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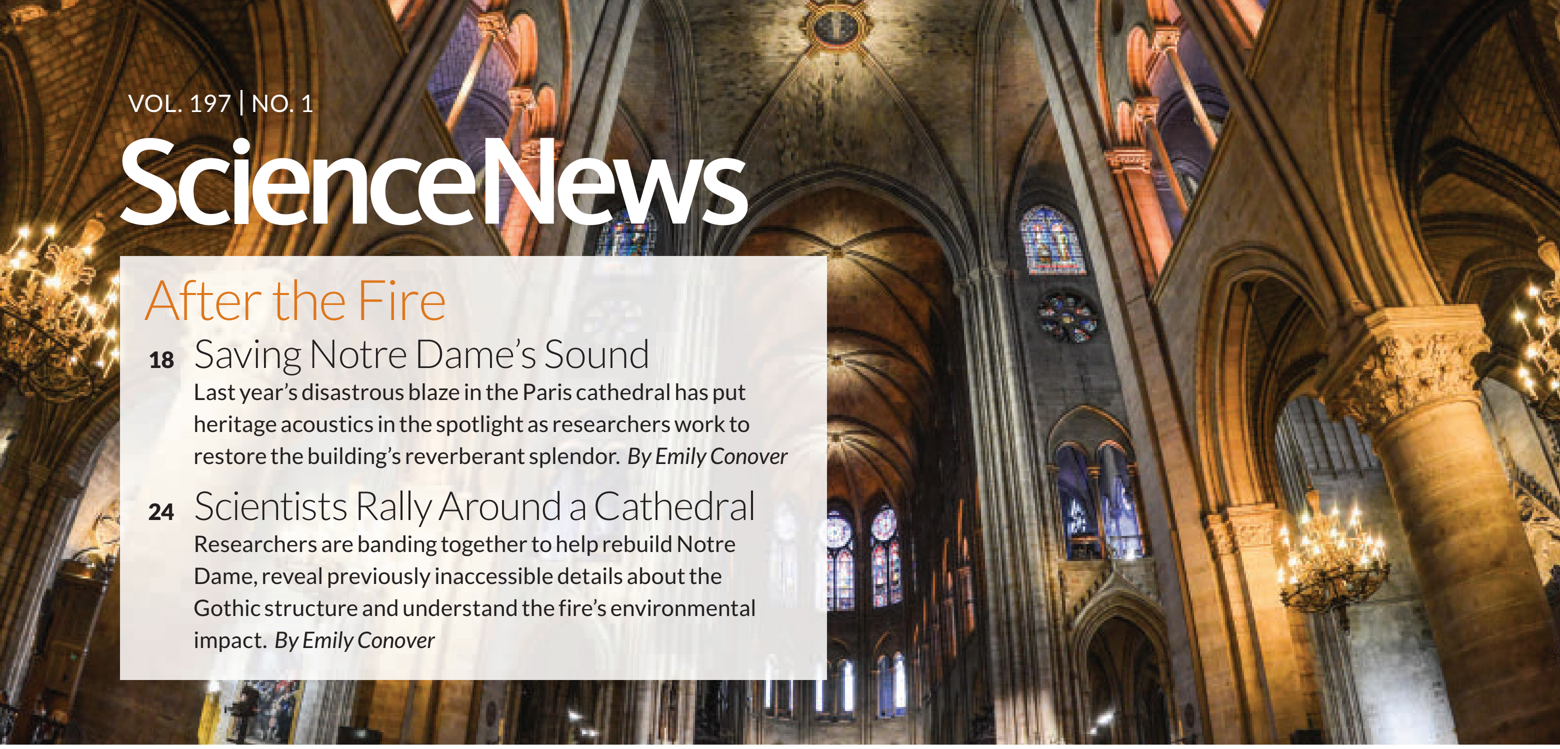
ScienceNews



After the Fire

News

6

4

Departments

COVER Engulfed in flames, the iconic spire of Notre Dame de Paris eventually collapsed in the April 15, 2019 blaze. *Hemis/Alamy Stock Photo*

FROM TOP: DUY PHUONG NGUYEN/ALAMY STOCK PHOTO; SUE ROBINSON/SHUTTERSTOCK; GENEVIEVE DE MESSIERES/SHUTTERSTOCK

Scientists embrace a cathedral's rebirth

The day that Notre Dame burned, we here at *Science News* watched the live coverage of flames raging into the clear April sky. Like so many other people around the world, we were heartsick. It was hard to imagine that the beloved 850-year-old cathedral could survive such a massive conflagration.

But Notre Dame somehow endured. And within days, scientists were springing into action, eager to offer their knowledge to ensure the cathedral's revival. One of them was Brian Katz, a physicist living in Paris who had studied Notre Dame's unique sound. When *Science News* physics writer Emily Conover learned about Katz's work a few weeks after the fire, she knew that this was a story she wanted to tell (Page 18).

Conover called Katz, and learned that he had recorded Notre Dame's acoustic properties in 2013 and had built a virtual reality evocation of the cathedral's unique sound. With the fortuitous data in hand, Katz started talking with other scientists about how to restore it. Heritage acoustics is "a whole field I'd never heard of," says Conover, who holds a Ph.D. in particle physics. The field melds a physicist's understanding of the properties of sound waves with how ears and brains process sound, and how people use a space like Notre Dame, packing it full of tapestries and statues and congregants.

To report the story, Conover flew to Paris in September, where she met Katz and his colleague Mylène Pardoen of CNRS, the Centre National de la Recherche Scientifique. Conover experienced some of their virtual reality reconstructions and went with them to another Paris church that Katz had studied. In the course of her reporting, Conover also interviewed scientists in other disciplines who have joined the international effort to rebuild the cathedral. Some of them plan to do research that wasn't possible when the building was intact. That includes looking for clues about past climate trends in charred timbers from the roof's iconic "forest" and analyzing the fire's effect on metalwork used to bind the timbers (Page 24).

While in Paris, Conover made her way to Île de la Cité, the ancient heart of the city, and stood outside the crippled cathedral. The area was a construction site, with scaffolding and a large crane hoisting materials aloft. But the grief that had gripped hearts worldwide persisted. "It was somber," Conover says.

The French government has pledged to rebuild the cathedral, and many scientists will be involved in that process. The tragedy of what has been lost will endure, but the scientists' work is already bringing the prospect of enlightenment and rebirth.

In this issue, we also report news from two major scientific meetings, held by the American Geophysical Union (Page 6) and by the American Society for Cell Biology and the European Molecular Biology Organization (Page 11). By sending journalists to meetings like these, we're able to keep you up to speed on the latest findings and scientists' responses to them; those discussions are an integral part of the process of science. Covering meetings requires a big investment of time and money, but we think it's worth it. We hope you do, too.

— Nancy Shute, Editor in Chief

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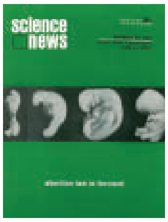


Excerpt from the January 17, 1970 issue of *Science News*

50 YEARS AGO

No life and not much potential

The lack of life on the moon, or even of biological compounds that might under some circumstance lead to it, had been expected long before Apollo 11 went there.... The closest thing to an exception comes from ... reports that at least the elements necessary for synthesis of organic compounds are present in some lunar rock types, but conditions on the moon leave them far removed from the compounds themselves.

UPDATE: The moon still looks barren. Decades of exploration has found no evidence for life, so planetary scientist Alan Stern of the Southwest Research Institute in Boulder, Colo., and colleagues have recommended easing mission rules for protecting the moon from contamination in some cases (*SN: 11/23/19, p. 10*). But the moon's south pole may still warrant safeguards. Orbiters saw evidence there of water ice, which may have arrived on comets, perhaps the same way Earth got its water and building blocks for life. Moon ice may have clues about the origins of life on Earth.

TEASER

To catch a dolphin's breath, scientists follow the flow

If you've ever had trouble catching your breath, try catching a dolphin's.

The plume produced when a dolphin comes up for air could reveal information about its health. But capturing samples of the blowhole spray from agile, skittish wild dolphins is challenging. To make the task easier, a team of engineers has characterized the flow of a dolphin's chuff, a forceful exhale that sends water, air and mucus hurtling skyward.

High-speed video of captive Atlantic bottlenose dolphins reveals that each chuff lasts around a quarter of a second, beginning with a spurt of water flung off the top of the blowhole. Then comes a second wave: the exhale. That powerful outflow produces a turbulent jet moving at a maximum speed of nearly 100 kilometers per hour, researchers reported November 24 at the American Physical Society's Division of Fluid Dynamics meeting in Seattle.

The expelled mucus contains health indicators, such as the stress hormone cortisol. Understanding these chuffs could help in designing drones to swoop in to catch the spray and reveal, for example, whether a pod is stressed by human activity. *—Emily Conover*

FIRST

How wind circulates in Mars' upper atmosphere

High above the surface of Mars, winds swirl from dayside to night, and the air undulates as it passes over mountains and valleys far below.

These insights come courtesy of NASA's MAVEN spacecraft, which has provided the first detailed maps of winds in the Martian thermosphere, one of the highest layers of the planet's atmosphere. The data, described in the Dec. 13 *Science*, could help researchers understand how the Martian climate has changed over time by looking into how its atmosphere bleeds into space.

It turns out wind movement in Mars' thermosphere is much simpler than on Earth. A single pattern persists from season to season, continually moving air from the planet's dayside to its nightside, whereas on Earth there are multiple flow patterns at any time. "Oceans on Earth complicate the circulation patterns," says Mehdi Benna, a planetary scientist at NASA's Goddard Space Flight Center in Greenbelt, Md.

The spacecraft also recorded waves in the thermosphere generated by winds near the ground diverting around canyons and mountains. The data from one and a half Martian years of tracking winds should help improve computer simulations to reveal how the Red Planet's atmosphere trickles into space, Benna says. *—Christopher Crockett*

FROM TOP: SUE ROBINSON/SHUTTERSTOCK; JPL/NASA, MALIN SPACE SCIENCE SYSTEMS

THE SCIENCE LIFE

Debate over signs of early life drives dueling teams to Greenland together

Deep in the heart of Greenland, in an area laid bare by melting ice, lies a controversy: a rocky outcrop that some scientists say contains the oldest known signs of life on Earth. Others disagree. So a handful of scientists recently traveled to the site to study the rocks together.

It's not easy to identify biological traces within rocks that have been churned and chewed by tectonic pressure and heat over billions of years. But figuring out how best to identify such traces on Earth could help scientists spot those signs on other worlds, such as Mars.

The Greenland outcrop, which dates to between 3.7 billion and 3.8 billion years ago, contains strange squiggles just a few centimeters tall. One team of scientists has suggested the wavy pattern was shaped by microbes living in ancient shallow pools (*SN: 10/1/16, p. 7*). The microbes shifted sediments until they formed thinly layered structures called stromatolites, geologist Allen Nutman of the University of Wollongong in Australia and colleagues reported in *Nature* in 2016.

Other scientists have rebutted that idea, based on geologic and chemical evidence from samples of the Greenland outcrop (*SN: 11/10/18, p. 12*). Astrobiologist Abigail Allwood of NASA's Jet Propulsion Laboratory in Pasadena, Calif., visited the site in 2016. Getting a fuller, 3-D picture of the pattern within the entire outcrop, she says, was key to her conclusion that microbes had played no part in the pattern.

With the two camps at an impasse, Allwood says she had an idea: What if a handful of scientists, including members of both teams, studied the outcrop together and compared notes? So in August, Allwood, Nutman and about 10 more geologists, astrobiologists and other specialists helicoptered in to the remote site.

Astrobiologist Abigail Allwood (shown) helped organize a trip to view a rocky outcrop in Greenland for scientists who disagree about whether patterns in the rock (photograph, right) are signs of ancient life.

Nutman introduced the group to the outcrop and laid out his evidence. The researchers spent a day and a half observing and debating, says Dawn Sumner, a geobiologist at the University of California, Davis.

"A number of us went in with an open mind," Sumner says. But by trip's end, Sumner and many of the other expedition members had concluded that the pattern's peaks probably weren't shaped by microbes. Seeing the structures in context, rather than in published images, was crucial, Sumner says. "One of the things we came away with is how difficult it is to get a sense [of what formed the pattern] without actually being there."

Nutman and his team remain committed to the microbial explanation. But all parties agreed that building a 3-D picture of a site could be the key to accurately identifying signs of life.

Expedition members are doing just that, using aerial drone photographs, stereoscopic images and scans taken by light detection and ranging, or lidar, equipment during the trip. The goal is for researchers to be able to study the site from afar, Sumner says — much like scientists one day might squint at mysterious structures in Martian rocks. — *Carolyn Gramling*

TOP TWO: MIKE TOILLION/NASA ASTROBIOLOGY; BOTTOM: ALEXANDER STAHN/UNIV. OF PENNSYLVANIA, CHARITÉ–UNIVERSITÄTSMEDIZIN BERLIN

HOW BIZARRE

Isolated in Antarctica, people's brains shrank

Socially isolated and faced with a white, polar expanse, a long-term crew at an Antarctic research station had a portion of their brains shrink, a study finds.

The crew of eight scientists and a cook stayed at the German research station Neumayer III for 14 months, joined by other scientists in summer but enduring the long, cold darkness of polar winter on their own.

Studies in lab animals show that monotony and isolation can harm the hippocampus, a brain area key to memory and navigation (*SN: 12/8/18, p. 11*).

Researchers used magnetic resonance imaging to capture views of eight team members' brains before and after the expedition. On average, an area of the hippocampus in the crew's brains shrank during their stay about 7 percent more than in people matched for age and gender but who didn't go to the station, the researchers report in the Dec. 5 *New England Journal of Medicine*.

But the change may be reversible, as the hippocampus can also respond to stimulation, says coauthor Alexander Stahn, a physiologist who began the work at Charité–Universitätsmedizin Berlin. — *Aimee Cunningham*

Snow and sky go on for kilometers around the German polar research station Neumayer III.

News

ATOM & COSMOS

Parker probe spies on meteor shower

NASA solar mission may help pinpoint the Geminids' origins

BY MARIA TEMMING

NASA's Parker Solar Probe is no one-trick pony.

Besides offering unprecedented views of the sun (*SN: 12/21/19 & 1/4/20, p. 6*), the spacecraft has gotten the first glimpse of the trail of space rubble responsible for the Geminid meteor shower that happens every December. Future Parker observations of this debris could help solve the mystery of where the Geminids came from.

Searches with ground-based observatories and the Hubble Space Telescope have never spotted the source of the Geminid meteors. "All we've ever seen of the Geminids are the shooting stars in the sky," says Karl Battams, a space scientist at the U.S. Naval Research Laboratory in Washington, D.C. But now Parker has gotten a look at the source from afar.

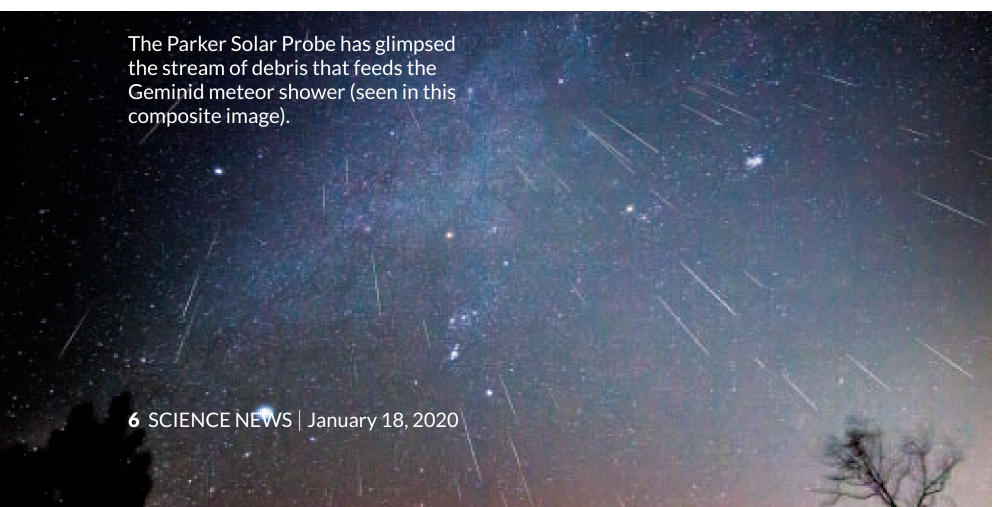
Battams reported the Parker probe's observations December 9 in a poster presentation at the annual American Geophysical Union meeting.

In November 2018, during its first close encounter with the sun, the Parker Solar Probe spotted a faint stretch of dust — about 100,000 kilometers wide and 20 million kilometers long — in the expected orbit of Geminid debris. Battams' team estimated the mass of that debris trail to be about 1 billion metric tons. Based on the location and mass of the debris, the researchers determined they were looking at part of the Geminid meteor stream.

Parker's outside perspective of the Geminids — as opposed to Earth's view from within during meteor showers — may help uncover their origin. "The weird thing about the Geminids is that most of the other [meteor] streams we associate with a comet," says space scientist Jamey Szalay of Princeton University. As comets swing by the sun, they shed material that feeds their meteor streams. But the Geminid meteor stream instead is associated with an asteroid called Phaethon, which loses hardly any material when it swoops past the sun.

"Something very violent maybe happened in the past, where a larger body lost a lot of its material" to create the crowd of Geminids and the remnant Phaethon asteroid, Szalay says. Pinning down the precise mass and distribution of material inside the Geminid stream may allow computer simulations to rewind the stream's evolution and figure out how it was born.

The observations from Parker's first solar orbit alone are not enough to reveal the Geminids' origin, says David Jewitt, a planetary scientist at UCLA. "But it represents a point of hope." Parker will view the same part of the meteor trail a few times each year over the next several years, potentially teasing out more structural details that contain clues about the space dust's beginnings. ■



The Parker Solar Probe has glimpsed the stream of debris that feeds the Geminid meteor shower (seen in this composite image).

GENEVIEVE DE MESSIERES/SHUTTERSTOCK

EARTH & ENVIRONMENT

How Arctic melt is harming Alaskans

Report tallies the effects of climate change in the far north

BY MARIA TEMMING

Polar bears have long been the poster children for the woes of Arctic warming. But climate change isn't just a danger to wildlife. The safety and livelihoods of people across the Arctic are threatened.

An annual report from the U.S. National Oceanic and Atmospheric Administration is for the first time giving voice to people in Alaska's Bering Sea region who deal with the impacts of rapid climate change in their daily lives.

These people face shrinking access to fish stocks, eroding shorelines and the disappearance of travel routes along ice. "We have seen change coming. Now, we know it is here," 10 elders from indigenous communities around the Bering Sea wrote in the 2019 Arctic Report Card.

The report, released December 10 at the American Geophysical Union's annual meeting, confirms that the Arctic is warming about twice as fast as the global average temperature rise. As a result, sturdy sea ice has given way to newer, more fragile ice. In March 2019, sea ice older than four years accounted for only about 1.2 percent of Arctic Ocean ice cover, compared with 33 percent in 1985, the report states. Other environmental anomalies in 2019 included a Greenland Sea algal bloom in May that was about 18 times as intense as usual.

But the report focused especially on dramatic changes in the Bering Sea. Local leaders say the biggest change is the loss of sea ice (*SN: 3/16/19, p. 20*). Sea ice depletion is making it more difficult for indigenous people to hunt marine mammals, such as walrus, that hang out on the ice. And diminishing ice, along with rising water temperatures, is driving fish like salmon to colder climes farther north. Climate change is "changing the migration of our marine resources that we depend on," Jerry Ivanoff, an elder from the village of Unalakleet, said December 10 during a news conference. "It's definitely going to hit us right here," Ivanoff said, indicating his stomach.

Sea ice loss also makes it more difficult to navigate. In the remote island community of Diomede, for instance, people who used to travel on and off the island via sea ice during winter now rely on helicopters.

On land, higher temperatures mean less snow and more rain. "Winter rains coat our runways in ice and prevent the planes from landing in our communities, the vast majority of which are not connected to road systems," the elders wrote. Thawing of permanently frozen soil, or permafrost, is leading to sinkholes and landslides. Stronger storm surges, thanks to diminished sea ice, lap at coastal roads and buildings, causing erosion.

It's "a great idea" for the Arctic Report Card to include local perspectives, says Brendan Kelly, a polar scientist at the University of Alaska Fairbanks who wasn't involved in the report. The indigenous peoples of Alaska "are experiencing [climate change] in very deep, personal ways. You can't live in the place where the climate is changing most rapidly on the planet and not have it affect your energy supply, your way of life, your foods."

As the Arctic warms and sea ice dwindles in the Bering Sea, it is becoming more difficult for indigenous peoples to hunt marine mammals that depend on the ice.

The report paints a similarly alarming picture of goings-on elsewhere in the Arctic. For instance, the report estimates that Greenland is losing, on average, nearly 267 billion metric tons of ice annually, contributing an average of about 0.7 millimeters per year to global sea level rise. Those higher sea levels are expected to lead to widespread coastal flooding.

New measurements also suggest that permafrost thaw is now releasing more carbon into the atmosphere than arctic tundra plants take up. That could, in turn, spur even more warming. "The big question is," Kelly says, "how big a [carbon] source is this going to be in the coming decades?" ■

EARTH & ENVIRONMENT

A simple explanation for Earth's oxygen

Basic nutrient cycling may account for the gas's accumulation

BY CAROLYN GRAMLING

Maybe the rise of oxygen on Earth required no special trigger.

Instead of tectonic shifts or the origin of land plants, as some scientists have suggested, nutrient cycles may have been sufficient to produce the dramatic shifts in atmospheric gases that occurred on ancient Earth. Benjamin Mills, a biogeochemist at the University of Leeds in England, presented the findings December 10 at the American Geophysical Union's annual meeting. The research is also reported in the Dec. 13 *Science*.

Earth's atmosphere lacked much oxygen until about 2.4 billion years ago, when levels of the gas skyrocketed during the Great Oxidation Event. Two more pulses followed, one about 800 million to 540 million years ago, and the other about 450 million to 400 million years ago, when oxygen reached modern levels.

Such dramatic surges beg an explanation. Some scientists say major tectonic events such as the formation of supercontinents funneled massive amounts of nutrients into the oceans, fueling sudden, world-changing algal blooms. Other researchers propose that the three pulses correspond to the rise of photosynthesizing algae, the diversifying of those algae and the rise of land plants.

In the new research, Mills and colleagues considered how carbon, oxygen and phosphorus move between reservoirs on Earth and interact with each other.

Adding phosphorus from weathered rocks to the ocean drives microbial or algal activity, which pulls oxygen out of the water. As the water loses oxygen, more oxygen is pulled from the sediments below. Eventually, this leads to more organic carbon getting buried in the seafloor, and more oxygen being produced. As the water eventually becomes oxygen-rich again, oxygen escapes into the air.

The researchers created a simulation of these different inputs and outputs, and ran the model over billions of years to see how atmospheric and ocean oxygen levels changed. The results, Mills says, were similar to the actual record of Earth's oxygen reconstructed using the rock record. "Our conclusions are that no large tectonic or biological events were required," he says. "If you just have simple photosynthetic bacteria ... you could reach modern levels."

Geologist Ashley Gumsley of Lund University in Sweden is concerned that leaving out tectonics is an oversimplification. "These biogeochemical systems are important," he says. But during the first oxygen pulses, "we see a symphony, if you like, of forces acting to drive and sustain oxygen production." Those included the coming and going of a supercontinent, massive volcanic eruptions and a global glaciation.

Mills acknowledges that these events may have played a role. But the models suggest that "we didn't need them."

That conclusion could be good news for scientists looking for life on other planets, says astrobiologist Joshua Krissansen-Totton of the University of California, Santa Cruz. "What is most exciting about this paper," he says, "is that it does away with the need for [triggering] events" or complex photosynthesizing organisms. ■

WORLDFOTO/ALAMY STOCK PHOTO

BODY & BRAIN

Alzheimer's drug may work after all

Once-scrapped aducanumab slows decline, company claims

BY LAURA SANDERS

Call it a comeback — maybe. After being shelved in March 2019 for lackluster preliminary results, a drug designed to slow Alzheimer's progression is showing signs of life. A more in-depth look at data from two clinical trials suggests that patients on the highest doses of the drug, called aducanumab, may indeed benefit, Biogen, the biotech company that is developing the drug, reported December 5.

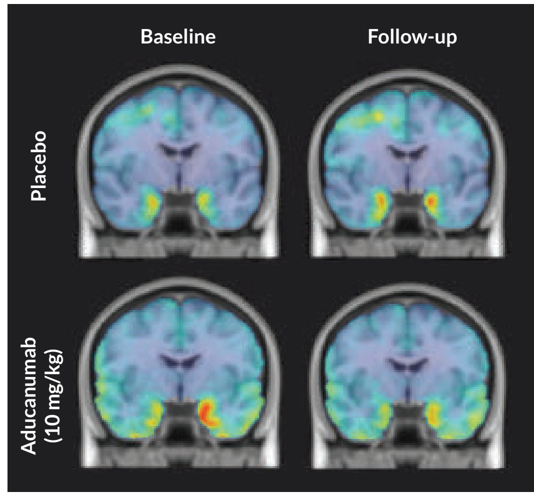
People who took the largest amounts of the drug declined about 30 percent less over a year and a half, as measured by an Alzheimer's scale, than people who took a placebo, Samantha Budd Haeberlein of Biogen reported at the Clinical Trials on Alzheimer's Disease meeting in San Diego. Biogen, based in Cambridge, Mass., plans to seek drug approval from the U.S. Food and Drug Administration.

The results mark "an important moment for the Alzheimer's field," says Rebecca Edelmayer, director of scientific engagement for the Alzheimer's Association in Chicago. Alzheimer's kills brain cells, gradually erasing people's abilities to remember, navigate and think clearly. A drug that slows or stops damage would have a "huge impact for patients and their caregivers," she says. Current medicines hold off symptoms temporarily but don't fight brain destruction.

If confirmed, the results could also bolster an idea that has been increasingly challenged: that the buildup of amyloid, a sticky protein that accumulates in the brains of people with Alzheimer's, is a key early step of the disease.

An early study showed that aducanumab, an antibody, can clear amyloid from the brain (*SN: 10/1/16, p. 6*). Researchers then launched two phase III trials, designed to prove a drug's worth by pitting it against standard treatments or a placebo, that enrolled people around age 70 who showed early signs of Alzheimer's.

In March, when initial trial data



In a study of the drug aducanumab, people who took the drug had fewer tangles of tau protein (red) in certain parts of the brain than people who took a placebo, brain scans reveal.

showed the drug was unlikely to hit its goals, Biogen stopped the trials before they were finished. But after three more months of data became available, Biogen decided in October that the drug showed promise after all, particularly for those who got the highest dose, 10 milligrams per kilogram of body weight. Midway

MATTER & ENERGY

A new kind of time crystal is proposed

The structure would operate free from outside influences

BY EMILY CONOVER

A newly proposed type of time crystal could be self-reliant.

Time crystals are structures that repeat regularly in time, just as a standard crystal is composed of atoms arranged in a regularly repeating pattern in space. Scientists first created time crystals in 2016 (*SN: 11/12/16, p. 12*). But those crystals require periodic blasts from a laser to initiate the rhythmic behavior.

Now, two scientists have sketched out a theoretical blueprint for a time crystal that would persist without any input from the outside world, the pair reports in the Nov. 22 *Physical Review Letters*.

First proposed in 2012, the idea of time crystals was controversial. Researchers soon proved a no-go theorem stating that, under typical conditions, time crystals couldn't exist.

But two situations not included in the theorem left open the possibility. One exception was systems for which energy is put in from the outside, for example, via lasers. And that's how scientists have so far created all time crystals.

But theoretical physicists Oleksandr Kyriienko of the University of Exeter in England and Valerii Kozin of the University of Iceland in Reykjavík wanted to design a self-sustaining time crystal.

The pair exploited the second exception to the no-go rule: systems that involve long-range interactions, in which atoms or other tiny particles separated by large distances could influence one another. Such long-range effects don't typically occur in nature. Two atoms on opposite sides of a room normally don't exert forces on one another, for example.

Based on such interactions, the researchers came up with a new time crystal scenario, consisting of a collection of many such particles, each with a spin — a quantum version of angular momentum. Interactions between the particles' spins would be configured so that particles near and far would influence one another simultaneously, via some unspecified quantum gymnastics in the lab. And the particles would be highly entangled with one another, meaning they share quantum links that can persist at large distances.

Under such conditions, distant parts of the system could affect one another. The result is that the correlation between the spins — whether neighboring particles' spins were aligned or not — would endlessly oscillate in time in a regular pattern, producing a time

BIOGEN

through the trials, Biogen had upped the doses of some people who had started on lower doses because of fear of side effects.

Updated results included 3,285 people. Surveys measured abilities on six aspects of life, including memory, orientation, personal care and problem solving. Analyzing a subset of 288 people in one trial who got the highest dose showed that, while they still lost some mental abilities during the study, they declined 30 percent less than those who had the placebo. A similar subset of 282 people in the other trial declined 27 percent less than those on the placebo. Brain scans showed that, compared with people on the placebo, people on aducanumab had less amyloid — and fewer tangles of tau, another protein associated with Alzheimer's.

Given the major changes to the trials — the change in dosing and the early ends — neurologist Samuel Gandy of the Icahn School of Medicine at Mount Sinai in New York City is withholding judgment until more data are available. "Complete open sharing is now the gold standard, and is especially important for aducanumab." ■

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crystal, the researchers say.

Scientists have typically studied systems of particles in which the interactions are short-range, or local. But researchers have long known that "something weird occurs once the locality is violated," says physicist Haruki Watanabe of the University of Tokyo, one of the researchers who proved the no-go theorem. "So I wouldn't be surprised by these kinds of behaviors of long-range interacting systems."

But it's unclear whether such a time crystal could be created in the lab. It's not an easy feat to produce long-range interactions between many particles at once. "I don't think it is possible to realize the long-range interacting system they proposed," Watanabe says. But Alfred Shapere of the University of Kentucky in Lexington, one of the physicists who proposed the idea of time crystals, is optimistic: Scientists might use quantum computers or cold atoms to create the proposed time crystal or one like it. ■

HUMANS & SOCIETY

Oldest known figurative art discovered

Cave panel dating to at least 43,900 years ago depicts hunting

BY BRUCE BOWER

An Indonesian cave painting that shows wild animals encountering otherworldly hunters may be the oldest known example of art depicting lifelike figures and the oldest example of visual storytelling.

Discovered in 2017 on the island of Sulawesi, this roughly 4.5-meter-wide hunting scene was painted at least 43,900 years ago, says a team led by archaeologists Maxime Aubert and Adam Brumm, both of Griffith University in Gold Coast, Australia. Part-human, part-animal hunters depicted in the mural indicate that people at the time believed in supernatural beings, the scientists report in the Dec. 19 *Nature*.

"We assume these ancient artists were *Homo sapiens* and that spirituality and religious thinking were part of early human culture in Indonesia," Brumm says.

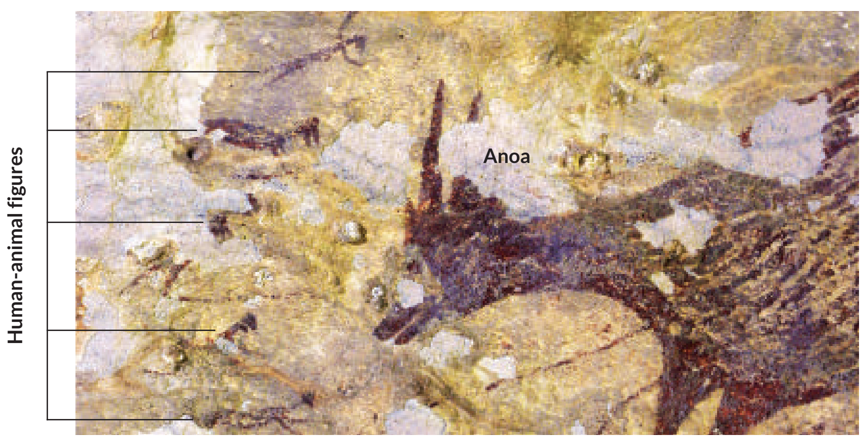
Two pigs and four miniature buffalo called anoas, which still inhabit Sulawesi forests, range across the scene. Eight humanlike figures with characteristics of animals appear to be hunting pigs and anoas with spears or ropes. One hybrid sports a tail. Another has a snout.

Mythical human-animal hybrids, also called therianthropes, often appear in folklore and in fiction of modern societies. Many religions regard therianthropes as gods, spirits or ancestral beings. Figurines previously found in Germany of a lion-headed person and a woman with exaggerated features (*SN: 6/20/09, p. 11*) date to as early as 40,000 years ago.

Abstract cave art generally attributed to *H. sapiens* dates to at least 40,800 years ago in Europe (*SN: 7/28/12, p. 15*). In other Sulawesi caves, wall stencils that people made by blowing or spraying pigment around outstretched hands date to about 40,000 years ago (*SN: 11/15/14, p. 6*). Researchers have reported evidence of Neandertals creating abstract cave art at least 65,000 years ago, but those reports have come under fire.

Measures of radioactive uranium's decay in mineral layers that formed over parts of the Sulawesi depiction provided minimum age estimates ranging from 35,100 to 43,900 years ago. The oldest mineral layer comes closest to the painting's actual age, the researchers say.

Proposed human-animal figures in the scene are small relative to the pigs and anoas, says archaeologist Nicholas Conard of the University of Tübingen in Germany. The artists may have depicted the therianthropes as flying. In stories from modern foraging groups, "movements through spirit worlds are often via flight rather than walking or running," Conard says. ■



This part of an ancient hunting scene found in an Indonesian cave includes a buffalo called an anoa (right) facing several faint human-animal figures (dark pigment) wielding spears or ropes.

M. AUBERT *ET AL*/*NATURE* 2019, R. SARDI

GENES & CELLS

Excess chromosomes feed tumors

Without the surplus, growth of cancer cells in mice stalls

BY TINA HESMAN SAEY

Some cancers are addicted to having extra chromosomes, a study suggests.

Cells usually have just two copies of each chromosome — one inherited from mom and one from dad. But about 90 percent of tumors have additional chromosomes. For instance, more than half of colorectal tumors have a surplus chromosome 13, and more than 40 percent carry an extra chromosome 7 or an extra copy of the long arm of chromosome 8. Cancers with extra chromosomes have been linked with poorer patient outcomes.

It turns out that those extra doses of genetic material are necessary for some cancer cells to keep growing, cell biologist Jason Sheltzer reported December 11 at a joint meeting of the American Society for Cell Biology and the European Molecular Biology Organization. Put another way, the tumors are addicted to the bonus chromosomes, he said.

Sheltzer, of Cold Spring Harbor Laboratory in New York, developed a method for purging extra copies of whole chromosomes or parts of chromosomes from cells to see how the removal affects the cells. A type of ovarian cancer cell called A2780 carries an extra copy of the long arm of chromosome 1, known as 1q. Sheltzer removed the extra copy of 1q from ovarian cancer cells, then compared how well the original and 1q-deprived cancer cells grew in lab dishes and when transplanted into mice.

Cells with the surplus chromosome arm formed many large colonies in dishes and grew into tumors in mice. But cells that lost 1q "barely grew at all," Sheltzer said. "They've almost entirely lost their ability to exhibit malignant growth." Somehow, however, these cells later regained another copy of the arm, restoring the cells' growth. "These cells for some reason really, really, really want to have three copies of this chromosome arm," Sheltzer said.

That result is persuasive, says Adrian Saurin, a cancer cell biologist at the University of Dundee in Scotland. "That's a real sign of addiction, if you take it away and they manage to get it back again."

The idea of "addicted" cancer cells isn't new. Scientists have known for decades that cancer cells require altered versions of certain genes to sustain growth. That fact forms the basis for many targeted cancer therapies, which interfere with the action of genes driving the cancer. Chromosomes contain thousands of genes, so narrowing down which gene or combination of genes is the source of addiction is much more complicated.

But finding out which genes turn cancer cells into addicts is necessary if researchers are ever going to develop treatments to negate the effect of bonus chromosomes, Saurin says. A greater understanding of cancer cell biology is probably needed before the new research becomes clinically useful, he says. "But I could see it in the future."

Sheltzer took a step toward pinpointing why 1q has ovarian cancer cells hooked. The gene *MDM4*, located on 1q, produces a protein that inhibits activity of p53, a protein that helps prevent cancer. With more MDM4 protein around, p53's tumor-suppressing activity is diminished, allowing cancer cells to grow unchecked, Sheltzer reasoned.

Sheltzer tested that idea by using the gene editor CRISPR/Cas9 to remove the *MDM4* gene from the surplus 1q. Cells lacking the third copy of *MDM4* formed fewer colonies in lab dishes than cells with three copies. But further experiments showed that the gene isn't the only one spurring growth.

Sheltzer hopes to do similar experiments with other types of cancers to see whether an addiction to extra chromosomes is common to all cancers. ■

MEETING NOTE

Prions clog nerve cell traffic

Clusters of misfolded proteins block passage of crucial cargo along intracellular roadways in brain cells, cell biologist Tai Chaiamarit of the Scripps Research Institute in La Jolla, Calif., reported December 10. And these traffic jams may have deadly consequences.

Prions, misshaped versions of a normal brain protein, clump into aggregates that are hallmarks of diseases including mad cow disease in cattle and Creutzfeldt-Jakob disease in people. The new finding may give clues about what goes wrong in these neurodegenerative diseases.

Axons, a nerve cell's stringlike projections that carry electrical signals to other nerves, are the sites of the traffic jams, Chaiamarit said. As more prions clump, they cause bulges that make the axon look like a snake that has just swallowed a big meal.

Through a microscope, Chaiamarit and colleagues saw mitochondria being transported toward the cell's farthest reaches derailed at the bulges. Mitochondria, cells' energy-generating organelles, are carried outbound from the main cell body by a motor protein called kinesin-1. The protein motors along molecular rails called microtubules. A different motor protein, dynein, transports mitochondria back toward the cell body along those same rails.

Prion clumps disrupt outbound traffic, causing kinesin-1 and mitochondria to jump the microtubule tracks in swollen sections. Microtubules may be bent or broken in those spots. Mitochondria movement back toward the cell body wasn't impaired, perhaps because dynein is better at avoiding obstacles than kinesin-1, Chaiamarit said.

Brain cells are alive when the traffic jams start, but the researchers think the jams contribute to cell death later. — *Tina Hesman Saey*

NEWS

Over a decade, scientists attached sensors to 300 whales (two humpbacks off Antarctica in 2018, shown) to track feeding behaviors.

LIFE & EVOLUTION

Why aren't whales even bigger?

Feeding style and prey availability influence size

BY JONATHAN LAMBERT

Sensors suction-cupped onto the backs of whales are helping answer two long-standing questions: Why are whales so big? And why aren't they bigger?

By estimating the energy used — and gained — when 13 species of whales and porpoises forage, scientists have shown that how big the animals get is influenced by feeding strategy and prey availability.

The sizes of toothed whales such as orcas, which use echolocation to hunt individual prey, appear to be constrained by how much food they can grab in a dive, the scientists note in the Dec. 13 *Science*. But blue whales and other filter feeders, which tend to be larger, aren't limited by food availability. Instead, these whales might be limited by biology or could be on their way to evolving to be even bigger.

Biologists have been thinking about the evolution of bigness for a long time, says evolutionary biologist Samantha Price of Clemson University in South Carolina. "But this paper, through incredible effort, actually got some data about these hard-to-study behaviors."

Over the last 5 million years, changes in glacial cycles, wind and ocean currents have intensified nutrient upwellings in pockets of the ocean, says comparative physiologist Jeremy Goldbogen of Stanford University. These upwellings have created sparse but dense patches of marine creatures. Scientists have suspected that being big helps whales exploit these food bonanzas. Bigger animals can travel across wide swaths of barren ocean using less energy per unit of mass than smaller animals, the thinking goes. And larger bodies support larger lungs, buying whales more time to feed during dives.

To test these ideas, Goldbogen and colleagues affixed sensors to the backs of 300 individual cetaceans. Over a decade, the team tracked more than 10,000 feeding events.

The tags, which had pressure sensors, accelerometers, hydrophones and cameras, relayed a daily diary for the whales and revealed how much energy they expend per dive. Sonar data and stomach dissections of stranded whales painted a picture of whale diets. With all of the data, the team estimated how much of a caloric bang a whale gets for its exertion buck.

Being big lets toothed whales dive deeper and access higher-calorie prey. But after a point, foraging efficiency wanes with increased size. Toothed whale prey just isn't concentrated enough in the ocean for the whales to get any bigger, Goldbogen says.

Filter feeders, which target dense aggregations of tiny prey, get only more efficient with size. The whales can get more than 10 million calories from a single gulp, Goldbogen says, which takes comparatively less effort than chasing down a squid. Instead of being limited by prey, filter feeders may be limited by physiology. Perhaps it is not physically possible to engulf more food than they currently do.

Or their size might not be limited at all and might continue to evolve. "Perhaps, millions of years from now, we'll see even bigger ocean giants," Goldbogen says. ■

MATTER & ENERGY

Quantum quivers transfer heat

Experimental findings could lead to better technologies

BY EMILY CONOVER

For the first time, scientists have measured the heat transferred by the quantum effervescence of empty space.

Two tiny, vibrating membranes reached the same temperature despite being separated by a vacuum, physicists report in the Dec. 12 *Nature*. The result is the first experimental demonstration of a predicted type of heat transfer.

Normally, a vacuum prevents most types of heat transfer — that helps a vacuum-sealed thermos keep coffee piping hot. But "quantum mechanics gives you a new way for heat to go through" a vacuum, says King Yan Fong, who worked on the study while at the University of California, Berkeley. For distances on the scale of nanometers, heat can be transferred through a vacuum via quantum fluctuations, a kind of churning of transient particles and fields that occurs even in empty space.

Made of gold-coated silicon nitride, the two membranes each measured about 300 micrometers across. The researchers cooled one membrane and heated the other, to a temperature difference of about 25 degrees Celsius. That heat translated into a drumhead-like motion of the membranes — the warmer the membrane, the more vigorously it vibrated. When the membranes were brought within a few hundred nanometers of one another, separated by nothing but empty space, their temperatures equalized, indicating that heat had transferred between them.

"It's super exciting," says Sofia Ribeiro, a quantum optics researcher at Durham University in England who was not involved with the study. Scientists have been working to develop tiny machines that take advantage of quirks of thermodynamics on quantum scales (*SN: 3/19/16, p. 18*). The new study could

GOLDBOGEN LAB/STANFORD UNIV., DUKE UNIV. MARINE ROBOTICS AND REMOTE SENSING, PHOTO TAKEN UNDER PERMIT ACA/NMFS #14809 be fodder for that effort. “This opens … a huge platform that’s going to be very interesting to explore,” she says.

Heat typically travels through three main pathways: conduction, convection and radiation. Conduction describes heat transfer via direct contact of materials, whereas convection is heat transfer arising from motions of gases or liquids, like hot air rising. Those two don’t apply for empty space. But radiation — heat transfer via electromagnetic waves — can occur across a vacuum, as in the sun warming the Earth. Now, the researchers say they’ve experimentally shown another mechanism by which heat can make it across a vacuum, though the effect is significant over only very small distances.

The new variety is a result of the Casimir effect, which describes how quantum fluctuations produce an attractive force between two surfaces separated by a vacuum. In quantum mechanics, empty space can never be truly empty: Transient electromagnetic waves constantly blip into and out of existence. Those waves, although virtual, exert real forces on materials. In the space between the surfaces, electromagnetic waves can occur only with particular wavelengths. But waves of any size can arise outside, and that excess of exterior waves creates an inward pressure. In the study, the two membranes influence one another by way of that force — the jiggling of the hotter object jolts the colder one, for example — equalizing the temperatures.

This new type of heat transfer could be harnessed to improve performance of nanoscale devices. “Heat is a huge issue in nanotechnology,” says physicist John Pendry of Imperial College London. Performance of the tiny circuits found in cell phones and other electronics is limited by how fast the devices can dissipate heat. ■

LIFE & EVOLUTION

Simple cell puts up a complex defense

Single-celled protist can ‘decide’ how to respond to a threat

BY JONATHAN LAMBERT

Being single-celled doesn’t necessarily doom a creature to a simple life. A fresh look at a long-dismissed experiment suggests that so-called primitive organisms can behave in surprisingly complex ways.

Stentor roeseli, a tiny trumpet-shaped protist, can dodge, duck or flee in response to an irritating stimulus, changing behavior when one strategy fails, researchers report in the Dec. 16 *Current Biology*. The study suggests that single cells, rather than being preprogrammed to react, are capable of “changing their minds” based on experience.

“This fascinating experiment reminds us that primitive organisms can do complicated things,” says Sindy Tang, a cellular engineer at Stanford University.

S. roeseli rose to prominence in 1906, when the American zoologist Herbert Spencer Jennings described some of the most complex behaviors ever reported for a single-celled organism. The millimeter-long freshwater protist spends much of its life fastened to drifting algae, using hairlike cilia on its body to sweep food into its mouth.

Jennings disturbed *S. roeseli* cells with a pipette-delivered stream of an irritating chemical. Instead of simple reflexive behaviors, he documented a hierarchy of avoidance tactics. First, the protist would bend to dodge the onslaught. If that failed, it would repel the irritant by using its cilia to “spit” water out of its mouth. When Jennings persisted, the cell would contract to shrink away. Its final act was to escape by detaching from its substrate and floating away.

At the time, biologists thought single cells were capable of only rudimentary behaviors, such as moving toward or away from a stimulus. So, Jennings’ work garnered attention. But replication attempts failed, and his observations were dismissed.

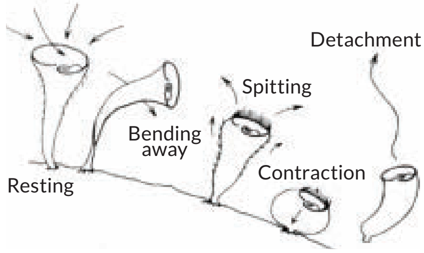
But when Jeremy Gunawardena, a systems biologist at Harvard Medical School in Boston, learned of Jennings’ work from a colleague’s lecture, “I was surprised and immediately fascinated,” he says. He tracked down some of the attempts at replication and noticed a flaw: The studies all used a different species of *Stentor* with a more mobile lifestyle than *S. roeseli*.

With the right species in hand, Gunawardena and colleagues redid Jennings’ experiment. Instead of chemicals, the team shot pulses of plastic beads at *S. roeseli* cells. Over 57 experiments, the team observed each of the behaviors described by Jennings, but noted more variability. Some of the cells repeated the same steps or skipped some altogether.

In analyzing the behaviors of all the studied *S. roeseli* cells, a hierarchy emerged. More often than not, an irritated cell will first bend away or try to spit out irritants. Later, a cell will try contracting or detaching, though it never detaches without contracting first. The team was especially surprised to find that, after contracting once, there’s a 50-50 chance that *S. roeseli* will either contract again or detach. Being unpredictable may give *S. roeseli* an advantage in keeping predators on their toes, Gunawardena says.

Rather than being genetically programmed to respond uniformly to some stimulus, he says, individual cells might instead be programmed with “machinery that allows the cell to have some autonomy about what it does depending on the context.” ■

Evasive maneuvers The unicellular protist *Stentor roeseli* exhibits a range of avoidance behaviors. From a resting position, during which cilia sweep water and food toward the mouth, *S. roeseli* can bend away from an irritant, reverse the direction of cilia to “spit” out the irritant, contract, or detach and float away.



J.P. DEXTER ET AL/CURRENT BIOLOGY 2019

HUMANS & SOCIETY

A sixth century plague wasn't so dire

Outbreak didn't radically change Eurasian history, a study finds

BY BRUCE BOWER

An ancient outbreak of the bubonic plague often characterized as a mass killer that felled Eurasian civilizations was actually pretty tame, researchers say.

Known as the Justinianic plague, the outbreak probably didn't cause enough deaths to trigger major events previously attributed to it, such as the eastern Roman Empire's decline, Islam's rise and the emergence of modern Europe, say environmental historian Lee Mordechai and his colleagues.

Many scholars have argued that this plague caused tens of millions of deaths starting in the sixth century and reduced European and Middle Eastern populations by 25 to 60 percent. As a result, economies crumbled, devastating what was left of the Roman Empire and ushering in a period of cultural deterioration.

But several new lines of archaeological evidence challenge that scenario, Mordechai and colleagues report in the Dec. 17 *Proceedings of the National Academy of Sciences*.

"Support for the claim that the Justinianic plague was a watershed event in the ancient world is just not there," says coauthor and environmental historian Merle Eisenberg of the University of Maryland's National Socio-Environmental Synthesis Center in Annapolis. Yet the idea that the plague wiped out populations and reshaped societies appears in many textbooks, he says.

The Justinianic plague, caused by the bacterium *Yersinia pestis*, occurred several centuries before the more widely known Black Death plague epidemic, which killed tens of millions in the 14th century. An initial outbreak began during the reign of Emperor Justinian, who ruled the eastern Roman Empire after the fall of Rome, and ran from about 541 to 544. Intermittent plague reoccurrences lasted until about 750 and stretched around the Mediterranean and into Europe and the Middle East.

Researchers in various disciplines have often wrongly assumed that evidence from archaeology, genetics, ancient texts and other sources indicate that the Justinianic plague wreaked social havoc, contends geographer Neil Roberts of the University of Plymouth in England. Mordechai's team has assessed evidence from across disciplines to reach a contrasting but plausible conclusion, Roberts says.

In one finding that points to the plague having only a modest impact, land use and cereal cultivation remained largely unchanged during the sixth century in several eastern Mediterranean regions often said to have been shattered by plague. Based on ancient pollen data collected by other investigators, Mordechai, of the National Socio-Environmental Synthesis Center, and colleagues found no signs of people abandoning farmland in those areas, including agricultural sites near Roman trade routes and cities such as Constantinople, now Istanbul, where plague could have spread quickly.

Neither did burials of five or more individuals in the same grave increase in sixth century Europe, the researchers say. In particular, evidence from 8,207 ancient graves across Great Britain suggests that multiple interments increased slowly starting in the 300s, with no unusual jumps during the time of the Justinianic plague. Mass burials could signal a particularly deadly plague outbreak, but in some regions could reflect a cultural practice aimed at keeping members of the same families or social groups together.

A plague outbreak that began in the sixth century, depicted in this Renaissance painting as suddenly striking the Italian man on the left, was not as deadly and politically destabilizing as scholars have assumed, an analysis finds.

Early historical texts and stone inscriptions from Europe and the eastern Mediterranean contain few plague references, the investigators also found. And other written sources indicate that official Roman legislation did not decline after the 541 outbreak, as would be expected in a social crisis. Archaeological finds from two Mediterranean sites suggest that coin circulation also remained stable during the 540s. Roman texts point to similar stability at that time for gold values.

What's more, some researchers have assumed that the Justinianic plague killed many Egyptians. But official papyruses dating from 520 to 570 don't refer to a plague outbreak and contain no evidence of population declines, land abandonment or drops in tax revenue, Mordechai's team found.

Although the Justinianic plague probably struck some densely populated areas, "the idea that it was a blanket catastrophe affecting all parts of the Mediterranean, Middle East and central and western European worlds needs to be rethought," says John Haldon, an historian of ancient Europe and the Mediterranean at Princeton University who did not contribute to the research but was Mordechai's Ph.D. adviser.

Even the Black Death didn't topple political systems, Haldon says. For instance, the Hundred Years' War, waged between the kingdoms of England and France from 1337 to 1453, barely wavered as the Black Death spread. There's no reason to expect that an apparently less deadly, sixth century plague capsized a big chunk of the Roman Empire or any other ancient state, he contends. ■

GENES & CELLS

Gene bolsters self-domestication idea

Humans selected among themselves for tameness, study hints

BY TINA HESMAN SAEY

Domestic animals' cuteness and humans' relatively flat faces may be the work of a gene that controls some important developmental cells, a study of lab-grown human cells suggests.

Some scientists tout the finding as the first molecular evidence for two theories about domestication. One of those ideas is that humans domesticated themselves over many generations, by weeding out hotheads in favor of the friendly and cooperative (*SN: 7/8/17 & 7/22/17, p. 26*). As people supposedly selected among themselves for tameness traits, other genetic changes occurred that resulted in humans having a different appearance than their predecessors. Human faces are smaller, flatter and have less prominent brow ridges than those of extinct Neandertal cousins, for instance.

The other idea is that as people selected for tameness in animals, that selection favored genetic changes that slightly hamper movement of some developmentally important cells (*SN: 8/23/14, p. 7*). These neural crest cells are present early in embryonic development and migrate to different parts of the embryo where the cells give rise to many tissues. Three scientists proposed in 2014 that mild genetic changes might produce neural crest cells that don't move as well, leading to the characteristic features of domestic animals, such as shorter snouts, curly tails, floppy ears and spotted coats — a suite of traits known as domestication syndrome.

Some studies have suggested that differences in some genes implicated in neural crest cell function might have been important in the domestication of cats, horses and other animals. But none of those studies explained how genetic differences led to altered behaviors or looks between wild and domestic animals.

In the new study, researchers studied human cells to learn what makes neural crest cells tick. One gene, *BAZ1B*, is a neural crest cell boss, the team found, controlling 40 percent of genes active in those cells. Altering levels of *BAZ1B*'s protein affects how quickly neural crest cells move in lab tests, the scientists report December 4 in *Science Advances*.

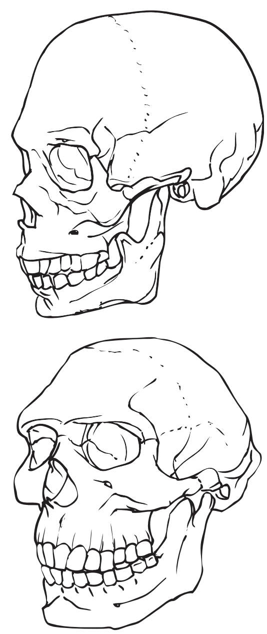
Genes under *BAZ1B*'s direction are among those that changed in animals during domestication and in humans as they evolved, the researchers found. Some variants of those genes are found in nearly every modern human, but either weren't found or were not as prevalent in the DNA of Neandertals or Denisovans, another extinct cousin.

That all adds up to one thing, says Matteo Zanella, a University of Milan neuroscientist: "We're giving the first proof of self-domestication in humans."

But that conclusion is a giant leap, says neuroscientist Kenneth Kosik of the University of California, Santa Barbara. Tying together human evolution, domestication and development of facial features based on the activity of one gene is an overinterpretation, he says.

The studied cells came from people with two developmental disorders. People with Williams-Beuren syndrome have only one copy of *BAZ1B*. These people are talkative, outgoing and not aggressive, and tend to have especially round faces with short noses, full cheeks and wide mouths with full lips.

People with what's known as 7q11.23 duplication syndrome have an extra copy of *BAZ1B* and are the polar opposite: They are aggressive, sometimes have difficulty speaking and have autism-like characteristics that affect their ability to socialize. Their facial features are exaggerated but different from those seen in Williams syndrome.



A gene that affects the movement of certain cells important in embryonic development may help explain why humans (top) have flatter, smaller faces than Neandertals (bottom).

BAZ1B was already known to affect neural crest cell function. So probing its actions in cells from people with the syndromes seemed likely to reveal more about how human faces evolved, says coauthor Alessandro Vitriolo, also a neuroscientist at the University of Milan. The researchers reasoned that variations in *BAZ1B* and its protein may slightly impair the function of the gene or protein, or how much protein is produced, leading to slower neural crest cell movement and the characteristics of domestication.

First, the team needed to know whether altering amounts of *BAZ1B*'s protein had any effect on neural crest cells. The team reprogrammed skin cells from people with Williams or the duplication syndrome into stem cells and then grew the stem cells into neural crest cells. For comparison, the team also made neural crest cells from people who have the usual two copies of *BAZ1B*.

The team also used genetic tricks to reduce levels of *BAZ1B*'s protein, to be sure that any effects were due to the *BAZ1B* gene. When the team reduced these protein levels in each of the different types of cells, neural crest cells moved more slowly. Other genes' activities were also influenced by the amount of *BAZ1B* and its protein in cells.

Evolutionary anthropologist Brian Hare of Duke University finds the study's results convincing. "This is the strongest test yet of the human self-domestication hypothesis, and seems to support the idea that humans, like many other animals, have evolved due to selection for friendliness that also shaped other features like our faces," he says. ■

HEAVYPRED/DIGITALVISION VECTORS/GETTY IMAGES

New Hoard Discovered!

Full Bags of Eisenhower Bicentennial Dollars

In 1975 and 1976, the United States Mint released special Bicentennial Eisenhower Dollars to mark the 200th birthday of our nation. Upon their release in 1975, a family purchased five full bags—5,000 coins in all—and simply stashed them away... until now!

Special Bicentennial Design

Normally, the short-lived Eisenhower Dollar displayed a stylized version of the Apollo 11 mission patch on its reverse. But for the nation's 200th birthday, a new one-time-only design was created, showing the Liberty Bell before an image of the Moon. This temporary design and dual dates of 1776 and 1976 make it a coveted piece that belongs in every U.S. coin collection.

Fresh Out of the Bag!

Though each of these coins is more than 40 years old, you wouldn't know it by looking at them. Each one is still in its original Brilliant Uncirculated (BU) condition, taken fresh out of a bag from the Philadelphia Mint that has been sealed for 43 years. They're just like new!

A Dual-Dated Mystery

Curiously, each of the U.S. Mint bags of Eisenhower Dollars are dated 1975. But how can that be, if the coins are dated 1976? To get a jump on the celebration, the mint struck special anniversary U.S. Dollars in both 1975 and 1976. That means that for nearly all Bicentennial Ike collectors, it's nearly impossible to tell when their coins were struck. But not with these. Thanks to the date on the bag, we can confirm that these Type II Bicentennial Ike Dollars were struck in 1975!

Secure Full Rolls NOW!

When this incredible new hoard was announced, we snatched them up as quickly as we could. These coins sell elsewhere for as much as $12.25 each. ut now, while our limited supply lasts, we're offering full 20-coin rolls for as low as $3.50 per coin when you buy three or more rolls. These Brilliant Uncirculated U.S. Bicentennial Eisenhower Dollars, featuring a special one-time-only design, are guaranteed to have come from a 1975-dated U.S. Mint bag! Plus, when you secure two or more full rolls of these historic U.S. Dollars, we'll include FREE Domestic Shipping. Grab them by the roll while our supply lasts!

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SAVING NOTRE DAME'S SOUND

Scientists aim to resurrect the acoustics of the Paris cathedral and other historic buildings

By Emily Conover

For centuries, the interior of Notre Dame never saw much sunlight. But when Brian Katz stepped inside the cathedral last July, the place was drenched in light, its famous arched ceiling open to the sky. Nearly three months before, on April 15, 2019, a fire had ripped through the Paris cathedral. Now, charred wood lay heaped on the floor, mingled with toxic lead dust. The acrid scent of fire lingered. But Katz and his colleague Mylène Pardoen had one main concern: the sound.

Something fundamental to Notre Dame's voice was missing: its reverberance, that echolike quality that the grandest cathedrals are known for. "You didn't hear the building anymore," Katz says.

Before the fire, the tap of a heel or a cough would hang in the air for many seconds, a feature that imbued visitors with a tendency to step softly and keep voices low. Notre Dame de Paris — which translates as "Our Lady of Paris" — had a way of imposing silence upon her guests. To Katz and Pardoen, the cathedral's personality had been erased.

But there was reason for hope. Much of the cathedral remained relatively untouched by the fire; wooden chairs still stood neatly in rows, and paintings and sculptures — though covered in dust — remained intact.

Preliminary repairs had already begun. Damaged pillars and flying buttresses were reinforced, and nets hung high in the arches to catch falling debris. Robotic devices swept up rubble in places too dangerous for humans to set foot.

As architects, builders and historians begin the process of rebuilding Notre Dame, Katz — an acoustics researcher at CNRS, the Centre National de la Recherche Scientifique, and Sorbonne University in Paris — is on a mission to help restore the building's sonic signature.

Similar work has been happening at other historical places, too. The disaster at Notre Dame has put a field known as heritage acoustics in the spotlight. Science has made it possible to document the acoustics and re-create the symphonic grandeur of destroyed or altered structures. Researchers are wielding their knowledge of physics to unveil a hidden history of sound in historical buildings.

"The past was not a silent place," says acoustician Damian Murphy of the University of York in England. "Sound is a fundamental part of our human experience."

At Notre Dame, Katz and colleagues had a fortuitous head start. Using a computer simulation and acoustic measurements the group made in the intact cathedral in 2013, the researchers had already digitally reproduced the building's reverberance. Katz is using that work to predict how choices made during the reconstruction might alter Notre Dame's effect on the ears.

He can also resurrect the acoustics of Notre Dame of old, showing the impact of renovations from previous eras in the medieval cathedral's past, focusing on how the building would have responded to the sounds within. Meanwhile Pardoen, of CNRS and the Maisons des Sciences de l'Homme in Lyon, aims to re-create those long-ago sounds.

Sound is a transient, ethereal phenomenon, and it tends to be neglected in historical records. While photographs and drawings can preserve the visual impact of a building or scene, documenting the sonic impact of a space is more complicated. But for many people, sound provides an intimate part of the sensation, the je ne sais quoi of being in a particular place. Eyes closed, you can still tell immediately whether a room is tiny or soaring and grand.

Aural history

Cathedrals are a classic study subject for heritage acoustics. But sonic scrutiny has been applied to other spaces, including other religious buildings, theaters and even prehistoric caves (*SN Online: 7/6/17*; *6/26/17*). Murphy, for instance, has studied the acoustics of a beloved chocolate factory and an underground nuclear reactor cavern.

For cathedrals in particular, "the sound and the feeling you get when you are inside … is key for the character" of the buildings, says acoustic engineer Lidia Álvarez-Morales of the University of York. She and colleagues recently measured the acoustics of four English cathedrals, including York Minster. That Gothic structure is larger than Notre Dame and suffered a catastrophic fire in 1984. The cathedral was later restored.

The acoustics within a room are all about how the sound reflects off the surfaces inside. When you clap your hands, for example, vibrations of air molecules travel in a wave, causing variations in pressure. Some of those waves travel directly to your ear, which registers an immediate sound. But others travel

Mylène Pardoen and Brian Katz (left to right) study the sounds of historical environments and buildings, and are helping with Notre Dame's recovery. Here, the two visit the Abbey of Saint-Germain-des-Prés, another Paris church where Katz has done acoustics research.

OPPOSITE PAGE: DUY PHUONG NGUYEN/ALAMY STOCK PHOTO; THIS PAGE: E. CONOVER in all directions until they reach a surface such as a wall, floor or object within the room. Sound waves can bounce off that surface and reach your ear at a later time (*SN: 7/13/13, p. 10*).

In a place with a single reflecting surface, such as the distant wall of a canyon, the reflected waves produce an echo, a delayed repetition of the original sound. But in a cathedral, reverberation is the rule. "Reverberation happens when we have, say, a thousand reflections that are all coming back to us so fast that we can't resolve any individual one of them with our auditory system," says acoustician Braxton Boren of American University in Washington, D.C. As a result, the sound is drawn out, slowly trailing off to silence over several seconds.

Materials that tend to reflect sound waves and enhance reverberation, such as marble and limestone, are common in cathedrals. In contrast, a more typical room has surfaces — carpets, drapes and even the people within the room — that mostly absorb sound waves (*SN: 11/15/03, p. 308*). Larger rooms also boost sound's staying power, as the waves take longer to travel between surfaces. Before the fire, with its arched limestone ceiling reaching 33 meters high and a 4,800-square-meter marble floor, Notre Dame was like a giant, mirrored fun house for sound, bouncing the waves around and around.

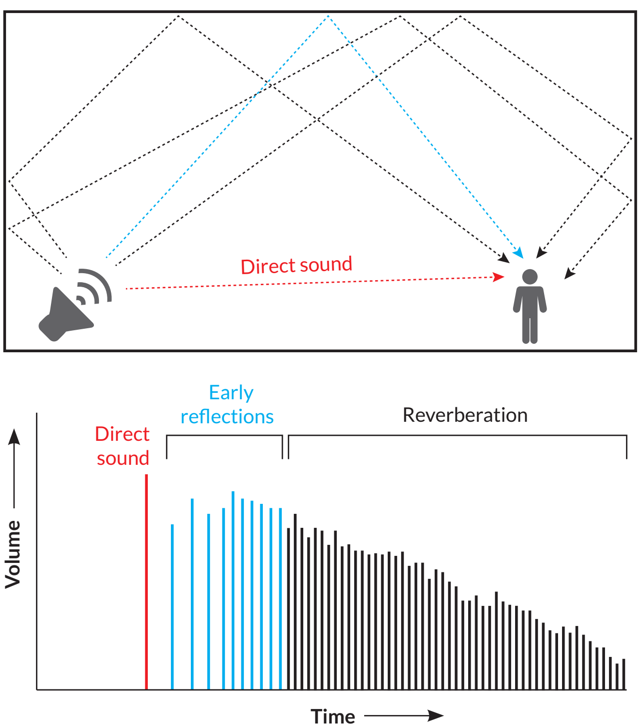
The reverberation time of a room is the number of seconds it takes for an initial, loud sound to become so quiet that it can no longer be heard. Specifically, it's an estimate of how long it takes a sound to fade by 60 decibels. While a typical living room might have a reverberation time of half a second, and a concert hall might reverberate for two seconds, cathedrals can have reverberation times in excess of five seconds.

With long reverberation times, fast-moving music or speech can be muddied, with notes and words stepping on top of one another. Gothic cathedrals were designed to be grand spaces — their long reverberation may have been a byproduct. But music evolved to fit the space: For organ music or religious chanting, "the acoustic conditions are really good, because this kind of music has been designed for those buildings," Álvarez-Morales says.

In fact, Notre Dame's special sound may have inspired the birth of polyphonic music — in which different voices sing separate notes, instead of the same pitch — in the 12th and 13th centuries. The Gregorian chants sung in the cathedral in medieval times were monophonic, featuring only one note at a time. But the drawn-out acoustics meant that consecutive notes tended to overlap.

Some acousticians believe this effect may have provided a chance to experiment with which notes sounded good together, eventually developing into voices singing in harmony. This practice is now so common it seems obvious. But at the time, it was revolutionary. As a result, the roots of modern Western music may have been shaped by the acoustics of Notre Dame. "It's incredibly historically significant," Boren says.

Lingering notes The first sound heard after a brief noise is produced is direct waves (red), followed by quickly arriving reflected waves (blue). Waves that reflect multiple times create reverberation (black); their volume dies away slowly over time (bottom).



SOURCE: B. BOREN

Sound of silence

On the day of the fire, Parisians gathered to watch the dramatic blaze. When Katz first heard the news, he didn't quite believe it. Like so many others, he decided he had to see for himself.

Despite the throngs, Paris was mostly silent, Katz says. "No one was really talking above a whisper. To have that many people staring in awe was really strange." Katz opens his eyes wide while remembering the scene. "No one knew what to say or what to do, but we were all standing there."

The next day, Katz realized there was something he could do. The 2013 data his group had taken were the only detailed measurements of the acoustics of Notre Dame. He also had his computer simulation of the cathedral. Such acoustic models include the locations of the various surfaces within a room along with estimates of how well each material would absorb sound. And despite the destruction of the cathedral's roof and medieval timbers, talk of restoring the wounded edifice had already started.

Inside the cathedral, Katz had measured a property known as "room impulse response," which captures how the sound levels within a room vary over time after a brief initial noise. From that impulse response, researchers can derive the reverberation time and subtle characteristics that can affect how a listener perceives a room. One such property is the length of the delay between when the first sound waves reach a listener and the arrival of the second, reflected set of sound waves.

Using these measurements of the cathedral, Katz had calibrated his computer model, which allowed him to accurately

C. CHANG

In July, three months after the fire, Mylène Pardoen (shown, left), Brian Katz and others wore protective suits and breathing masks inside Notre Dame. Fallen masonry and charred timbers littered the cathedral's floor.

BOTH: B. KATZ AND M. PARDOEN/CNRS

reproduce Notre Dame's lost acoustics. And now he could tell architects what they needed to do to ensure the building would maintain its acoustic splendor.

Katz exudes a nearly constant air of bemusement, as if he can't fully grasp the cosmic circumstances that led him to become the foremost expert on Notre Dame's acoustics. With a graying beard and long wavy hair tied back in a loose knot, his look is halfway between musician and physicist. But neither category quite fits: He doesn't play any instruments, and he's not a conventional physicist.

As a child, Katz's attempts at learning musical instruments fizzled: He abandoned both the cello and the saxophone. While studying physics at Brandeis University in Waltham, Mass., Katz diverged from his college classmates, who were fascinated with astrophysics or subatomic particles. "That wasn't really my thing," Katz says: He stuck to the human scale.

Eventually, Katz stumbled into acoustics thanks to his experience setting up sound systems for events at Brandeis. With a Ph.D. from Penn State, he eventually became an acoustics researcher in Paris. But he's no audio-gear geek either. He declares that his home audio system is "crap."

Music from ruins

The acoustic properties of damaged or demolished buildings have been resurrected before. Murphy and colleagues re-created the 16th century sound of a ruined church called St. Mary's Abbey, founded in 1088 in York. Today, only remnants of the abbey's walls endure — arched windows frame sky and trees within a city park. But Murphy and colleagues pieced together the architecture of the lost church as best they could, consulting with archaeologists and studying historical references. By putting that information into a computer simulation, the group got a sense of how the space would reverberate.

In 2015, singers performed a concert within the ruins, with the original reverberation of the abbey applied to their voices in real time. Audience members seated within the church's footprint heard what the music would have sounded like in the intact space.

Like an acoustic time machine, such techniques can also help researchers understand how the acoustics of still-intact buildings might have differed in the past, as a result of either renovations or differences in how the church was used or decorated, and how that would have altered the music played within them. "For anyone who's fallen in love with music from another era, we can't really re-create it without re-creating the acoustic conditions," Boren says.

For example, in the 16th century Church of the Redentore in Venice, Italy, music was composed for a special festival held each July, when citizens packed the church. All those people could have had a big impact on the sound: Humans "are actually one of the most absorbent surfaces," Boren says.

The festival still takes place today, but the church uses speakers to amplify the music, which drastically changes the acoustics, Boren says. He wanted to understand how the church sounded during festivals of the past.

Boren and colleagues produced an auralization of the church, the acoustic equivalent of a visualization. The researchers took a musical recording from a space with very little reverberation and applied the acoustics from their simulation of the church — both with and without the crowd.

That involved a process called convolution, which changes how long various frequencies hang in the air. The musical recording was broken up into tiny slices in time, and each slice was multiplied by the room's impulse response. Summing up all those slices produced the final sound.

Prior measurements had revealed that the empty church had a reverberation time of seven seconds. But in Boren and colleagues' simulation, reverberation time was cut in half when the church was filled with people and decked out with festive tapestries.

When the church was full, sounds didn't ring out as long, so the notes came through more clearly. In the past, when composers wrote music for the Venice landmark, they may have taken the room's reverberation time into account, including the effects of the crowd.

The work was made easier by the fact that the building the team was studying is intact, and the researchers had measurements from within. Whereas Murphy's team had to use a fair bit of guesswork to simulate the ruined St. Mary's Abbey, Boren's group used its data to ensure the simulation faithfully re-created the building's sound. The same goes for Katz's Notre Dame simulation, which is why his prefire measurements are so crucial.

"It's incredibly lucky that Brian [Katz] was able to get into that space and take all the measurements that he did," Boren says. "Those are going to be very critical for actually isolating what the acoustics of Notre Dame were like before."

The measure of a cathedral

On April 24, 2013, six years before the fire and 850 years after Notre Dame's first stone was laid, Katz and colleagues arrived at the cathedral lugging microphones and other equipment.

Brian Katz took detailed acoustic measurements in Notre Dame in 2013, using microphones on stands and a dummy head. These benchmark data will help reveal how rebuilding could alter the cathedral's sound.

B. KATZ/CNRS

Late that night, after a concert had ended and the last of the musicians and concertgoers had spilled out into the spring evening, Katz and his team got to work.

Microphones stood like silent sentinels in the centuries-old aisles. Orange and black cables threaded through walkways. A laptop rested on a chair — a seat normally occupied by the faithful now reserved for technology. And a dummy of a human head outfitted with microphones in its ears perched on a post, its blank face surveying the ornate surroundings.

To precisely pin down Notre Dame's room impulse response, Katz's group played a sound called a sine sweep, which starts on a low note and slides gradually up to a higher pitch. It's designed to test the full range of pitches that humans can hear, because different pitches can reverberate for different lengths of time.

Microphones measured the cathedral's response to the sine sweep. That response varies based on where in a room the sound is coming from, and where the microphone is. So the researchers moved the speaker and microphones from place to place, repeating the measurements. Using that data, Katz calculated that Notre Dame's reverberation time was around six seconds on average — more than 10 times as long as a typical living room's. The reverberation time varied depending on the pitch; for a note of middle C, the reverberation lasted eight seconds.

Tuning up

Next, Katz and colleagues turned to the computer simulation, comparing the simulated reverberation with the reverberation they measured in the cathedral. The results were close, but didn't quite match for all frequencies of sound. That's to be expected: Notre Dame's walls might be a little better or worse at absorbing sound than a typical limestone wall, for example. So Katz and colleagues tweaked the amount of absorption of various surfaces until the acoustic properties of the simulated cathedral aligned with reality.

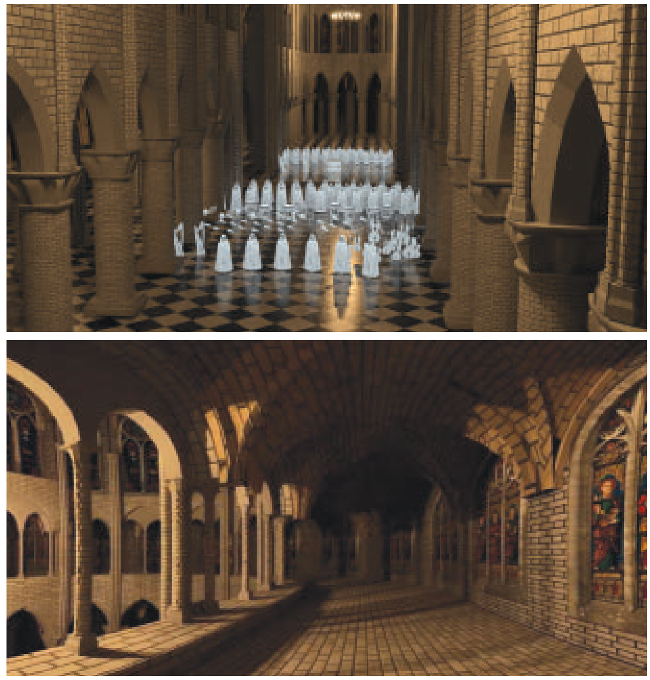
The researchers then made an auralization of Notre Dame, using audio from the concert that took place in Notre Dame the night that Katz made his measurements. That concert, a performance of "La Vierge," composed by Jules Massenet in the late 19th century, was recorded with microphones positioned very close to the performers. The mics picked up mostly direct sound rather than the cathedral's reverberation. Katz used his computer model to re-create how the concert would have sounded for a listener wandering through other parts of the church.

Next, Katz and colleagues added visuals to that audio to make a virtual reality re-creation of the performance, which they reported at the European Acoustics Association's EuroRegio conference in 2016. Wearing a virtual reality headset, the viewer flies about the simulated cathedral as the music plays, swooping low over the orchestra, then zipping into high, secluded passages. In the back of the building, the individual notes are more muddied. Turn your head, and as your ears move positions, the sound changes too.

Moving forward, Katz plans to tweak his model to account for the design and materials to be used in the proposed cathedral refurbishments. Even relatively minor choices — such as whether to carpet some of the aisles — could create a noticeable difference. Katz also aims to adjust his model to understand how Notre Dame may have sounded in the past, cataloging its progression through a series of changes. Some of the past renovations could have altered the cathedral's acoustics, even cosmetic changes like coatings of paint and the hanging of tapestries or artwork.

No building stands for 850-plus years without damage, refurbishments and aesthetic tweaks. Once Notre Dame's construction began in 1163, it continued off and on for almost 200 years, until the middle of the 14th century. In 1699, King Louis XIV started a round of updates, including a new marble altar, with statues of himself and his father flanking the Virgin Mary holding Jesus' dead body.

During the French Revolution, statues were beheaded, and the church was used as a warehouse, falling into disrepair. Victor Hugo's novel *The Hunchback of Notre Dame* was published in 1831 and may have inspired Parisians to give the cathedral some TLC. Beginning in 1845, renovations led by architect Eugène-Emmanuel Viollet-le-Duc shored up the crumbling structure and added the cathedral's spire (destroyed by the 2019 fire), among other changes. The fire is believed to have broken out accidentally during restoration work.



A virtual reality simulation of a concert in Notre Dame (musicians illustrated, top), made by Brian Katz and colleagues, re-creates the acoustics from various locations, including the cathedral's upper levels (bottom).

B. KATZ/CNRS

Crafting a soundscape

One thing Katz can't do is reproduce the actual sounds that might have been present in those earlier eras. That's the specialty of Pardoen, Katz's companion on the July visit to the damaged Notre Dame. Calling herself a "soundscape archaeologist," Pardoen pieces together the sounds of past environments: battlefields, cathedrals and cities.

With close-cropped gray hair and dark clothes, Pardoen seems no-nonsense. But chatting with Katz over coffee, she breaks the veneer of seriousness by frequently interrupting the conversation to mimic the noises she studies, like the "choo click choo click" of a loom or the "crrrrrr" of stone cutters.

Her magnum opus is a video soundscape of central Paris during the second half of the 18th century, when Paris streets bustled with people, and bridges were crammed with buildings several stories high. In the video, the viewer wanders the city streets, taking in the sounds: the clacking of horse hooves, washerwomen working at the banks of the Seine, leatherworkers engaged in their craft and even the buzzing of flies around the fish market.

To cultivate this sonic bouquet, Pardoen consulted maps, historical documents and paintings. She found replicas of the tools that would have been common at the time and recorded them in use to collect historically accurate sounds.

Now, Pardoen plans to exhume the forgotten sounds of Notre Dame. Rather than re-creating religious ceremonies or concerts, she'll focus on the everyday noises. In earlier times, artisans and merchants crowded the neighborhood around the cathedral, and the resulting cacophony leaked into the church's interior. By filtering these sounds through Katz's acoustic model, Pardoen and Katz aim to achieve the ambience of Notre Dame at various periods of its history.

As the cleanup progresses, Katz and Pardoen will return regularly to monitor the acoustics of the damaged building. The two are part of a group — Association des Scientifiques au Service de la Restauration de Notre-Dame de Paris, the Association of Scientists in the Service of the Restoration of Notre Dame of Paris — that aims to consolidate scientific expertise to better understand the cathedral and assist in its reconstruction (see Page 24).

Parisians will have to decide which version of the cathedral to aim for, the Notre Dame that existed just before the fire, a version from an earlier era or something new and different. Giving architects, politicians and the public a chance to explore the sonic history of Notre Dame could help inform decisions about its future.

"No historic building is ever completely static," says Murphy, of the University of York. "This terrible fire, which is a considerable tragedy, is just the next stage in the life of Notre Dame." ■

Explore more

- "Ghost orchestra: A virtual reconstruction of the acoustics of Notre Dame cathedral." bit.ly/VR-NotreDame
- Mylène Pardoen. "Restoring the historical sound of Paris." *Mondes Sociaux*. January 16, 2019. bit.ly/PardoenParis

After the April 15 fire at Notre Dame de Paris, rubble from the collapsed roof littered the floor, but many parts of the cathedral remained intact.

Scientists Rally Around a Cathedral

Efforts to rebuild offer a chance to learn more about Notre Dame's medieval roots **By Emily Conover**

The "forest" of Notre Dame was one of Olivier de Châlus' favorite places. That dense lattice of timbers under the building's lead roof epitomized the medieval construction techniques that the engineer has spent years analyzing.

"There was a very special wood smell, very strong, coming from the Middle Age," de Châlus says. "And it was very, very calm — impressive, compared to the very noisy life inside the cathedral." As one of the few visitors allowed in the forest, de Châlus had the rare privilege of hearing the creaking noises emitted by the timeworn wood and peering at numbers scrawled on the timbers by long-gone carpenters.

That beloved forest is now gutted, lost in an April 15, 2019 blaze that destroyed the cathedral's roof and spire and damaged parts of the masonry. De Châlus, who works for the global engineering firm Arcadis, is finishing a Ph.D. on the construction of the cathedral.

There's little documentation of the building process, which began in 1163 and continued for about 200 years. De Châlus has devoted himself to teasing out the unwritten rules of construction — how builders decided the size of columns or the height of flying buttresses, for example. He notes that builders lifted 100-kilogram stones more than 60 meters off the ground without the benefits of modern technology. Exactly how this was accomplished has been lost to time, he says.

"Notre Dame is my life, my whole life," says de Châlus, who spent four years supervising the guides that show tourists around the cathedral. So, after the fire, he quickly joined an international effort organized by French scientists to use their expertise to help rebuild the cathedral and learn more about the iconic building. He is now the spokesperson for the group, Association des Scientifiques au Service de la Restauration de Notre Dame de Paris — the Association of Scientists in Service of the Restoration of Notre Dame of Paris.

The fire has opened up access to parts of the building that could not be studied when the structure was intact. Scientists have come together with plans to research the history of the cathedral, as well as the fire's environmental impact on the surrounding city. Some will even explore what the cathedral's aged materials can reveal about climate change.

The "forest" of Notre Dame held up the cathedral's roof and spire. It was destroyed in the fire, but researchers hope to study the charred remains of the medieval oak beams to learn about climate change.

Getting organized

As the flames died out, Paris despaired at the damage to one of its most treasured historic structures. But "there's much more to lose than what was lost already," says archaeologist Maxime L'Héritier of Université Paris 8. If the materials that fell from the top of the cathedral — stone, wood, iron, lead — are not studied, he says, the opportunity lost is "even worse than what the fire has caused."

The day after the fire, L'Héritier and art historian Arnaud Ybert of the Université de Bretagne Occidentale in Quimper, France, formed the association of scientists. Today, more than 200 scientists are part of the group, including geologists, archaeologists and engineers. The association aims to coordinate work among experts in various specialties, share knowledge and advocate for scientific study of the cathedral.

Olivier de Châlus studies Notre Dame construction techniques.

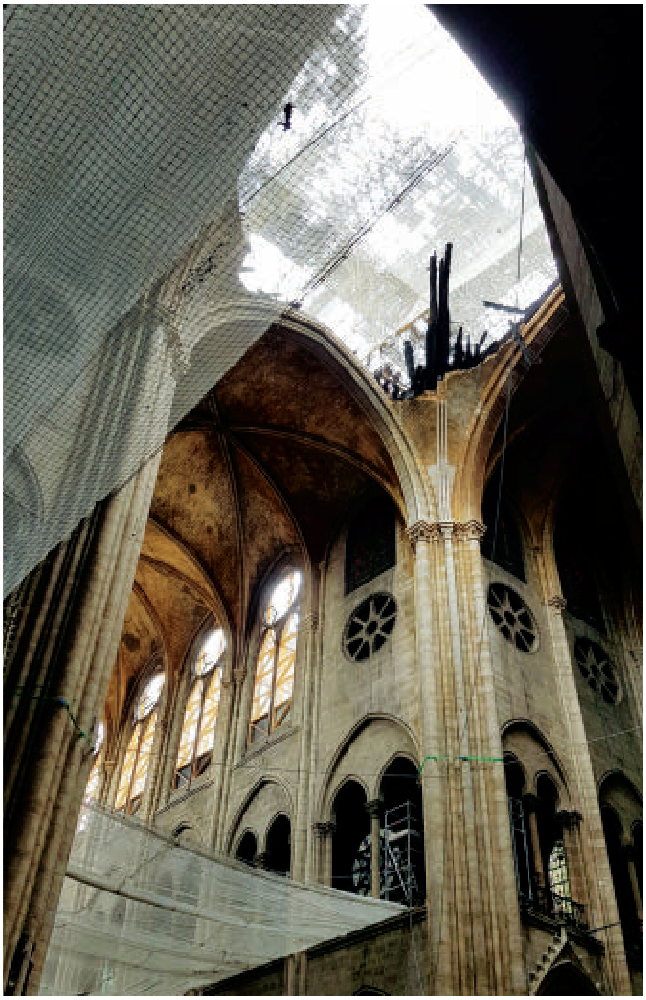
L'Héritier, who studies ancient metals, wants to know more about how iron was used in the structure, including its integration in the stone walls and the carpentry that held up the roof. While renovations in the 19th century added iron to the structure, the researchers will be searching for medieval iron placed during the original construction.

Radiocarbon dating is commonly used to sort out the age of materials, but for that, the materials must contain some carbon. Luckily, medieval iron-production techniques introduced small traces of carbon, which, when alloyed with iron, make steel. Carbon dating those steel bits could demonstrate whether the metal is original, L'Héritier says.

And the iron, medieval or not, could act "like a thermometer," revealing how hot the fire got, says Philippe Dillmann, an archaeometallurgist at the Centre National de la Recherche Scientifique, or CNRS. As temperatures rose inside the fire, the corrosion on the iron — essentially rust — would have transformed from typical rust into more unusual compounds. Analyzing that corrosion could indicate how much heat was inflicted on the building, and so could help scientists understand how much that heat weakened the limestone that makes up the bulk of the cathedral's structure.

Dillmann is co-leader of a second effort to organize researchers to study Notre Dame, spearheaded by CNRS. The CNRS team will also plan scientific meetings and compile research.

Both groups are still in the planning stages



Falling debris punched holes in the cathedral's vaulted ceiling. Scientists are assisting with efforts to determine which of the remaining stones are damaged and need to be replaced.

because the cathedral is still contaminated with the toxic dust released when the lead roof burned. Most scientists do not yet have access to the building, and all the materials within must be sorted and cataloged before researchers can get their hands on them.

Inside the cathedral

A third group of scientists is already on the scene assisting with the building's cleanup and restoration. Researchers from the French Ministry of Culture's Laboratoire de Recherche des Monuments Historiques, or LRMH, develop scientific techniques for restoring monuments throughout France.

The laboratory, located in Champs-sur-Marne near Paris, employs 23 scientists "for all the materials and for all the monuments in France," says LRMH's Lise Leroux. "We are very busy." Even more so after the fire.

A geologist and expert in the conservation of stone, Leroux is helping to determine which of Notre Dame's limestone blocks can stay in place or be reused, and which must be replaced with new stones. "The monument is very degraded," she says. As the fire raged that night, the intense heat and the deluge of water from firefighting efforts caused cracking and other damage in the stones nearest the flames. And when the church's spire collapsed, the impact punched gaping holes in the limestone ceiling.

Finding stones to replace damaged or destroyed ones will demand great care. Placing stones of different compositions next to one another — for example, distinct types of limestone quarried from different parts of the world — can cause water or pollutants to accumulate in one stone more than another, weakening the structure.

Even before the fire, "the monument was very, very dirty," says LRMH metals expert and chemist Aurélia Azéma. Now, LRMH researchers are devising and testing techniques for removing lead, which was strewn throughout the cathedral when the roof burned. Metal, stone, paint and other materials require tailored methods to extract the lead without causing damage.

A fire's fingerprints

Problems with lead extend beyond the cathedral walls. During the fire, extremely high temperatures caused the lead to aerosolize into small particles that billowed into the air and fell as dust nearby. That gave geochemist Sophie Ayrault, who studies toxic metals, a new project.

Ayrault, of the Laboratoire des Sciences du Climat et de l'Environnement in Gif-sur-Yvette, France, previously searched for metals in the sediments of the Seine, the river that runs through Paris. Analysis of sediment cores from the river's floodplain reveals how contamination has varied over the last 100 years.

To pinpoint the origins of the lead she detects, Ayrault measures the relative concentrations of its isotopes — different versions of the element with varying numbers of neutrons in the nucleus. The ratios are a fingerprint that can be used to trace the contamination's source.

For example, in a paper published in 2012 in *Chemosphere*, Ayrault and colleagues reported that the signature of leaded gasoline was detectable in older Seine sediments, but faded away in sediments deposited after leaded gasoline was phased out in the mid-1980s.

Before Notre Dame went up in flames, Ayrault had hoped to search the Seine's sediments for runoff from Notre Dame's roof — which, when intact, contained as much as 460 metric tons of lead, she says. But Ayrault hadn't yet procured the roof samples she needed to discern its fingerprint. Now, to understand the fire's impact, determining that signature has become more important.

After the fire, tests in parks and schools near the cathedral found lead levels high enough to endanger children. But it's not clear if all of that lead was a result of the fire, or if some contamination predated it. To resolve that question, Ayrault aims to collect samples of melted lead and dust from the fire,

BRIAN KATZ AND MYLÈNE PARDOEN/CNRS

After the fire, lead contamination near the cathedral mandated cleanup efforts (above). Researchers are measuring the isotopes of lead in samples taken from the Seine and other spots around Paris to tell which contamination came from the fire and which came before.

FRANCOIS MORI/AP PHOTO

as well as remaining intact parts of the roof. Then she'll search for signs of that lead in future tests around the city.

Into the woodwork

The charred remnants of de Châlus' beloved forest can also tell a story.

The oak trees that became the roof's wooden frame grew during a hot spell in Europe known as the Medieval Warm Period, which lasted from the 11th century to the early 14th century (*SN: 8/17/19, p. 6*). Studying that wood could reveal details about that natural warming — such as how often droughts occurred — and may lead to a better understanding of what to expect from modern-day climate change, says Alexa Dufraisse of CNRS.

Dufraisse plans to analyze tree rings within the burnt timber. The width of the rings and the amounts of various isotopes found within the wood reveal the conditions under which the tree grew. That could include how wet or dry the climate was and the approximate geographic location of the forest.

She and colleagues also hope to learn how builders chose the trees and whether the forests were managed in some way. "This is a study that ... could never have been conducted without the destruction of the structure by fire," says Dufraisse, a dendroanthracologist, a scientist who studies tree rings within charred wood.

Other researchers are investigating less-tangible aspects of the cathedral, like its acoustics (see Page 18) and its sociological significance. Anthropologists plan to interview people affected by the fire, including tour guides and musicians who've performed in the cathedral, to understand the psychological toll of the fire. "We all remember what we were doing when it was burning," says molecular archaeologist Martine Regert of CNRS, who leads the CNRS group alongside Dillmann.

"This is a study that ... could never have been conducted without the destruction of the structure by fire."
ALEXA DUFRAISSE

Regert compares the Notre Dame disaster to the 2018 fire in Brazil's National Museum in Rio de Janeiro, in which millions of artifacts and preserved specimens were lost or damaged (*SN Online: 9/7/18*). In the Rio fire, "for me, we lost more" in terms of the scientific value, she says. Yet, emotionally, "I was probably more upset by Notre Dame."

The cathedral holds an outsize place in the hearts of Parisians and people around the world. If another cathedral had burned, says de Châlus, there would have been less interest. Determining how to rebuild requires understanding our relationship with it, too, he says.

Subject to bouts of emotion himself, de Châlus says he cried when he first entered the cathedral after the fire. He felt an unfamiliar wind at his back, sweeping into the church and up through the holes where parts of the ceiling had collapsed. He says of Notre Dame: "It was much more than a church ... much more than a study subject for me." ■

Explore more

- Laboratoire de Recherche des Monuments Historiques: bit.ly/historicmonuments
- Léa Galanopoulo. "Notre Dame: Research steps in." CNRS News. June 17, 2019. bit.ly/N-Dresearch

EXHIBIT

Step into Jane Goodall's life

"Becoming Jane," organized by National Geographic and the Jane Goodall Institute, celebrates the work of Jane Goodall (shown at left observing chimpanzees in 1965 with then-husband Hugo van Lawick).

Jane Goodall began observing chimpanzees in 1960, but her first study of animal behavior took place some 20 years earlier, when she was about 5 years old. One afternoon, she disappeared from home for several hours. Just as her panicked mother was about to contact the police, young Jane returned. "Well, I've been in a henhouse, waiting to see how a hen laid an egg," she explained. "Nobody'd tell me, so I just sat down. And now I know."

That curiosity helped propel Goodall to become one of the most famous scientists of the 20th century. Her evolution from precocious child to "global icon" is documented in "Becoming Jane," an exhibit at the National Geographic Museum in Washington, D.C., through September 7. After that, the exhibit heads to the Natural History Museum of Los Angeles County.

For an exhibit devoted to a researcher whose equipment was as simple as a pen and paper, "Becoming Jane" is technology heavy. Interactive digital displays, 3-D experiences and a hologram-like appearance by Goodall herself will capture the attention of both adults and youngsters. For those who have followed Goodall's career closely, the real treat is seeing her childhood mementos, field notes, Ph.D. thesis and other personal belongings and photos.

"Becoming Jane"
THROUGH SEPTEMBER 7, 2020
NATIONAL GEOGRAPHIC MUSEUM | *Washington, D.C.*

Goodall's early possessions tell a story of someone who seemed destined to study chimpanzees. On her first birthday, her father gave her a stuffed animal, a chimp. The toy is in the exhibit, its fur nearly all worn away, perhaps from too many hugs. Goodall's favorite books included *Tarzan of the Apes* and *The Story of Doctor Dolittle*. On a page from a nature magazine Goodall made with her friends, visitors can see neatly drawn hands of different creatures, including chimps, with details on what "purpose" each kind of hand has.

As the exhibit segues to Goodall's adulthood, visitors learn that her childhood dream of going to Africa came true in 1957, when a friend who had moved to Kenya invited Goodall for a visit. While there, she met the famed paleoanthropologist Louis Leakey and became his secretary. Leakey was looking for someone to study wild chimps. At the time, most of what science knew about the apes came from captivity, the exhibit explains.

Leakey thought observing chimps' natural behaviors would provide insight into the lives of early human ancestors. He wanted a female researcher because he thought women were more patient and observant than men. The exhibit lets Leakey speak for himself, through a video as well as a letter he wrote to the National Geographic Society in search of funding.

Goodall accepted Leakey's challenge, despite having no formal training, and on July 14, 1960, she arrived at the Gombe Stream Game Reserve in what is today Tanzania. Almost 60 years later, Gombe is home to the world's longest-running study of wild chimps. A life-size replica of Goodall's tent helps visitors experience what life was like during the early days. The work required patience. For the first few months, the chimps ran away when Goodall would approach. But then one day, two chimps stayed, and others eventually followed suit.

That pivotal moment is re-created in an immersive 3-D film (anyone prone to motion sickness should skip it) that precedes the most fun part of the exhibit: what Goodall learned about chimps. Visitors can mimic various types of chimp calls or try on a pair of augmented reality binoculars that reveal CGI chimps using tools. Goodall, in fact, was the first scientist to see wild chimpanzees use and make tools (*SN: 3/21/64, p. 191*) — including plant stems for fishing termites out of a mound. Until then, tool use was thought to be a uniquely human endeavor. Some real chimp tools are on display. Another of Goodall's revolutionary observations was that chimps hunt and eat meat, a fact recorded in her field notes. The exhibit brings some of Goodall's notes and drawings to life in animations projected above real documents.

In 1986, Goodall took up environmental activism full time, motivated by how endangered chimpanzees are. Today, just 340,000 remain in the wild, compared with the 1 million to 2 million thought to have lived a century ago. Several text-heavy panels describe the main threats chimpanzees face today, including habitat loss, disease and trafficking. It's a bit overwhelming to follow the intertwining factors that contribute to these problems. Featuring a few of Goodall's conservation success stories more prominently — and concretely — would have been helpful.

"Becoming Jane" ends on a note of hope. Human ingenuity, young people and the power of social media are among the things that keep Goodall, who celebrated her 85th birthday last year, optimistic about the planet's future. The exhibit ends with a digital "Tree of Hope," where visitors can make Earth-friendly pledges, such as avoiding single-use plastics.

At a time when the environmental challenges facing the world can feel insurmountable, Goodall reminds us that individuals can make a difference. — *Erin Wayman*

FROM LEFT: VANNE MORRIS-GOODALL, NATIONAL GEOGRAPHIC; REBECCA HALE/NATIONAL GEOGRAPHIC

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A new spin on lab-grown meat

To make lab-grown meat, researchers used a technique similar to spinning cotton candy. They spun a gelatin-containing solution to make tiny fibers. Then the researchers added stem cells from cows or rabbits that developed into muscle cells. As the cells grew, they worked their way into the edible gelatin scaffold. By controlling how the gelatin fibers had been spun, the scientists could set the fibers' alignment and spacing. That determined if the tissue ended up more like a burger or a steak. — *Carolyn Wilke*

Read more: **www.sciencenewsforstudents.org/lab-meat**

Chemistry's ever-useful periodic table celebrates a big birthday

This wooden device is about as far as you can get from the typical periodic table of the elements hanging on nearly every chemistry classroom wall. But this periodic table is one of many alternative types created over the last 150 years. Chemists designed some of them. Teachers and scientists in different fields developed others. These alternative forms "are useful because of the different aspects of the science that they illustrate," says Carmen Giunta of Le Moyne College in Syracuse, N.Y. The nontraditional periodic tables not only highlight some of chemistry's quirks, he says, but also bring them into better focus. — *Sarah Webb*

Read more: **www.sciencenewsforstudents.org/periodic-table**

Tests challenge whether centuries-old violins really are the best ever

In 2010, a violin made in the 1690s sold for $3.6 million. That record price for a musical instrument was broken the very next year when another violin sold for more than $15.9 million. What could make a violin worth so much? To find out, scientists conducted tests of the design, woods and sound. What they learned: When blinded to what was being played or listened to, most musicians couldn't tell the difference between a Stradivarius, a famous brand in the 17th and 18th centuries, and a well-made modern instrument. — *Sid Perkins*

Read more: **www.sciencenewsforstudents.org/violin-challenge**

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Safety first

Three scientists won the 2019 Nobel Prize in chemistry for developing lithium-ion batteries, ***Maria Temming*** *and* ***Jonathan Lambert*** *reported in "Nobel Prize winners announced" (*SN: 11/9/19, p. 12*). Since the rechargeable batteries were first created in the 1970s, they have become safer and cheaper.*

"I love my devices, but it's not yet a brave new world for tech," reader **Doug Pruner** wrote. Victims of lithium-ion battery explosions would probably emphasize that "safer" batteries are not necessarily "safe," **Pruner** noted. "Marketing pressures, not tech, drive the push for more power and concurrent smaller size. Sometimes, Kaboom!" he wrote.

Temming agrees that lithium-ion batteries aren't totally safe. The batteries can explode when heat from a short circuit ignites their highly flammable liquid electrolyte. Exploding smartphones, wireless headphones and hoverboards have made headlines.

Amanda Morris, a chemist at Virginia Tech in Blacksburg, told **Temming** that researchers are developing new materials to incorporate into lithium-ion batteries that don't short-circuit or combust as easily. "Solid gel electrolytes are supposedly more robust than traditional liquid," **Temming** says.

Meanwhile, some scientists are figuring out ways to add flame retardants to the liquid electrolyte in lithium-ion batteries. But mixing in flame retardants makes the batteries less efficient. To solve this problem, one group developed microscopic plastic-coated fibers that contain a flame retardant. If a battery overheats, the fibers' plastic shells melt and release the flame retardant into the liquid (*SN: 2/18/17, p. 19*).

Correction

In "A year of closer looks at distant rocks" (*SN: 12/21/19 & 1/4/20, p. 32*), the NASA InSight mission on Mars is described as having a rover. InSight actually has a stationary lander.

My, what a lovely head cone you have

Long before extraterrestrial Coneheads in *Saturday Night Live* skits claimed to have come from France, real-life cone heads existed in Egypt.

Prominent people wearing cone-shaped headgear appear frequently in Egyptian art dating from around 3,550 to 2,000 years ago (examples shown above left). But none of those cones have ever been found, until now. Archaeologists report unearthing such headpieces at the ancient Egyptian city of Amarna.

Built by the pharaoh Akhenaten and occupied from around 1347 B.C. to 1332 B.C., Amarna contains thousands of graves of ordinary people (*SN: 10/2/04, p. 216*). Two excavated skeletons were topped by remnants of head cones, archaeologist Anna Stevens of Monash University in Melbourne, Australia, and colleagues report in the December *Antiquity*. One cone adorned the remains of a woman in her 20s (above right); the other was atop a 15- to 20-year-old of undetermined sex.

Scientists expected that graves of social elites would yield the first head cones, Stevens says. “But the most surprising thing is that these objects turned up at all.” Some scholars have argued the cones were artistic devices, not real objects.

Portable infrared and X-ray machines determined that the cones were hollow and made of wax, probably beeswax. Some investigators have speculated that head cones contained animal fat or wax scented with a substance such as tree resin, but the Amarna finds contain no fat traces or perfume. If the two head cones originally had any perfume, it likely evaporated, Stevens says.

Names and occupations of the cone-topped individuals, as well as the meanings attached to such headgear, are unknown. Stevens suspects the head cones were believed to provide spiritual assistance in the afterlife. *— Bruce Bower*

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