supernova remnant," says study coauthor John Raymond, an astronomer at Harvard & Smithsonian's Center for Astrophysics in Cambridge, Mass.

So the team studied the cloud at visible and ultraviolet wavelengths, which demonstrate that the Antlia object is indeed a supernova remnant. In particular, the visible light shows spectral signatures of shock waves, which result when high-speed gas from a supernova slams into gas around it.

"The evidence for it being shocks in a supernova remnant seems to be very good," says Roger Chevalier, an astronomer at the University of Virginia in Charlottesville who was not involved with the work. He notes that the team detected red light from sulfur atoms that are missing one electron, a hallmark of shocks in supernova remnants.

Astronomer Peter McCullough, who discovered the object two decades ago, had little doubt it was a genuine supernova remnant. "They've done good work," says McCullough, at the Space Telescope Science Institute in Baltimore. "This is a case where it looks like a duck, quacks like a duck, walks like a duck and now someone else 20 years later comes along and says, 'Not only that, it has feathers.' " ■

LIFE & EVOLUTION

How female tree frogs tune out noise

Inflated lungs help filter which sounds get sent to eardrums

BY JONATHAN LAMBERT

To find a mate amid a cacophony of frog croaks, groans, squeaks and trills, a female green tree frog just needs to take a deep breath.

During mating season, ponds resound with the sounds of hundreds of males from many different species crying out to potential mates. Homing in on eligible males against all this crooning presents a challenge for females, akin to straining to understand a friend at a raucous party. But by inflating her lungs, an American green tree frog (*Hyla cinerea*) can make her eardrums less sensitive to the sounds of other species, researchers report online March 4 in *Current Biology*.

"We think the lungs are working a bit like some noise-canceling headphones," says Norman Lee, a neuroethologist at St. Olaf College in Northfield, Minn., allowing females to filter out environmental noise at the eardrum itself.

An eardrum is taut tissue that vibrates when sound waves hit it, the first step in translating the bleating and buzzing of the world into signals that get processed in the brain. To mammals like us, eardrums and lungs seem unrelated. But in frogs, there's a direct connection via an open space that runs through the throat and into the head. That lets frog eardrums both pick up sound from outside the ear and register vibrations from the lungs.

When inflated, the lungs of female green tree frogs (one shown mating) act as noise-canceling headphones, reducing sensitivity to the mating calls of other frog species.

Earlier research hinted that this lung-to-ear connection might boost a female frog's ability to pinpoint a suitor's call by providing an extra input of sound. But that hypothesis didn't pan out when Lee and his colleagues tested it in the lab.

Instead, they found something strange when they played female frogs a suite of sounds and measured the frogs' vibrations with a laser. Between 1,400 and 2,200 hertz, the frogs' inflated lungs resonated with extra vibrations, and eardrum movement quieted by the equivalent of four to six decibels, on average.

"That's a difference that would be noticeable by a frog," says Lee, who conducted the research at the University of Minnesota in St. Paul. Somehow, the vibrations of the lungs cancel out sounds of the same frequency at the eardrum, reducing sensitivity in this range.

This sensitivity dip falls just between the two most prominent frequencies of a male green tree frog's croak, suggesting that inflated lungs don't affect a female's ability to hear her own species. But the dip coincides with the dominant frequencies of five species, including bullfrogs and barking tree frogs, that are often found calling at the same ponds. How the lungs quiet sounds at the eardrum remains unclear, but the resulting noise reduction allows females to focus on calls that matter, the researchers say.

"I was almost overwhelmed by this paper," says evolutionary biologist Mike Ryan of the University of Texas at Austin. These frogs are in noisy environments, Ryan says, and sifting through the clamor to find relevant signals requires a lot of brain processing power. "This lung trick really cleans up the sounds" before they even reach the brain, he says. "We don't think of the lungs playing a role in hearing, but the way this is working is just really, really cool." ■

LIFE & EVOLUTION

Bonobos take in infant outsiders

Adoption from different groups is a first for great apes

BY CAROLYN WILKE

Attentive parenting appears across the animal world, but adoption is rarer, especially when youngsters taken in aren't kin. Now researchers have witnessed bonobos adopting infants from outside of their own communities.

Two females, each from a different bonobo group in the Luo Scientific Reserve in Congo, took charge of infants from other groups — grooming them, carrying them and providing food for at least a year. Two instances of adopted outsiders are known in other nonhuman primates, but this is the first time it's been observed in great apes, researchers report March 18 in *Scientific Reports*.

During a week when the scientists couldn't observe the bonobos, two groups each gained an infant. One mom named Marie was already caring for two infants when she adopted Flora, identified from her facial features and color patterns as formerly part of another group. Marie carried and nursed Flora and her youngest biological daughter and groomed all three. "She seemed to be very tired but was a great mother," says Nahoko Tokuyama, a primatologist at Kyoto University in Japan. Sometimes Marie favored her offspring, grooming them more frequently than she did Flora.

Tokuyama and her colleagues also noticed that a female bonobo named Chio, estimated to be in her mid-50s, had adopted an infant the team dubbed Ruby. Though Chio probably wasn't producing milk, she suckled Ruby. Neither infant was maternally related to any female in their new group, a genetic analysis found.

Seeing caretaking beyond the group "blew me away," says ethologist Cat Hobaiter of the University of St. Andrews in Scotland, who wasn't part of the study. Chimpanzees, for example, may adopt siblings and unrelated orphans from

N. LEE

within their clique. But chimps, who along with bonobos are humans' closest living evolutionary relatives, can be hostile toward and even kill outsider infants.

In many ways, the adoptions make sense, Hobaiter says. Unlike chimps, bonobos are notoriously tolerant and seek opportunities to interact with members of other groups. Groups come together for days to "share food and sex and everything else with the neighbors in a really free way," she says.

Researchers sometimes attribute adoptions to females practicing maternal care skills or helping their kin and advancing their genes. But with unrelated adoptees and females who have already raised young, those explanations don't fit the new observations. The adoptions may stem from bonobos' nature, Tokuyama says, including their empathy, tolerance and tendency toward behavior that benefits others (*SN: 6/23/18, p. 6*).

Such behavior may pay off down the line, says Klaree Boose, a primatologist at the University of Oregon in Eugene who wasn't part of the work. In bonobo society, in which females typically hold the highest ranks, youngsters could remain allies even after joining another group, helping their adoptive mothers when the groups cross paths. But the researchers will have to wait to see where the adoptees' allegiances lie. ■

A bonobo named Marie (left) grooms Flora (right), an infant that Marie adopted from another social group. Such adoptions have never before been observed among great apes.

N. TOKUYAMA

LIFE & EVOLUTION

Cone snails may lure prey with venom

Experiments show the poison mimics bristle worm mating signals

BY JONATHAN LAMBERT

Normally, it takes the waxing and waning of the moon to coax certain worms from their hiding spots on the seafloor to mate. Out in the open, sex-inducing chemicals kick off a swirling dance that culminates in a shower of eggs and sperm.

But just a whiff of cone snail venom might also get the worms in the mood.

Conus imperialis venom contains two molecules that mimic bristle worm pheromones and can stimulate mating behaviors, researchers report in the March 10 *Science Advances*. The find raises the possibility that the cone snails are "weaponizing the worms' own pheromone as a sort of lure," says medicinal chemist Joshua Torres of the University of Copenhagen. "It's really wild."

Cone snails pack their potent venom into self-made harpoons that they fling into fish, mollusks or worms. The venom of each of the more than 700 cone snail species is a treasure trove of chemicals that hijack specific physiological pathways in their prey. For example, one cone snail species produces its own fish insulin that saps prey's blood sugar, making a lethargic target. (*SN: 2/21/15, p. 15*).

The venom's specificity of action has attracted drug researchers' attention. A painkiller used as an alternative to morphine, called Prialt, for example, was inspired by cone snails. Torres and his colleagues were keen to scour the venom of *C. imperialis*, an Indo-Pacific species that hunts worms, for possible drugs. Chemical analysis revealed two compounds, conazolium A and genuanine, that piqued the researchers' interest.

To Torres' surprise, these molecules didn't seem to target neuromuscular pathways and impair their function, like many venom constituents. But the molecules were remarkably similar to some bristle worms' mating pheromones. Chemically, the snail's mimics are actually more stable than the worm pheromones, which degrade relatively quickly after release, Torres says. The match seemed too perfect to be coincidental.

While venom usually does its dirty work via injection, there are some examples of cone snails releasing chemicals into the water. To test the lure hypothesis, the researchers exposed *Platynereis dumerilii* worms in petri dishes to the pheromone mimics. When hit with the snail chemicals, 13 of 16 males in the experiment released sperm, and seven of 11 females began swirling around in tight circles — a precursor to mating. While *C. imperialis* isn't known to eat this specific worm, the researchers found the DNA of close relatives in the guts of some snails, suggesting that the compounds could be used against more typical prey, such as fireworms.

"Cone snails are full of surprises, and this paper raises an exciting possibility," says Thomas Duda, a zoologist and evolutionary biologist at the University of Michigan in Ann Arbor who wasn't involved in the study. "The next step needs to be figuring out how this actually works in nature."

C. imperialis' hunting behavior is mostly known from laboratory studies, where worms are sitting ducks for snails, Torres says. In the wild, however, worms spend time hidden below sediment and under crevices. Observations in more natural settings could confirm whether *C. imperialis*' specialized venom entices worms with the promise of a mate, only to make them a meal. ■

Watch a video of the snail venom in action at **bit.ly/SN_ConeSnail**

EARTH & ENVIRONMENT

Aftermath of Australia's fires

One year later, hundreds of species may face extinction

Glossy black cockatoos on Kangaroo Island are one species bouncing back from Australia's catastrophic wildfires, thanks to a prolific fledgling year in 2020.

ANDREW PEACOCK/ISTOCK/GETTY IMAGES PLUS

BY JOHN PICKRELL

As Isabel Hyman prepared to head out to the wilds of northern New South Wales in March, she was worried about what she wouldn't find. Fifteen years ago, the mollusk researcher with the Australian Museum made an incredible discovery among the limestone outcrops there: a 3-millimeter-long snail, with a ribbed, golden brown shell, that was new to science.

Subsequently named after her husband, Hugh Palethorpe, Palethorpe's pinwheel snail (*Rhophodon palethorpei*) "is only known from a single location," she says. Now it may become known for a more devastating distinction: It is one of hundreds of species that experts fear have been pushed close to, or right over, the precipice of extinction by the wildfires that blazed across more than 10 million hectares of southeastern Australia in the summer of 2019–2020.

"This location was completely burnt," says Hyman, who is based in Sydney. "We expect the mortality at this site could be very high and ... there is a possibility this species is extinct."

A year after the last of the fires were doused, their toll is becoming increasingly clear. Flames devoured more than 20 percent of Australia's temperate forest cover, according to a 2020 analysis in *Nature Climate Change*. Even if plants and animals survived, their habitats may have been so changed that their survival is at risk. Experts estimate that more than 500 species of plants and animals may now be threatened, endangered — or completely gone.

The koala became the poster child of the crisis as images of rescuers carrying singed koalas out of the flames went global: More than 60,000 of the nation's estimated 330,000 koalas were killed or harmed by the fires, ecologists concluded in December in a report for WWF-Australia. But the greatest toll is likely to have been in other species that often escape the public's attention.

As Kingsley Dixon, an ecologist at Curtin University in Perth, told the Associated Press last year: "I don't think we've seen a single event in Australia that has destroyed so much habitat and pushed so many creatures to the very brink of extinction."

Vanishing vertebrates

Even before the fires, many vertebrate species were already on downward trends, says John Woinarski, an ecologist at Charles Darwin University in Darwin. The blazes have "exacerbated the threats that were driving the declines," he says.

For example, arboreal marsupials called greater gliders (*Petauroides volans*) had already experienced a 50 percent population decline in recent decades. The fires then burned a third of their remaining habitat along Australia's eastern coastline. An ongoing assessment may lead to the gliders being recategorized from vulnerable to endangered.

Overall, 49 vertebrates now qualify for being listed as threatened under Australian guidelines, researchers reported in July in *Nature Ecology & Evolution*. That shift would increase the tally of nationally protected nonmarine vertebrate species by about 15 percent, from 324 to 373.

Another 21 already threatened vertebrates had more than 30 percent of their ranges burned, and some may now qualify for higher categories of threat, the authors found.

The WWF-Australia report suggests that as many as 3 billion individual mammals, birds, reptiles and frogs were displaced, harmed or killed during the crisis. Though those figures are astounding, the impacts on invertebrates and plants may have been even greater.

Invertebrate impact

In February, more than 100 biologists convened the first of several online workshops to assess whether 234 Australian invertebrates now need to be added to the International Union for Conservation of Nature's Red List — a global who's who of threatened species.

Snails, similar to many invertebrates, are particularly susceptible to wildfires, as they are unable to outrun flames and can't survive intense heat, Hyman notes. Many also have small ranges that were completely incinerated, possibly leaving no survivors that can recolonize the burned area.

"A snail can't do much to escape," she says. "You could expect more than 90 percent mortality in a high-intensity bushfire." In October, Hyman's team published one of the first papers quantifying the impacts on invertebrates in New South Wales in the *Technical Reports of the Australian Museum, Online*.

The team's surveys showed that 29 species, including dung beetles, freshwater crayfish, flies, snails and spiders, had their entire ranges burned. Another 46 species had at least half their known habitat within the fire zones. Together, those 75 species were among the 234 under consideration for adding to the IUCN Red List.

"We've gathered together 230-odd species that are believed to now be of concern. These include a range of different taxa from land snails to millipedes to arachnids to insects, and this 230 is growing rapidly," says arachnologist Jess Marsh of Charles Darwin University, who was one of the conveners of the February workshop.

Some of the spiders she studies were the first to be added to that list. She has already spent several months on South Australia's Kangaroo Island searching without luck for the Kangaroo Island assassin spider (*Zephyrarchaea austini*). Dependent on leaf litter suspended in the understory, and restricted to just a few locations that were burned in early 2020, the species may be extinct, she says.

Generally, the species being considered for endangered status had more than 50 percent of their ranges burned, lived in flammable parts of the habitat and have little ability to disperse to other areas. Another problem is the reshaped environment left behind by the flames. Millipedes, for example, are very vulnerable not only to fire but also to drying out in the reduced shade and shelter of the postfire environment.

"A lot of invertebrates are very susceptible to desiccation, and need cover and humidity to survive a hot summer," Marsh says. "Taking into account all of the threats ... we could be looking at significant numbers going extinct."

Rooted in place

Many plants may also be at risk, though experts have yet to compile an official list.

Rachael Gallagher, a plant ecologist at Macquarie University in Sydney, has been prioritizing for the Australian government the endemic plant species that are in most urgent need of conservation. She's particularly worried about some trees that actually depend on fire to survive. Eucalypts known as alpine ash (*Eucalyptus delegatensis*) and mountain ash (*E. regnans*), for instance, are typically killed by fire and then the forests regenerate from surviving seeds in the aftermath. Australia has many trees that must complete their entire life cycle from germination through to reproductively mature adult before the next major bushfire passes through. For some species, this may take 15 to 20 years.

But climate change has increased the frequency of fires so much that many of these plants are unable to reach adulthood and set seed before the next fire passes through, meaning they may be lost from the ecosystem.

The fires burned 25 to 100 percent of the ranges of 257 plant species for which "the historical intervals between fire events across their range are likely to be too short to allow them to effectively regenerate," Gallagher says. These species are at "increased risk of extinction."

Found, not lost

Nevertheless, as researchers head out into the field to assess what's lost, they are finding glimmers of hope. "There's been regeneration in places where nobody thought there would be," Gallagher says.

One species that survived against all odds is the Gibraltar Range waratah (*Telopea aspera*), a drought-resistant shrub with leathery leaves and bright red flowers. "This species has a very small range, being specialized to granite outcrops in one mountain range, which was burnt during the fires," Gallagher says. Park rangers have seen it resprouting, she says, "and in the absence of another fire in coming years, is likely to be able to recover."

Several animal species that were thought to be in grave peril on Kangaroo Island have survived better than expected too. For instance, tiny marsupial carnivores called Kangaroo Island dunnarts (*Sminthopsis aitkeni*) are frequently appearing on camera traps. Swiftly erected predator-exclusion fences now protect survivors from feral cats.

Similarly, large flocks of the glossy black cockatoo (*Calyptorhynchus lathami*) have adapted by moving to unburned areas with food trees, says Karleah Berris of Natural Resources Kangaroo Island, who heads the crew that manages the endangered birds. A surprising number of birds bred and fledged young in mid-2020. "The important thing now is to protect what is left from fire until the burnt areas regenerate," she says. "But I think, at present, all signs are that they are coping."

Hyman says her team found handfuls of survivors of some snail species during surveys in New South Wales in late 2020. The snails turned up in small patches of unburned habitat, sometimes at the bottom of gullies or in deep leaf litter around the bases of large trees. That gives her hope that other snail species may have held on in other, larger unburned patches with greater numbers of survivors.

"But the question then becomes, what sort of recovery can they make?" she says. "Whether they can recover and breed up and start to move back into surviving areas again perhaps depends on how dry the weather is in coming years and if there are more fires."

Before heading off into the bush, she was still hoping that a handful of Palethorpe's pinwheel snails may have clung on. "My husband is on tenterhooks wondering if his snail is still there or not," she says. ■

Some trees, such as the mountain ash (shown), depend on fire for their life cycle, but recent wildfires may have been too much too soon.

STATION96/ISTOCK/GETTY IMAGES PLUS

ScienceNews 100

This article is an excerpt from a series celebrating some of the biggest advances in science over the last century. For an expanded version of the story of the atom's power, and to see the rest of the series, visit www.sciencenews.org/century

Calder Hall, in Cumbria, England, was the first full-scale commercial nuclear power plant (shown in 1962).

BETTMANN/GETTY IMAGES

Cracking the Atom

Over the last 100 years, scientists reshaped our knowledge of matter and our ability to control it **By Emily Conover**

Matter is a lush tapestry, woven from a complex assortment of threads. Diverse subatomic particles weave together to fabricate the universe we inhabit. But a century ago, people believed that matter was so simple that it could be constructed with just two types of subatomic fibers — electrons and protons. That vision of matter was a no-nonsense plaid instead of an ornate brocade.

Physicists of the 1920s thought they had a solid grasp on what made up matter. They knew that atoms contained electrons surrounding a positively charged nucleus. And they knew that each nucleus contained a number of protons, positively charged particles identified in 1919. Combinations of those two particles made up all of the matter in the universe, it was thought. That went for everything that ever was or might be, across the vast, unexplored cosmos and at home on Earth.

The scheme was appealingly tidy, but it swept under the rug a variety of hints that all was not well in physics. Two discoveries in one revolutionary year, 1932, forced physicists to peek underneath the carpet. First, the discovery of the neutron unlocked new ways to peer into the hearts of atoms and even split them in two. Then came news of the positron, identical to the electron but with the opposite charge. Its discovery foreshadowed many more surprises to come. Additional particle discoveries ushered in a new framework for the fundamental bits of matter, now known as the standard model.

That "annus mirabilis" — miraculous year — also set physicists' sights firmly on the workings of atoms' hearts, how they decay, transform and react. Discoveries there would send scientists careening toward a most devastating technology: nuclear weapons. The atomic bomb cemented the importance of science — and science journalism — in the public eye, says nuclear historian Alex Wellerstein of the Stevens Institute of Technology in Hoboken, N.J. "The atomic bomb becomes the ultimate proof that ... indeed this is world-changing stuff."

Two-particle appeal

Physicists of the 1920s embraced a particular type of conservatism. Embedded deep in their psyches was a reluctance to declare the existence of new particles. Researchers stuck to the status quo of matter composed solely of electrons and protons — an idea dubbed the "two-particle paradigm" that held until about 1930. In that time period, says historian of science Helge Kragh of the University of Copenhagen, "I'm quite sure that not a single mainstream physicist came up with the idea that there might exist more than two particles." The utter simplicity of two particles explaining everything in nature's bounty was so appealing to physicists' sensibilities that they found the idea difficult to let go of.

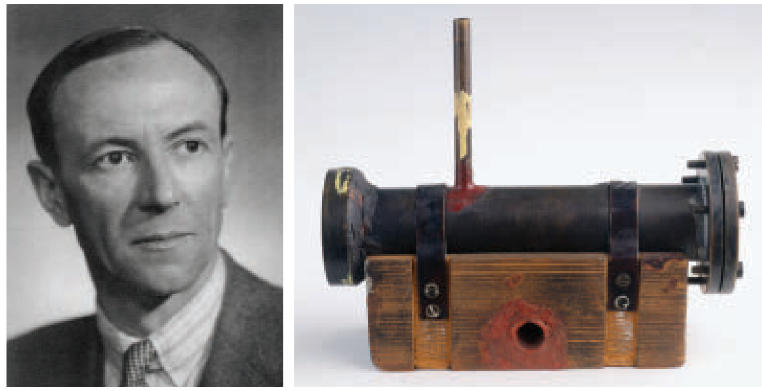
The paradigm held back theoretical descriptions of the neutron and the positron. "To propose the existence of other particles was widely regarded as reckless and contrary to the spirit of Occam's razor," science biographer Graham Farmelo wrote in *Contemporary Physics* in 2010.

Still, during the early 20th century, physicists were investigating a few puzzles of matter that would, after some hesitation, inevitably lead to new particles. These included unanswered questions about the identities and origins of energetic particles called cosmic rays, and why chemical elements occur in different varieties called isotopes, which have similar chemical properties but varying masses.

The neutron arrives

New Zealand–born British physicist Ernest Rutherford stopped just short of positing a fundamentally new particle in 1920. He realized that neutral particles in the nucleus could explain the existence of isotopes. Such particles came to be known as "neutrons." But rather than proposing that neutrons were fundamentally new, he thought they were composed of protons combined in close proximity with electrons to make neutral particles. He was correct about the role of the neutron, but wrong about its identity.

Rutherford's idea was convincing, British physicist James Chadwick recounted in a 1969 interview: "The only question was how the devil could one get evidence for it." The neutron's lack of electric charge made it a particularly wily target. In between work on other projects, Chadwick began hunting for the particles at the University of Cambridge's Cavendish Laboratory, then led by Rutherford.



Physicist James Chadwick used this device to discover the neutron in 1932, based on radiation emitted after beryllium was hit with alpha particles, the nuclei of helium atoms.

Chadwick found his evidence in 1932. He reported that mysterious radiation emitted when beryllium was bombarded with the nuclei of helium atoms could be explained by a particle with no charge and with a mass similar to the proton's. In other words, a neutron. Chadwick didn't foresee the important role his discovery would play. "I am afraid neutrons will not be of any use to anyone," he told the *New York Times* shortly after his discovery.

Physicists grappled with the neutron's identity over the following years before accepting it as an entirely new particle, rather than the amalgamation that Rutherford had suggested. For one, a proton-electron mash-up conflicted with the young theory of quantum mechanics, which characterizes physics on small scales. The Heisenberg uncertainty principle — which states that if the location of an object is well-known, its momentum cannot be — suggests that an electron confined within a nucleus would have an unreasonably large energy.

And certain nuclei's spins, a quantum mechanical measure of angular momentum, likewise suggested that the neutron was a full-fledged particle, as did improved measurements of the particle's mass.

Positron perplexity

Physicists also resisted the positron, until it became difficult to ignore.

The positron's 1932 detection had been foreshadowed by the work of British theoretical physicist Paul Dirac. But it took some floundering about before physicists realized the meaning of his work. In 1928, Dirac formulated an equation that combined quantum mechanics with Albert Einstein's 1905 special theory of relativity, which describes physics close to the speed of light. Now known simply as the Dirac equation, the expression explained the behavior of electrons in a way that satisfied both theories.

But the equation suggested something odd: the existence of another type of particle, one with the opposite electric charge.

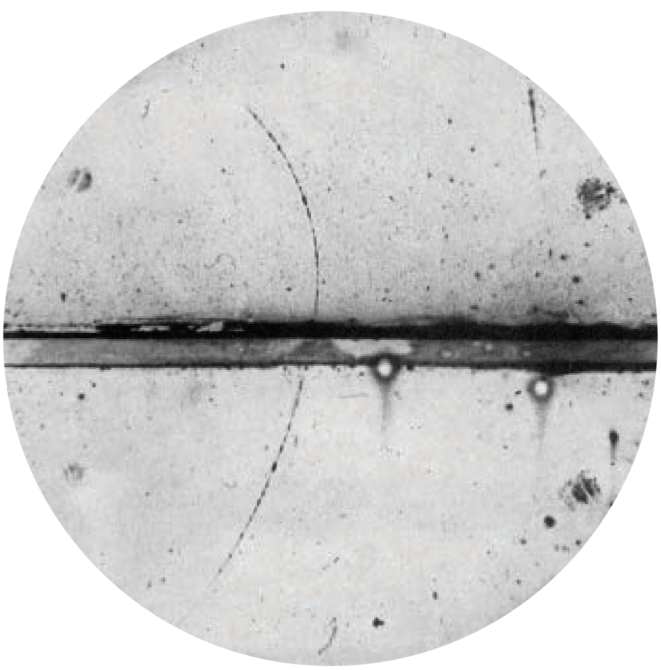
At first, Dirac and other physicists clung to the idea that this charged particle might be the proton. But this other particle should have the same mass as the electron, and protons are almost 2,000 times as heavy as electrons. In 1931, Dirac proposed a new particle, with the same mass as the electron but with opposite charge.

Meanwhile, American physicist Carl Anderson of Caltech, independent of Dirac's work, was using a device called a cloud chamber to study cosmic rays, energetic particles originating in space. Cosmic rays, discovered in 1912, fascinated scientists, who didn't fully understand what the particles were or how they were produced.

Within Anderson's chamber, liquid droplets condensed along the paths of energetic charged particles, a result of the particles ionizing gas molecules as they zipped along. In 1932, the experiments revealed positively charged particles with masses equal to an electron's. Soon, the connection to Dirac's theory became clear.

Science News Letter, the predecessor of *Science News,* had a hand in naming the newfound particle. Editor Watson Davis proposed "positron" in a telegram to Anderson, who had independently considered the moniker, according to a 1933 *Science News Letter* article (*SN: 2/25/33, p. 115*). In a 1966 interview, Anderson recounted considering Davis' idea during a game of bridge, and finally going along with it. He later regretted the choice, saying in the interview, "I think that's a very poor name."

The discovery of the positron, the antimatter partner of the electron, marked the advent of antimatter research. Antimatter's existence still seems baffling today. Every object we can see and touch is made of matter, making antimatter seem downright extraneous. Antimatter's lack of relevance to daily life — and the term's liberal use in *Star Trek* — means that many nonscientists still envision it as the stuff of science fiction. But even a banana sitting on a counter emits antimatter, periodically spitting out positrons in radioactive decays of the potassium within.



A particle track in a cloud chamber in the early 1930s was the first evidence of a positron, a positively charged particle with the mass of an electron. The track curves due to a magnetic field, and the curvature increases as the positron loses energy after crossing the center lead plate from below.

C.D. ANDERSON/WIKIMEDIA COMMONS

Physicists would go on to discover many other antiparticles — all of which are identical to their matter partners except for an opposite electric charge — including the antiproton in 1955. The subject still keeps physicists up at night. The Big Bang should have produced equal amounts matter and antimatter, so researchers today are studying how antimatter became rare.

In the 1930s, antimatter was such a leap that Dirac's hesitation to propose the positron was understandable. Not only would the positron break the two-particle paradigm, but it would also suggest that electrons had mirror images with no apparent role in making up atoms. When asked, decades later, why he had not predicted the positron after he first formulated his equation, Dirac replied, "pure cowardice."

But by the mid-1930s, the two-particle paradigm was out. Physicists' understanding had advanced, and their austere vision of matter had to be jettisoned.

Unleashing the atom's power

Radioactive decay hints that atoms hold stores of energy locked within, ripe for the taking. Although radioactivity was discovered in 1896, that energy long remained an untapped resource. The neutron's discovery in the 1930s would be key to unlocking that energy — for better and for worse.

The neutron's discovery opened up scientists' understanding of the nucleus, giving them new abilities to split atoms into two or transform them into other elements. Developing that nuclear know-how led to useful technologies, like nuclear power, but also devastating nuclear weapons.

Just a year after the neutron was found, Hungarian-born physicist Leo Szilard envisioned using neutrons to split atoms and create a bomb. "[I]t suddenly occurred to me that if we could find an element which is split by neutrons and which would emit two neutrons when it absorbed one neutron, such an element, if assembled in sufficiently large mass, could sustain a nuclear chain reaction, liberate energy on an industrial scale, and construct atomic bombs," he later recalled. It was a fledgling idea, but prescient.

Because neutrons lack electric charge, they can penetrate atoms' hearts. In 1934, Italian physicist Enrico Fermi and colleagues started bombarding dozens of different elements with neutrons, producing a variety of new, radioactive isotopes. Each isotope of a particular element contains a different number of neutrons in its nucleus, with the result that some isotopes may be radioactive while others are stable. Fermi had been inspired by another striking discovery of the time. In 1934, French chemists Frédéric and Irène Joliot-Curie reported the first artificially created radioactive isotopes, produced

Lise Meitner (left) and Otto Hahn (shown in their lab in Germany in 1913) established that atoms could split, or fission, when bombarded with neutrons. The two worked together before Nazi policies forced Meitner to flee to Sweden.

by bombarding elements with helium nuclei, called alpha particles. Now, Fermi was doing something similar, but with a more penetrating probe.

There were a few scientific missteps on the way to understanding the results of such experiments. A major goal was to produce brand-new elements, those beyond the last known element on the periodic table at that time: uranium. After blasting uranium with neutrons, Fermi and colleagues reported evidence of success. But that conclusion would turn out to be incorrect.

German chemist Ida Noddack had an inkling that all was not right with Fermi's interpretation. She came close to the correct explanation for his experiments in a 1934 paper, writing: "When heavy nuclei are bombarded by neutrons, it is conceivable that the nucleus breaks up into several large fragments." But Noddack didn't follow up on the idea. "She didn't provide any kind of supporting calculation and nobody took it with much seriousness," says physicist Bruce Cameron Reed of Alma College in Michigan.

In Germany, physicist Lise Meitner and chemist Otto Hahn had also begun bombarding uranium with neutrons. But Meitner, an Austrian of Jewish heritage in increasingly hostile Nazi Germany, was forced to flee in July 1938. She had an hour and a half to pack her suitcases. Hahn and a third member of the team, chemist Fritz Strassmann, continued the work, corresponding from afar with Meitner, who had landed in Sweden. The results of the experiments were puzzling at first, but when Hahn and Strassmann reported to Meitner that barium, a much lighter element than uranium, was a product of the

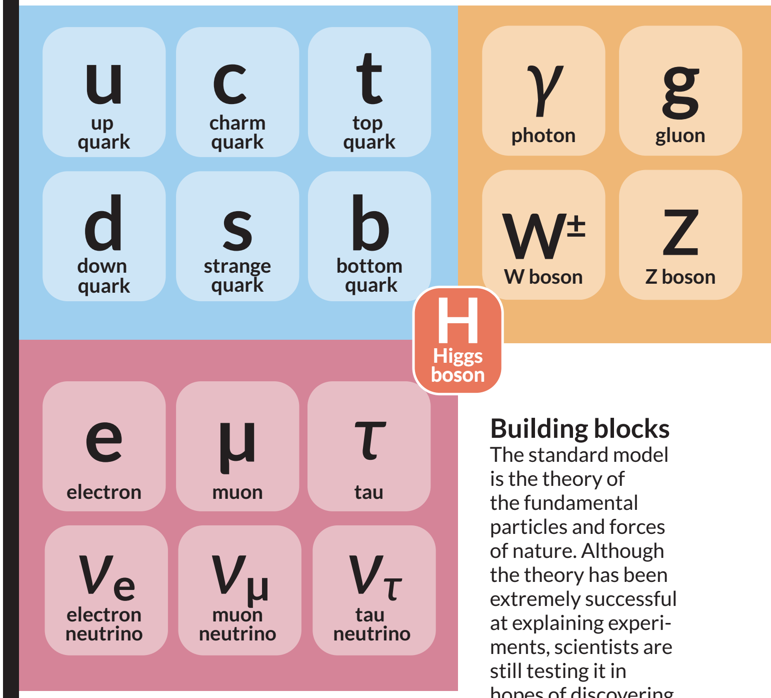
FROM TOP: SMITHSONIAN INSTITUTION/SCIENCE PHOTO LIBRARY; T. TIBBITTS

The standard model

In the 1950s, physicists began to realize that matter was even more complicated than they'd thought, as particle accelerators, machines that smash particles together at high energies, revealed a wide variety of previously unknown subatomic constituents. Today, a framework known as the standard model describes the complexity that exists on subatomic scales. Notably, that complexity includes particles called quarks, proposed in 1964 and confirmed in experiments over the next decade. Mashed together in different combinations, quarks make up a variety of larger particles, including protons and neutrons.

The standard model is a coherent picture of the fundamental particles and forces of nature, and the work of many physicists operating independently and in groups. It consists of 17 particles, many of which have antiparticle partners. Included on the list are six types of quarks (blue) and six leptons (red). Electrons and their heavier relatives, muons and taus, are leptons, as are a trio of lightweight particles called neutrinos. The Higgs boson (center) explains the origin of particles' mass.

The standard model also accounts for three of the four known fundamental forces: electromagnetism, the weak nuclear force and the strong nuclear force. The force-carrying particles (orange) transmit these forces. The weak force governs certain radioactive decays, and the strong force holds quarks together inside particles. (One of nature's most familiar forces, gravity, is not yet incorporated into the framework.) *— Emily Conover*



Building blocks The standard model is the theory of the fundamental particles and forces of nature. Although the theory has been extremely successful at explaining experiments, scientists are still testing it in hopes of discovering any flaws.

reaction, it became clear what was happening. The nucleus was splitting.

Meitner and her nephew, physicist Otto Frisch, collaborated to explain the phenomenon, a process the pair would call "fission." Hahn received the 1944 Nobel Prize in chemistry for the discovery of fission, but Meitner never won a Nobel, in a decision now widely considered unjust. Meitner was nominated for the prize — sometimes in physics, other times in chemistry — a whopping 48 times, most after the discovery of fission.

"Her peers in the physics community recognized that she was part of the discovery," says chemist Ruth Lewin Sime of Sacramento City College in California, who has written extensively about Meitner. "That included just about anyone who was anyone."

Word of the discovery soon spread, and on January 26, 1939, renowned Danish physicist Niels Bohr publicly announced at a scientific meeting that fission had been achieved. The potential implications were immediately apparent: Fission could unleash the energy stored in atomic nuclei, potentially resulting in a bomb. A *Science News Letter* story describing the announcement attempted to dispel any concerns the discovery might raise. The article, titled "Atomic energy released," reported that scientists "are fearful lest the public become worried about a 'revolution' in civilization as a result of their researches," such as "the suggested possibility that the atomic energy may be used as some super-explosive, or as a military weapon" (*SN: 2/11/39, p. 86*). But downplaying the catastrophic implications didn't prevent them from coming to pass.

A ball of fire

The question of whether a bomb could be created rested, once again, on neutrons. For fission to ignite an explosion, it would be necessary to set off a chain reaction. That means each fission would release additional neutrons, which could then go on to induce more fissions, and so on. Experiments quickly revealed that enough neutrons were released to make such a chain reaction feasible.

In October 1939, soon after Germany invaded Poland at the start of World War II, an ominous letter from Albert Einstein reached President Franklin Roosevelt. Composed at the urging of Szilard, by then at Columbia University, the letter warned, "it is conceivable ... that extremely powerful bombs of a new type may thus be constructed." American researchers were not alone in their interest in the topic: German scientists, the letter noted, were also on the case.

Roosevelt responded by setting up a committee to investigate. That step would be the first toward the U.S. effort to build an atomic bomb, the Manhattan Project.

On December 2, 1942, Fermi, who by then had immigrated to the United States, and 48 colleagues achieved the first controlled, self-sustaining nuclear chain reaction in an experiment with a pile of uranium and graphite at the University of Chicago. *Science News Letter* would later call it "an event ranking with man's first prehistoric lighting of a fire" (*SN: 12/6/52, p. 358*). While the physicists celebrated their success, the possibility of an atomic bomb was closer than ever. "I thought this day would go down as a black day in the history of mankind," Szilard recalled telling Fermi.

The experiment was a key step in the Manhattan Project. And on July 16, 1945, at about 5:30 a.m., scientists led by J. Robert Oppenheimer detonated the first atomic bomb, in the New Mexico desert — the Trinity test.

It was a striking sight, as physicist Isidor Isaac Rabi recalled in his 1970 book, *Science: The Center of Culture*. "Suddenly, there was an enormous flash of light, the brightest light I have ever seen or that I think anyone has ever seen. It blasted; it pounced; it bored its way right through you. It was a vision which was seen with more than the eye. It was seen to last forever. You would wish it would stop; although it lasted about two seconds. Finally it was over, diminishing, and we looked toward the place where the bomb had been; there was an enormous ball of fire which grew and grew and it rolled as it grew; it went up into the air, in yellow flashes and into scarlet and green. It looked menacing. It seemed to come toward one. A new thing had just been born; a new control; a new understanding of man, which man had acquired over nature."

Physicist Kenneth Bainbridge put it more succinctly: "Now we are all sons of bitches," he said to Oppenheimer in the moments after the test.

The bomb's construction was motivated by the fear that Germany would obtain it first. But the Germans weren't even close to producing a bomb when they surrendered in May 1945. Instead, the United States' bombs would be used on Japan. On August 6, 1945, the United States dropped an atomic bomb on Hiroshima, followed by another on August 9 on Nagasaki. In response, Japan surrendered. More than 100,000 people died as a result of the two attacks, and perhaps as many as 210,000.

"I saw a blinding bluish-white flash from the window. I remember having the sensation of floating in the air," survivor

The first controlled, self-sustaining nuclear chain reaction took place in a pile of uranium and graphite (at right in this illustration) at the University of Chicago in 1942.

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION

Setsuko Thurlow recalled in a speech given upon the awarding of the 2017 Nobel Peace Prize to the International Campaign to Abolish Nuclear Weapons. She was 13 years old when the bomb hit Hiroshima. "Thus, with one bomb my beloved city was obliterated. Most of its residents were civilians who were incinerated, vaporized, carbonized."

Nuclear anxieties

Humankind entered a new era, with new dangers to the survival of civilization. "With nuclear physics, you have something that within 10 years ... goes from being this arcane academic research area ... to something that bursts on the world stage and completely changes the relationship between science and society," Reed says.

In 1949, the Soviet Union set off its first nuclear weapon, kicking off the decades-long nuclear rivalry with the United States that would define the Cold War. And then came a bigger, more dangerous weapon: the hydrogen bomb. Whereas atomic bombs are based on nuclear fission, H-bombs harness nuclear fusion, the melding of atomic nuclei, in conjunction with fission, resulting in much larger blasts. The first H-bomb, detonated by the United States in 1952, was 1,000 times as powerful as the bomb dropped on Hiroshima. Within less than a year, the Soviet Union also tested an H-bomb. The H-bomb had been called a "weapon of genocide" by scientists serving on an advisory committee for the U.S. Atomic Energy Commission, which had previously recommended against developing the technology.

Fears of the devastation that would result from an all-out nuclear war have fed repeated attempts to rein in nuclear weapons stockpiles and tests. Since the signing of the Comprehensive Nuclear Test Ban Treaty in 1996, the United States, Russia and many other countries have maintained a testing moratorium. However, North Korea tested a nuclear weapon as recently as 2017.

Still, the dangers of nuclear weapons were accompanied by a promising new technology: nuclear power.

In 1948, scientists first demonstrated that a nuclear reactor could harness fission to produce electricity. The X-10 Graphite Reactor at Oak Ridge National Laboratory in Tennessee generated steam that powered an engine that lit up a small Christmas lightbulb. In 1951, Experimental Breeder Reactor-I at Idaho National Laboratory near Idaho Falls produced the first usable amount of electricity from a nuclear reactor. The world's first commercial nuclear power plants began to switch on in the mid- and late 1950s.

But nuclear disasters dampened enthusiasm for the technology, including the 1979 Three Mile Island accident in Pennsylvania and the 1986 Chernobyl disaster in Ukraine, then part of the Soviet Union. In 2011, the disaster at the Fukushima Daiichi power plant in Japan rekindled society's smoldering nuclear anxieties. But today, in an era when the effects of climate change are becoming alarming, nuclear power is appealing because it emits no greenhouse gases directly.

UPI/ALAMY STOCK PHOTO

Workers take measurements of radiation after the Chernobyl disaster in 1986, which raised awareness of the dangers of nuclear power.

And humankind's mastery over matter is not yet complete. For decades, scientists have been dreaming of another type of nuclear power, based on fusion, the process that powers the sun. Unlike fission, fusion power wouldn't produce long-lived nuclear waste. But progress has been slow. The ITER experiment has been in planning since the 1980s. Once constructed in southern France, ITER aims to, for the first time, produce more energy from fusion than is put in. Whether it is successful may help determine the energy outlook for future centuries.

From today's perspective, the breakneck pace of progress in nuclear and particle physics in less than a century can seem unbelievable. The neutron and positron were both found in laboratories that are small in comparison with today's, and each discovery was attributed to a single physicist, relatively soon after the particles had been proposed. Those discoveries kicked off frantic developments that seemed to roll in one after another.

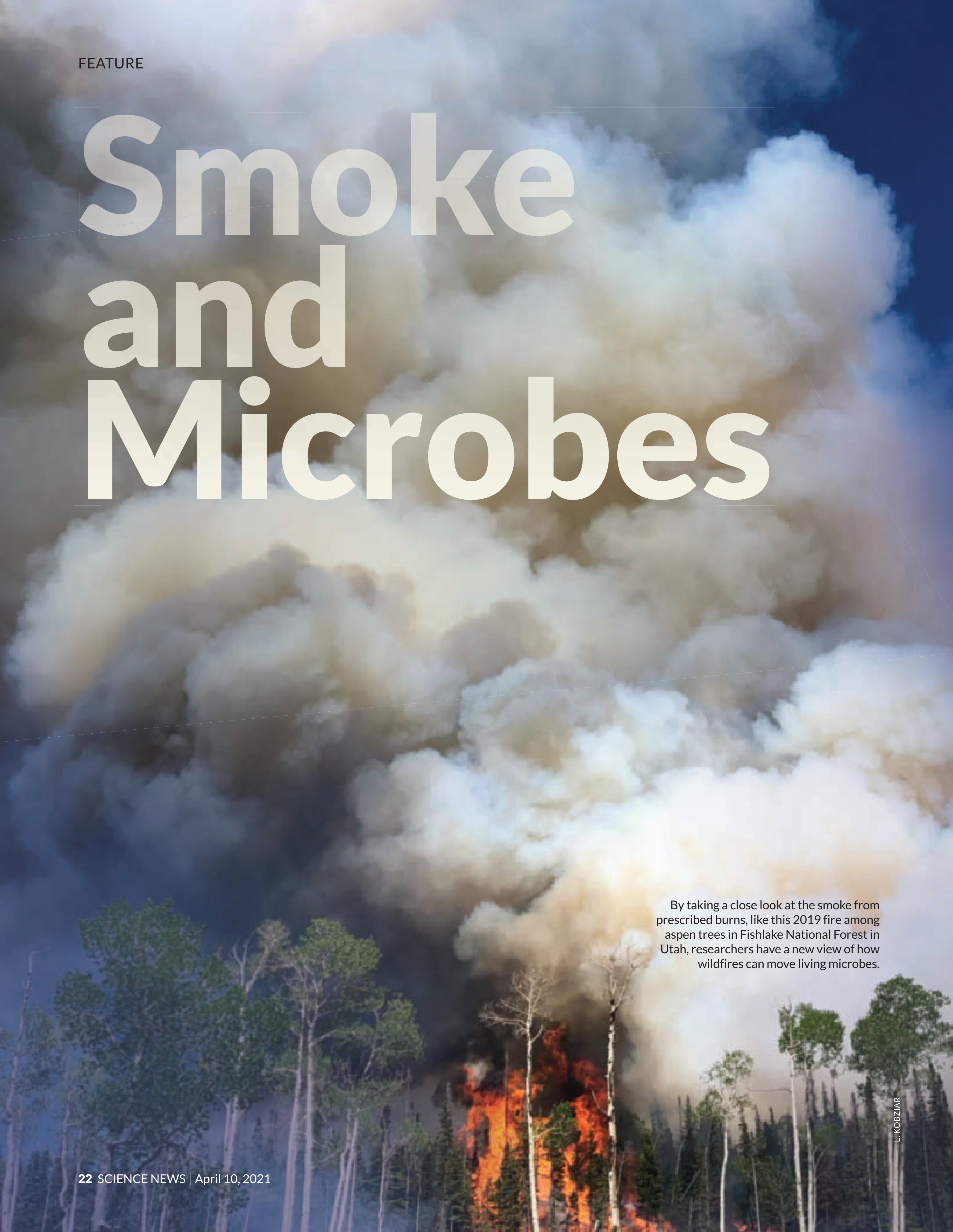
Now, finding a new element, discovering a new elementary particle or creating a new type of nuclear reactor can take decades, international collaborations of thousands of scientists, and huge, costly experiments.

As physicists uncover the tricks to understanding and controlling nature, it seems, the next level of secrets becomes increasingly difficult to expose. ■

Explore more

- Niels Bohr Library & Archives at the American Institute of Physics. "Oral history interviews." bit.ly/AIP_interviews
- Atomic Heritage Foundation. "Preserving and interpreting the Manhattan Project." www.atomicheritage.org

Smoke and Microbes



By taking a close look at the smoke from prescribed burns, like this 2019 fire among aspen trees in Fishlake National Forest in Utah, researchers have a new view of how wildfires can move living microbes.

L. KOBZIAR

How does wildfire smoke move bacteria and fungi — and what harm might they do to people when the microbes land?

By Megan Sever

As climate change brings more wildfires to the western United States, a rare fungal infection has also been on the rise. Valley fever is up more than sixfold in Arizona and California from 1998 to 2018, according to the U.S. Centers for Disease Control and Prevention.

Valley fever causes coughs, fevers and chest pain and can be deadly. The culprit fungi, members of the genus *Coccidioides*, thrive in soils in California and the desert Southwest. Firefighters are especially vulnerable to the disease. Wildfires appear to stir up and send the soil-loving fungi into the air, where they can enter people's lungs.

If the fires are helping these disease-causing fungi to get around, could they be sending other microorganisms aloft as well? Leda Kobziar, a fire ecologist at the University of Idaho in Moscow, decided in 2015 to see if she could find out if and how microorganisms like bacteria and fungi are transported by wildfire smoke — and what that might mean for human and ecological health.

By 2018, Kobziar had launched a new research field she named "pyroaerobiology." First, she asked if microorganisms can even survive the searing heat of a wildfire. The answer, she found, is yes. But how far bacteria and fungi can travel on the wind and in what numbers are two of the many big unknowns.

With a recent push to spark new collaborations and investigations, Kobziar hopes that scientists will start to understand how important smoke transport of microbes may be.

Invisible but pervasive

Air may look clear, but even in the cleanest air, "hundreds of different bacteria and fungi are blowing around," says Noah Fierer, a microbiologist at the University of Colorado Boulder.

Winds whisk bacteria and fungi off all kinds of surfaces — farm fields, deserts, lakes, oceans. Those microbes can rise into the atmosphere to travel the world. Scientists have found microorganisms from the Sahara in the Caribbean, for example.

Many (if not most) of the airborne microorganisms, including bacteria, fungi and viruses, are not likely to cause disease, Fierer notes. But some can make people sick or cause allergic reactions, he says. Others cause diseases in crops and other plants.

The billions of tons of dust that blow off of deserts and agricultural fields each year act as a microbial conveyor belt. In places like Arizona, people know to be alert for symptoms of airborne illnesses like Valley fever after dust storms, since infections increase downwind afterward. If dust can move living microorganisms around the globe, it makes sense that particulates in smoke would be microbe movers too, Kobziar says — assuming the microscopic life-forms can survive a fire and a spin in the atmosphere.

Tiny travelers

Rising temperatures and worsening droughts have led to longer and more intense wildfire seasons across the West (*SN: 9/26/20, p. 12*). Breathing wildfire smoke makes people sick (*SN Online: 9/18/20*), even causing premature death from heart and lung illnesses. In the United States, wildfire smoke causes about 17,000 premature deaths per year — a number projected to double by 2100, according to a 2018 study in *GeoHealth*.

In other parts of the world, the effects are far worse. In 2015, smoke from illegal land-clearing blazes plus wildfires in Indonesia killed an estimated 100,000 people across Southeast Asia, according to a 2016 report in *Environmental Research Letters*. Blame is usually attributed to particulate matter — organic and inorganic particles suspended in the air, including pollen, ash and pollutants. But scientists and health officials are increasingly realizing that there's an awful lot we don't know about what else in smoke is affecting human health.

The most intense fires, the ones that burn the hottest and release the most energy, can create their own weather systems and send smoke all the way into the stratosphere, which extends about 50 kilometers above Earth's surface (*SN: 9/14/19, p. 12*). Once there, smoke can travel around the world just as ash from explosive volcanoes does. Kobziar's team and others provided compelling evidence in the February *ISME Journal* that live, viable microorganisms can be carried in smoke plumes — at least near Earth's surface if not higher up.

In 2015, while at the University of Florida in Gainesville, Kobziar and her students collected the first air samples for this line of research during a series of planned, or prescribed, burns that Kobziar set at the school's experimental forest. The group arrived at the forest armed with 3-meter-long poles topped with petri dishes to collect samples from the air.

Before any fires were set, the team held the petri dishes in the air for three minutes to collect air samples as a pre-fire baseline. Then Kobziar, a certified prescribed burn manager (or as she calls it, a "fire lighter"), lit the fires. Once flames were spreading at a steady rate and smoke was billowing, students hoisted new petri dishes into the smoke, almost as if aiming a marshmallow on a stick at a campfire. This allowed them to collect smoky air samples to compare to the "before" samples.

Back in the lab, in a dark room held at a constant 23° Celsius, both the baseline and smoky petri dishes — covered and sealed from further contamination — were left for three days. Microbes began to grow. Far more bacterial and fungal species populated the smoky petri dishes than the baseline dishes, indicating that the fire aerosolized some species that weren't in the air before the fire, Kobziar says.

"We were stunned at how many different microbial colonies survived the combustion environment and grew in the smoke samples, compared to very few in the ambient air," she says. Based on DNA tests, Kobziar's team identified 10 types of bacteria and fungi; some are pathogenic to plants, one is an ant parasite and one helps plants absorb nutrients. "This was the moment when the way we thought about smoke was completely transformed," she says.

In 2017, after Kobziar had moved to Idaho, her team collected soil samples from the University of Idaho's experimental forest and burned them — this time, in the lab. As smoke unfurled above the burning soils, the researchers collected air samples, and again, sealed them and put them in a dark, warm room to see what would grow. After a week, lots of different microbes, including fungi, had multiplied into colonies on the plates, the researchers reported in 2018 in *Ecosphere*.

Alive and on the move

Since then, Kobziar's team has collected more air samples during prescribed burns of varying intensities in Florida, Idaho, Montana and Utah, joining forces with the U.S. Forest Service Fire and Smoke Model Evaluation Experiment, or FASMEE, team. For her students' safety, she's replaced the poles and petri dishes with drones. She sends a single drone carrying a vacuum pump with a filter into smoke plumes at varying altitudes up to 120 meters, the team described in the journal *Fire* in 2019.

In every experiment, the researchers have found living bacteria and fungi, many of which were not found in any of the air samples taken before the fires. In Utah smoke samples, for example, the FASMEE team found more than 100 different fungi that were not in the air before the fire, Kobziar says. Findings included species of *Aspergillus*, which can cause fevers, coughs and chest pain, as well as *Cladosporium*, molds that can cause allergies and asthma.

Whether any of these microorganisms pose a danger to people is unknown, Kobziar cautions. Her team has not tested whether the microbial species that survive the heat can cause disease, but the group plans to do so.

The research in Utah revealed another crucial fact: These microbes are tough. Even in smoke from high-intensity, high-temperature fires, about 60 percent of bacterial and fungal cells are alive, Kobziar says. Roughly 80 percent seem to survive lower-intensity fires, which is "about the same percentage of cells we'd expect to see alive in ambient air conditions," she says. Thus, these first studies show that fires are sending live bacteria and fungi into the air. And that they can travel at least 120 meters above the ground and close to a kilometer from a flame front.

But many basic questions remain, Kobziar says. How do the microbes change — in quantity, type or viability — based on distance traveled away from the flames? How far can they actually go? How do different fuel sources — pine trees, grasslands, deciduous trees or crops, for example — affect microbial release? How does fire intensity affect what is released and how far it travels? Does the type of combustion — smoldering (like a wet log on a campfire) versus high-intensity

For Kobziar's earliest studies in 2015, her students held up petri dishes on long poles (left) to collect samples of the smoky air near a prescribed fire. Today, she and colleagues use drones to collect samples (right). Both burns shown are at the University of Florida experimental forest.

BOTH: L. KOBZIAR

flaming fires — affect what is released? How does temperature or humidity or weather affect microbial survival?

Then, of course, Kobziar has plenty of questions about how to conduct this new field of research: What are the safest and best ways to sample the air in the dangerous environment of an unpredictable wildfire? How do you avoid contaminating the biological samples?

She's been learning as she goes, honing her methodology. The answers to many of those questions could come if one of Kobziar's dream collaborations comes true: She wants to work with the researchers whose studies involve the NASA DC-8 "flying laboratory," which explores Earth's surface and atmosphere for studies ranging from archaeology to volcanology.

Researchers have already tracked many different chemicals released by fires into the stratosphere from the Arctic to the South Pacific and everywhere in between, using the DC-8 for NASA's Atmospheric Tomography Mission, says Christine Wiedinmyer, a fire emissions modeler at the Cooperative Institute for Research in Environmental Sciences in Boulder, Colo. Finding traceable signatures of fires everywhere in the atmosphere suggests that fires could also be sending bacteria and fungi around the world, she says.

"Pyroaerobiology is so cool," says Wiedinmyer, who tracks and simulates the movement of chemicals in wildfire smoke around the world. She sees no reason that such atmospheric chemistry models couldn't also be used for tracking and forecasting the movement of microbes in smoke plumes — once researchers collect sufficient measurements. Those data might answer basic questions about the human health hazards of microorganisms in smoke.

Microbiologist Fierer in Boulder and Wiedinmyer have collaborated on chemistry sampling and modeling. The two plan to move to bacterial and fungal modeling using data Fierer is gathering on microbial concentrations in wildfire smoke.

Kobziar, meanwhile, is working with atmospheric modelers to figure out how to model microbes' movements in smoke. The long-term aim is to develop models to supplement current air-quality forecasts with warnings of air-quality issues across the United States related to wildfire-released microorganisms in smoke.

A U.S. map

While Kobziar's team focuses on measuring microbes in smoke, Fierer's team is working to get a baseline of what microbes are in the air at different locations during normal times and then comparing the baseline to smoke. The group has been sampling indoor and outdoor air at hundreds of U.S. homes to "map out what microbes we're breathing in as we're walking around doing our daily business," Fierer says. They are also sampling air across Colorado, which experienced record-breaking fires in 2020 (*SN: 12/19/20 & 1/2/21, p. 32*).

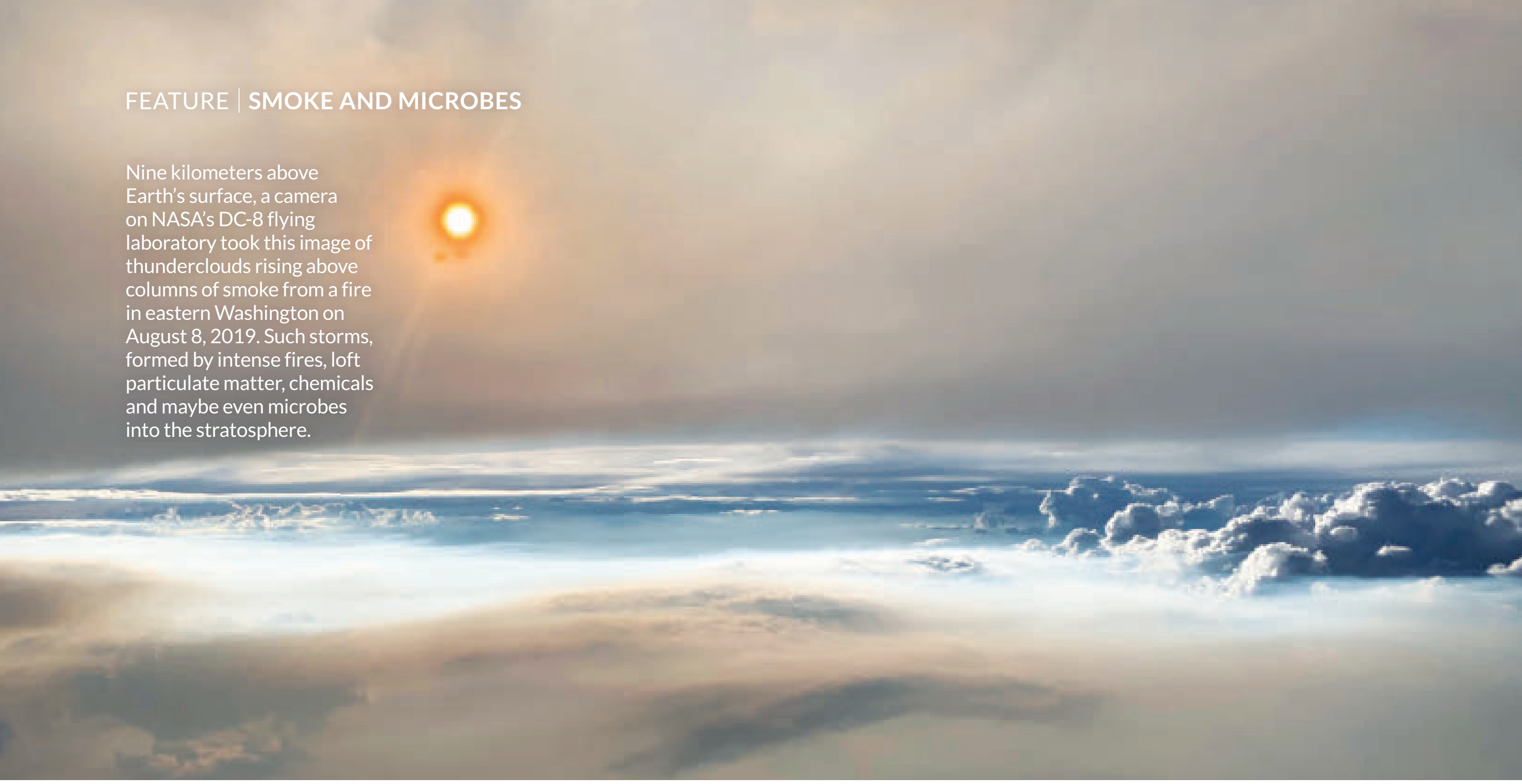
Fierer's team uses sampling stations with small, high-powered vacuums atop 2-meter-high poles to "sample air for a period of time without smoke. Then boom, smoke hits [the site], we sample for a few days when there's smoke in the air, and then we also sample afterward," Fierer says. Analyzing samples from before, during and after a fire is ideal, he says, as there's tremendous variation in microbial and fungal populations in the air. Near a Midwestern city in winter, for example, microorganisms might include ones associated with local trees or, strangely, dog feces; near a Colorado cattle feedlot in summer, microbes might include those associated with cattle feces.

N. FIERER

Joanne Emerson, then a postdoctoral researcher at the University of Colorado Boulder, samples air atop a 300-meter-tall tower at the Boulder Atmospheric Observatory.

When the team gets its results — data collection and analysis have been delayed by the pandemic — Fierer says, "we will know the amounts and types of microbes found in wildfire smoke compared with paired smoke-free air samples, and whether those microbes are viable." At least in Colorado. Once scientists get the measurements of how many microbes can be carried in smoke, and to what altitudes, Fierer's group can combine that information with global smoke production numbers to come up with "some back-of-the-envelope calculations" of the volume of microbes traveling in smoke plumes. Eventually, he says, scientists could figure out how many are alive, and whether that even matters for human health — still "an outstanding question."

Big leaps forward could be made if more scientists get involved in the research, Fierer and Kobziar both say. This research needs a truly multidisciplinary approach, with microbiologists, forest ecologists and atmospheric scientists collaborating, Fierer says. Going it alone would "be equivalent to a microbiologist studying microbes in the ocean and not knowing

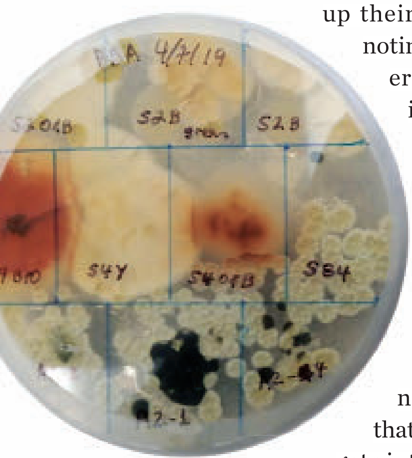


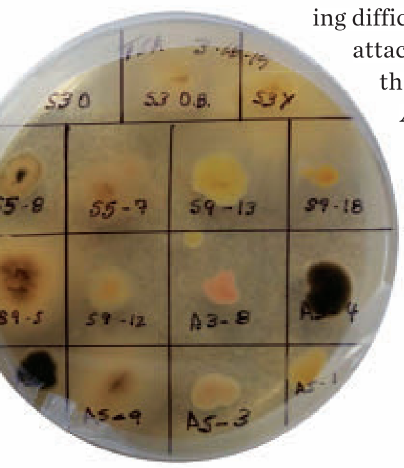
Nine kilometers above Earth's surface, a camera on NASA's DC-8 flying laboratory took this image of thunderclouds rising above columns of smoke from a fire in eastern Washington on August 8, 2019. Such storms, formed by intense fires, loft particulate matter, chemicals and maybe even microbes into the stratosphere.

anything about oceanography," he says. Fortunately, after Kobziar and infectious disease physician George Thompson of the University of California, Davis published a call-to-arms paper in *Science* last December, summing up their pyroaerobiology research and noting key questions, several researchers from different fields expressed interest in investigating the topic. "That's exactly what we hoped would happen," Kobziar says.

Is there danger?

In recent years, Thompson has seen a substantial increase in patients getting Valley fever and other fungal infections after nearby wildfires. He was well aware that when particulate matter in smoke gets into the lungs, it can cause breathing difficulties, pneumonia and even heart attacks. In fact, scientists reported in the *Journal of the American Heart Association* in April 2020 that exposure to heavy smoke during 2015–2017 wildfires in California raised the risk of heart attacks by up to 70 percent.





These petri dishes show bacterial and fungal colonies that grew after five minutes of exposure to smoke. The smoke came from pine needles collected from Florida then burned in Kobziar's University of Idaho lab.

He began to wonder if California's record-breaking infernos were stirring up other microbes along with the fungus that causes Valley fever. So he joined forces with Kobziar.

The Valley fever link appears to be real, but so far, local. For example, after the 2003 Simi Fire burned through Ventura County, more than 70 people got sick with Valley fever. But whether the *Coccidioides* fungi can travel to make people sick at a distance from the fire, no one knows.

There are ways to figure out if more people, either locally or farther away, are getting sick with bacterial or fungal infections after wildfires. One way, Thompson says, is to look at a community's antibiotic prescriptions and hospitalizations in the month preceding and the month after a fire: More prescriptions or hospitalizations from bacterial or fungal infections after a fire could indicate a link.

In 2019 at the American Transplant Congress meeting, for example, researchers linked California wildfires with increased hospitalizations related to *Aspergillus* mold and *Coccidioides* fungi infections.

But until we know more about what microbes fires release and where they go, we won't know how important such a link is for human health, Fierer says.

There's so much we don't know yet, Thompson agrees. "We still have a lot of work to do. This is sort of the beginning of the beginning of the story." ■

Explore more

- Leda N. Kobziar and George R. Thompson III. "Wildfire smoke: a potential infectious agent." *Science*. December 18, 2020.

Megan Sever is a freelance science editor and writer based in Portland, Ore.

FROM TOP: DAVID PETERSON/U.S. NAVAL RESEARCH LAB.; L. KOBZIAR

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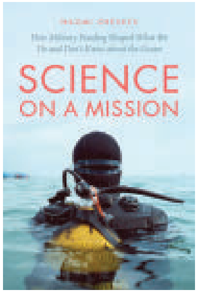


Science on a Mission
Naomi Oreskes
UNIV. OF CHICAGO, $40

BOOKSHELF

Navy funding both nurtured and stunted ocean science

In 2004, Japanese scientists captured the first underwater images of a live giant squid, a near-mythical, deep-ocean creature whose only interactions with humans had been via fishing nets or beaches where the animals lay dead or dying.

Getting such a glimpse could have come much sooner. In 1965, marine scientist Frederick Aldrich had proposed studying these behemoths of the abyss using *Alvin*, a submersible funded by the U.S. Navy and operated by the Woods Hole Oceanographic Institution in Massachusetts. During the Cold War, however, studying sea life was not a top priority for the Navy, the main funder of U.S. marine research. Instead, the Navy urgently needed information about the terrain of its new theater of war and a thorough understanding of the medium through which submarines traveled.

In *Science on a Mission*, science historian Naomi Oreskes explores how naval funding revolutionized our understanding of earth and ocean science — especially plate tectonics and deep ocean circulation. She also investigates the repercussions of the military's influence on what we still don't know about the ocean.

The book begins just before World War II, when the influx of military dollars began. Oreskes describes how major science advances germinated and weaves those accounts with deeply researched stories of backstabbing colleagues, attempted coups at oceanographic institutions and daring deep-sea adventures. The story flows into the tumult of the 1970s, when naval funding began to dry up and scientists scrambled to find new backers. Oreskes ends with oceanography's recent struggles to align its goals not with the military, but with climate science and marine biology.

Each chapter could stand alone, but the book is best consumed as a web of stories about a group of people (mostly men, Oreskes notes), each of whom played a role in the history of oceanography. Oreskes uses these stories to explore the question of what difference it makes who pays for science. "Many scientists would say none at all," she writes. She argues otherwise, demonstrating that naval backing led scientists to view the ocean as the Navy did — as a place where men, machines and sound travel. This perspective led oceanographers to ask questions in the context of what the Navy needed to know.

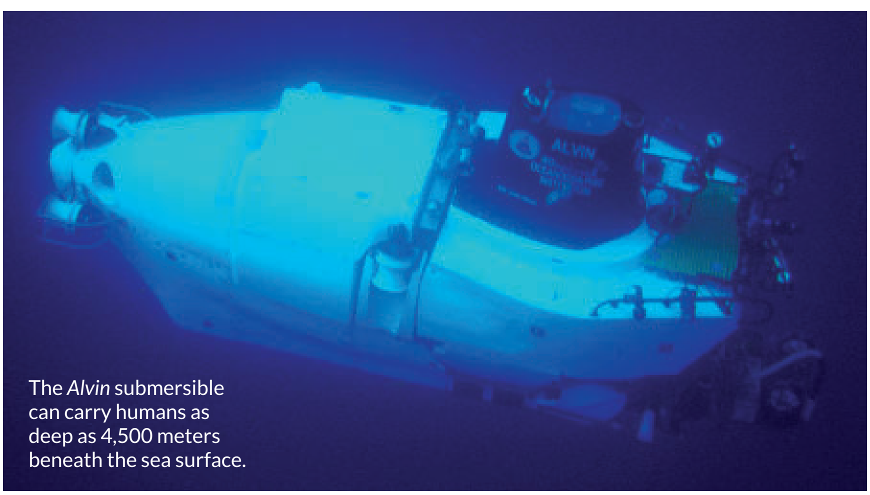
One example Oreskes threads through the book is bathymetry. With the Navy's support, scientists discovered seamounts and mapped mid-ocean ridges and trenches in detail. "The Navy did not care why there were ridges and escarpments; it simply needed to know, for navigational and other purposes, where they were," she writes. But uncovering these features helped scientists move toward the idea that Earth's outer layer is divided into discrete, moving tectonic plates (*SN: 1/16/21, p. 16*).

Through the lens of naval necessity, scientists also learned that deep ocean waters move and mix. That was the only way to explain the thermocline, a zone of rapidly decreasing temperature that separates warm surface waters from the frigid deep ocean, which affected naval sonar. Scientists knew that acoustic transmissions depend on water density, which, in the ocean, depends on temperature and salinity. What scientists discovered was that density differences coupled with Earth's rotation drive deep ocean currents that take cold water to warm climes and vice versa, which in turn create the thermocline.

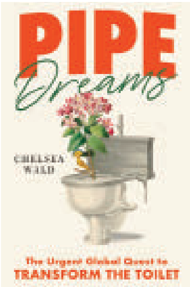
Unquestionably, naval funding illuminated physical aspects of the ocean. Yet many oceanographers failed to recognize that the ocean is also an "abode of life." The *Alvin*'s inaugural years in the 1960s focused on salvage, acoustics research and other naval needs until other funding agencies stepped in. That switch facilitated startling discoveries of hydrothermal vents and gardens of life in the pitch black of the deep ocean.

As dependence on the Navy lessened, many Cold War scientists and their trainees struggled to reorient their research. For instance, their view of the ocean, largely driven by acoustics and ignorant of how sound affects marine life, led to public backlash against studies that could harm sea creatures.

"Every history of science is a history both of knowledge produced and of ignorance sustained," Oreskes writes. "The impact of underwater sound on marine life," she says, "was a domain of ignorance." — *Alka Tripathy-Lang*



The *Alvin* submersible can carry humans as deep as 4,500 meters beneath the sea surface.



Pipe Dreams
Chelsea Wald
AVID READER PRESS, $27

BOOKSHELF

Reimagined toilets will transform human waste into resources

Everyone poops. But not everyone has a safe, sanitary place to do it. What's more, existing wastewater treatments consume tons of water and energy while flushing away materials that could make fertilizers, fuels and other products.

"We can do better," science journalist Chelsea Wald writes in *Pipe Dreams*, which recounts how scientists, entrepreneurs and activists are coming up with creative ways to make bathrooms more available and sustainable.

About 2 billion people lack access to adequate toilets. *Pipe Dreams* spotlights organizations that seek to change that. One such nonprofit is Sustainable Organic Integrated Livelihoods, or SOIL, which serves neighborhoods that lack sewers in Cap-Haïtien, Haiti. Residents there traditionally have relied on pit latrines, which can poison well water. But SOIL users get home toilets outfitted with removable plastic pails, which SOIL employees collect regularly to dump in a nearby composting site.

> *Pipe Dreams* plunges into all the strange, unexpected ways that excrement can be used beyond compost.

Pipe Dreams really lives up to its title when Wald plunges into all the strange, unexpected ways that excrement can be used beyond compost. She describes a company in South Africa that feeds human waste to maggots; these critters then can be fed to animals or crushed to make oil. In Kenya, she finds an organization that makes briquettes from poop — in stoves, these burn cleaner and last longer than charcoal. Pure urine can make fertilizer, but Wald notes that when mixed with sand and bacteria, it can also make bricks. Inventions like the Lapee female urinal, a pink cubicle in which the user squats over an oval-shaped receptacle to relieve herself, can help gather this pure pee. But peeing in one is a weird enough experience that, as one woman who used one at an outdoor festival said, "You need to be a little bit drunk to do it," Wald quotes.

Wald may not have sat on this particular pink throne, but she's had enough experience with newfangled toilet technology to earn the nickname "Queen of Loo-topia" among her peers. Readers couldn't ask for a more qualified guide to take them on a world tour of next-gen sewage schemes. In the book, Wald visits a facility in Africa that cleans portable toilets, enriches her home garden with Swiss-made urine-based fertilizer and sits on pee-diversion toilets in the Netherlands — which go beyond Lapee to harvest both pee and poop.

After years of (metaphorically) immersing herself in excrement, Wald is immune to squeamishness. Her narration is frank and funny, and her sewage savvy allows her to weave in fascinating scientific and historic details, from the health benefits of squatting versus sitting to rumors that Joseph Stalin used a special toilet to steal the excretions of world leaders.

Pipe Dreams leaves readers knowing everything they ever wanted to know (and probably more) about toilets, perhaps inspiring them to start giving way more of a crap about crap. That's a good thing: As Wald demonstrates, issues around excrement involve social justice and environmental sustainability.

"We shouldn't settle for the toilets we've inherited," Wald writes. After finishing *Pipe Dreams*, a reader can't help but agree and hope that, thanks to toilet visionaries around the world, we may someday achieve Loo-topia. — *Maria Temming*

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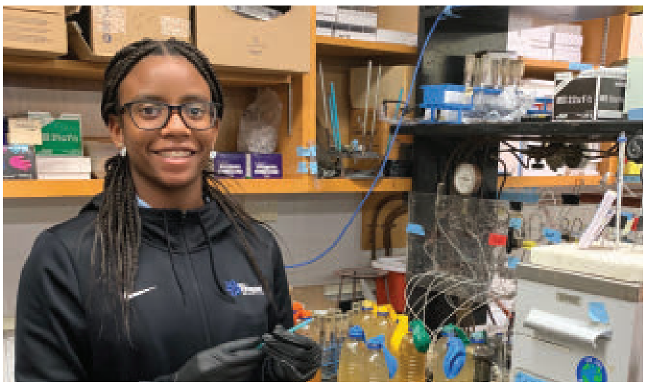

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SOCIAL MEDIA

Mini marvels

Some *Steatoda* spiders can lift prey up to 50 times their own weight using a pulleylike system (shown below), **Susan Milius** reported in "Tiny spiders hoist heavy prey with silk" (*SN: 2/27/21, p. 13*). On Facebook, reader **Thomas Newmann** marveled at the arachnids' ingenuity: "I understand that people are afraid of spiders. But, man, are they magnificent little creatures."

EMANUELE OLIVETTI

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Seeing double

New Zealand's lizardlike tuatara is the first known vertebrate with two mitochondrial genomes, ***Devin A. Reese*** *reported in "The tuatara hides an extra set of genes" (*SN: 2/27/21, p. 10*).*

Reader **Alfonso Solimano** wondered if each mitochondrion in tuatara cells has a copy of both genomes.

The two genomes likely don't exist in a single mitochondrion, says genomicist **Robert Macey** of the Peralta Genomics Institute in Oakland, Calif. How DNA is arranged in the organelle is unknown. It's possible that the 200 to 1,200 mitochondria in a single cell could house both genomes, with one version per mitochondrion, **Macey** says. Or perhaps only one of the two genomes appears in a single cell.

Turn up the heat

Diamond retains its structure even when compressed to more than five times the pressure in Earth's core, ***Emily Conover*** *reported in "Diamond holds up under pressure" (*SN: 2/27/21, p. 15*).*

Reader **Robert Stenton** asked what would happen to diamond if scientists also subjected the material to about 6000° Celsius, the temperature at Earth's center.

When researchers pummeled diamond with powerful lasers, they not only increased the pressure in the material, but also raised its temperature to thousands of degrees C, **Conover** says. In fact, the diamond got hot enough that the scientists thought it might melt. But that's not what happened. "The result actually raises two puzzling issues: Why the diamond didn't convert to another phase, and why it didn't melt," she says.

Harvesting energy

The Milky Way emanates gamma rays with energies approaching a quadrillion electron volts, ***Emily Conover*** *reported in "Milky Way's glow is highly energetic" (*SN: 2/27/21, p. 12*).*

Reader **Mark Blackham** wondered if it is possible to harness those gamma rays for practical use.

Such high-energy particles are rare and difficult to detect, **Conover** says. And while a quadrillion electron volts is a huge amount of energy for a single fundamental particle to carry, it's not that impressive on a macroscopic scale. A flying mosquito's kinetic energy, for example, is about 1 trillion electron volts. The gamma rays that researchers found each carried the energy of hundreds of mosquitoes, **Conover** says. "I don't think it would be particularly useful to try to harvest this energy."

COVID-19 Q&A

Science News *reporters* ***Tina Hesman Saey***, ***Aimee Cunningham***, ***Jonathan Lambert*** *and* ***Erin Garcia de Jesús*** *are following the latest research to keep you up to date on the coronavirus pandemic. A year in, we revisit reader questions about COVID-19 from the April 11, 2020 issue.*

Reader **Ken M.** asked a year ago if there are two versions of the coronavirus, one that causes mild symptoms and another that has more severe effects.

In April 2020, there weren't two versions of the virus going around in the United States or elsewhere. Now that's no longer the case. Multiple variants of the coronavirus are circulating globally. The new variants seem to spread more easily and quickly than the original.

"Why are people in such a tizzy about [COVID-19]?" reader **Joe B.** asked at the time. In the United States, influenza seems like a much bigger cause for concern, he wrote.

Even a year ago, scientists knew that COVID-19 killed at a higher rate than the flu. COVID-19 has now killed 2.7 million people globally as of late March 2021, with more than half a million deaths in the United States. Meanwhile, social distancing, mask wearing and other efforts to reduce the spread of the coronavirus probably sent cases of flu and other respiratory diseases plummeting (*SN Online: 2/2/21*).

Even as COVID-19 vaccines become more widely available, experts worry a surge in cases may be on the horizon as more contagious variants spread (*SN: 3/27/21, p. 6*) and some U.S. states begin to lift public health restrictions.

Archaeal microbes contort their DNA in extreme ways

Single-celled archaea pack their DNA into flexible, Slinky-like coils that open like a clamshell. This kind of molecular gymnastics has not been seen in other organisms and may represent a way for gene-reading proteins to get easy access to the genetic material, researchers report March 2 in *eLife*.

Some of the observed structures "really look like you take a Slinky and force it open, like a book," says Karolin Luger, a Howard Hughes Medical Institute investigator at the University of Colorado Boulder. "You would think that this would really contort the DNA in an awful shape, but it actually flows very naturally."

Similar to the cassette tapes Luger grew up listening to, DNA stores information in a thin, fragile filament of nucleic acids. But unlike tapes, which easily tangle and tear, genetic material can be read, opened like a zipper and replicated without tangles and breaks — all while confined in a tiny package.

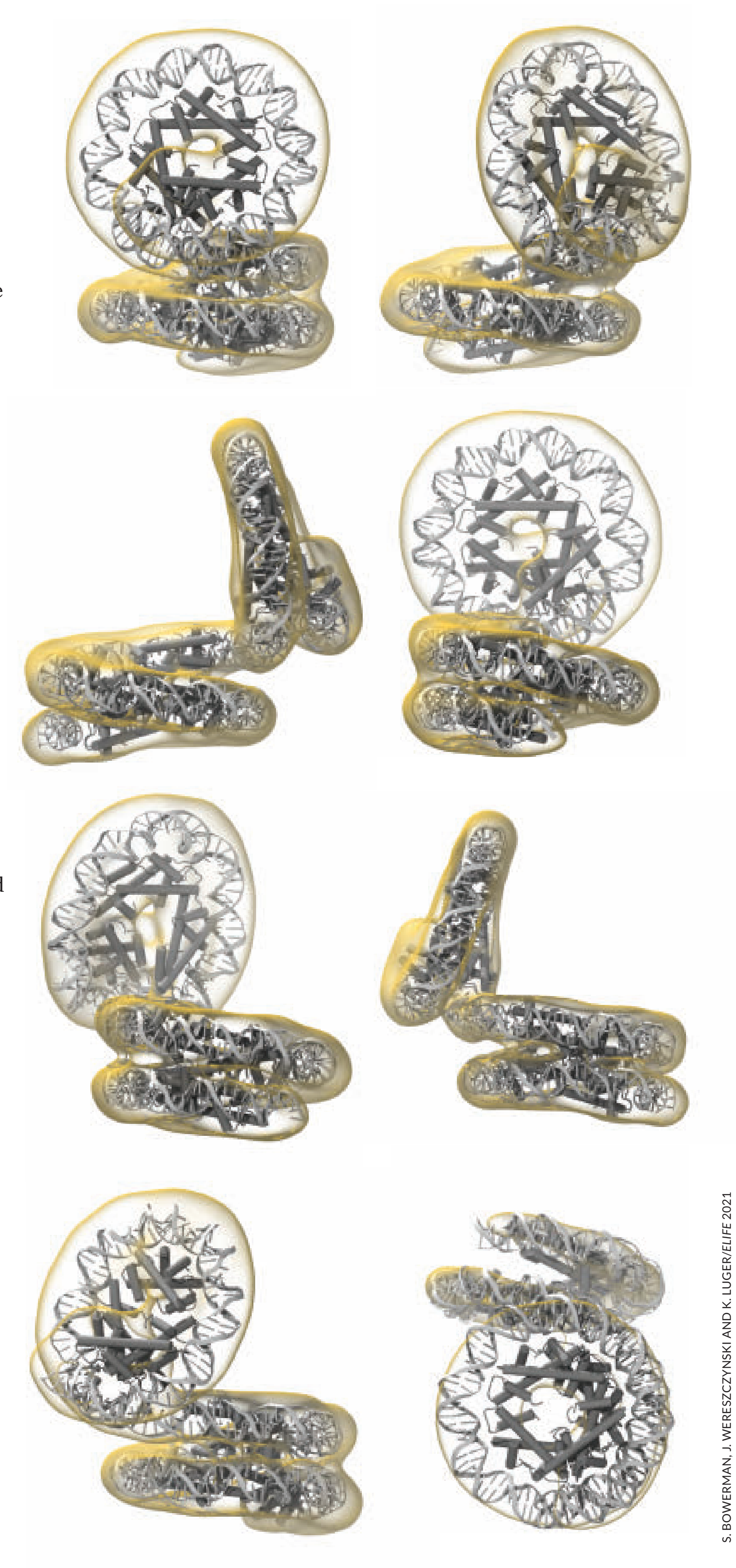
In 2017, Luger and her colleagues discovered that archaea — microbes that resemble bacteria under the microscope — can spool their DNA around small proteins called histones. This process is similar to how plants, animals and fungi bend and fold their own genomes into compact, disk-shaped nucleosomes (*SN: 9/2/17, p. 14*).

But nobody knew what these structures looked like in archaea or how other parts of the cell gained access to the spooled DNA. Using electron microscopy experiments on the genetic material of *Methanothermus fervidus*, a heat-loving archaean, the researchers found the coiled DNA opens and closes in a clamshell motion.

When open, the entire structure resembles a Slinky bent open by about 90 degrees. A computer simulation of this open position (right, from eight viewpoints) shows the gray DNA helices — the "wire" of the Slinky — coiled around cylindrical histones, at a section where the coils bend open.

Complex organisms such as humans, palm trees and mushrooms depend on a sophisticated machinery to loosen their highly compacted nucleosomes and expose specific genes for copying. Archaea might instead simply contort their DNA to turn genes on and off — allowing proteins to "read" the genes when the Slinkys open, and cutting off access when they close.

Luger now hopes to look at other archaeal species to see whether "other solutions have been invented for this DNA packaging problem."
— *Emiliano Rodríguez Mega*



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