Finger Snap Physics | The Amazon's Shrinking Birds

Science News MAGAZINE OF THE SOCIETY FOR SCIENCE - DECEMBER 18, 2021 & JANUARY 1, 2022

2021 THE LONG CLIMB

Year two of the pandemic brought hope with vaccines and plenty of new challenges

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2021 Year in Review

Lessons Learned From a Year of COVID-19 Vaccines

As vaccines against the coronavirus reached billions of people globally, scientists learned more about the ever-changing virus. Others worked to overcome misinformation and inequities in vaccine access.

PLUS: Read about the cool science – on cicadas, human evolution, outer space and more – that carried on.

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COVER At the end of 2021, the effort to conquer the coronavirus feels like a longer slog than anticipated. *Ran Zheng*



The triumph and fallibility of science in a historic year

Two years ago, *Science News* closed out 2019 with a lively cover illustrating 10 big news stories of the year, including the first image of a black hole, a claim of quantum supremacy in computing and the first U.S. clinical trials to test CRISPR/Cas9 gene editing in humans. But this year-end

cover, like last year's, features just one story: humankind's battle against the coronavirus pandemic.

It's not how I imagined celebrating *Science News*' 100th anniversary, but it seems apt that our centennial coincides with what will probably be the biggest story of our lives.

Last December, despite the horrors of 2020, there was reason for hope. Multiple vaccines had proved highly effective at preventing serious illness and death from COVID-19, and new treatments were emerging. But even with the vaccine rollouts, we have continued to see wave after wave of new infections, including in places with widespread access to vaccines like the United States and Europe.

This long pandemic is a cruel reminder of just how good viruses are at evolving, with the emergence of the delta variant (Page 22), and now the newly discovered omicron variant as well. We learned once again how hard it is to mount a public health effort for lifesaving vaccines. Vaccine hesitancy is not new; people have been skeptical of vaccines since the very first one, for smallpox, was invented by Edward Jenner in the 18th century (*SN: 5/8/21 & 5/22/21, p. 32*). During this pandemic, that skepticism has been amplified by global misinformation campaigns.

This year has also reminded us that while science can do extraordinary things, it's a human endeavor, inevitably a work in progress. Early in the pandemic, scientists thought that the coronavirus spread primarily by people touching contaminated surfaces. Despite growing evidence in 2020 that the virus spreads largely through the air, it wasn't until this spring that the World Health Organization and the U.S. Centers for Disease Control and Prevention acknowledged the importance of airborne transmission (Page 17). That slow process was also an example of how science *does* work, by questioning assumptions and rigorously testing hypotheses.

This year-end issue offers many other examples of scientists' search for answers. And many of their findings were surprising, illuminating and often delightful. That includes the physics of a finger snap (Page 5), how Stone Age "networking" events may have powered human evolution (Page 30) and amazing animal feats — including squirrels that parkour and spiders that can lift 50 times their weight (Page 35).

And despite the year's travails, we have been able to celebrate our centennial in a big way, with our Century of Science project at www.sciencenews.org/century. There, you can immerse yourself in stories of the biggest scientific advances of the last 100 years, along with reporting from our archive of more than 80,000 articles. As we provide accurate, engaging news of science in the next century, I hope you'll continue to be among our 21 million–plus readers exploring the challenges and wonders of science. — *Nancy Shute, Editor in Chief* PUBLISHER Maya Ajmera EDITOR IN CHIEF Nancy Shute

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NOTEBOOK



Excerpt from the December 18, 1971 issue of *Science News*

50 YEARS AGO

Sterility gene for mosquito control

Scientists are working hard to find a substitute for DDT in the control of malaria vector mosquitoes.... Two experiments with mosquitoes breeding in old tires in New Delhi point to an answer: a gene for sterility that would be passed to offspring.

UPDATE: Today, scientists are testing a variety of pesticidefree ways to control mosquito populations that spread malaria, Zika, dengue and yellow fever. One approach involves infecting male bloodsuckers with a strain of Wolbachia bacteria (SN: 6/10/17, p. 10). When the infected males mate with females, their offspring die before hatching. Another method tweaks mosquito DNA so that males pass on a daughter-killing trait and all female offspring die, shrinking populations over time. The mosquitoes, bred by the England-based biotech company Oxitec, took their first U.S. flight in May following a years-long debate about the safety of such organisms (see Page 32).



It's hard to imagine what Earth might look like in 2500. But a collaboration between science and art is offering an unsettling window into how ongoing climate change might transform familiar terrain into alien landscapes over the next few centuries.

These visualizations — of Midwestern farms in the United States overtaken by subtropical plants, of a dried-up Amazon rainforest, of extreme heat baking the Indian subcontinent — emphasize why researchers need to push climate projections long past the customary benchmark of 2100, environmental social scientist Christopher Lyon and colleagues contend September 24 in *Global Change Biology*.

Fifty years have passed since the first climate change projections, says Lyon, of McGill University in Montreal. As early as the 1980s, such models set that distant

INTRODUCING

Scientists find the Milky Way's first known 'feather'

The Milky Way has a "feather" in its cap. A long, thin filament of cold, dense gas extends jauntily from near the galactic center and may connect two of the galaxy's spiral arms, astronomers report in the Nov. 10 *Astrophysical Journal Letters*. This is the first time that such a structure, which looks like the barb of a feather fanning off the central quill, has been spotted in the Milky Way.

The team that discovered our galaxy's feather named it the Gangotri wave, after the glacier that is the source of India's longest river, the Ganges. In Hindi and other Indian languages, the Milky Way is called Akash Ganga, "the river Ganga in the sky," says astrophysicist Veena V.S. of the University of Cologne in Germany.

She and colleagues found the Gangotri wave by looking for signs of clouds of cold, dense carbon monoxide gas in data from the APEX telescope in Chile. The structure stretches 6,000 to 13,000 light-years from the Milky Way's Norma arm to a minor arm called the 3-kiloparsec arm near the galactic center. All other known Milky Way gas tendrils align with the spiral arms.

> The Gangotri wave has another unusual feature: waviness. The filament appears to wobble over thousands of light-years. It's not clear what causes that.

Other galaxies have gaseous plumage, but when it comes to the Milky Way, "it's very, very difficult" to map the galaxy's structure from the inside out, Veena says. She hopes to find more feathers and other bits of our galaxy's structure. "One by one, we'll be able to map the Milky Way." — *Lisa Grossman* By 2500, protective gear such as a cooling suit (shown in this painting) may be required for working outdoors in India's extreme heat.

target at the year 2100. But that date isn't so far off anymore, and the effects of greenhouse gas emissions from the past and present will linger for centuries.

To visualize what that distant future world might look like, the researchers considered three possible climate trajectories: the low, moderate and high emissions used in past reports by the United Nations' Intergovernmental Panel on Climate Change. From there, the team projected changes all the way out to 2500, focusing particularly on impacts on civilization, such as heat stress, failing crops and changes in land use and vegetation (SN: 4/1/17, p. 14).

For all but the lowest-emissions scenario, which is roughly in line with limiting global warming to "well below" 2 degrees Celsius as approved by the 2015 Paris Agreement (SN: 1/9/16, p. 6), the average global temperature continues to increase until 2500, the team found. For the highest-emissions scenario, temperatures increase by about 2.2 degrees C by 2100 and by about 4.6 degrees C by 2500 relative to the present day. That results in "major restructuring of the world's biomes," the team writes: loss of most of the Amazon rainforest, poleward shifts in crops and scorching temperatures in the tropics.

The researchers then collaborated with James McKay, an artist and science communicator at the University of Leeds in England, to bring the data to life. Based on the study's projections, McKay created a series of detailed paintings representing different global landscapes now and in 2500.

The team stopped short of trying to speculate on future technologies or cities to keep the paintings based more in realism than science fiction, Lyon says. "But we did want to showcase things people would recognize: drones, robotics, hybrid plants." In one painting of India in 2500, a person is wearing a sealed suit and helmet, a type of garment that people in some high-heat environments might wear today, he says.

The goal of these images is to help people picture the future in such a way that it feels more urgent, real and close — and, perhaps, to offer a bit of hope that humans can still adapt. "We wanted to show that, despite the [future] climate people have moved into, people have figured out ways to exist." — *Carolyn Gramling*

TEASER Plants give this glitter its colorful sparkle

All that glitters is not green. Glitter and shimmery pigments are often made using microplastics or toxic compounds. That makes the sparkly stuff, notoriously difficult to clean up in the house, a scourge on the environment too.

A new alternative (shown above) designed to be nontoxic and biodegradable could change that. Cellulose — the main building block of plant cell walls — in the material creates nanoscale patterns that give rise to vibrant structural colors. Such a material could be used to make eco-friendly glitter and shiny pigments for paints, cosmetics or packaging, scientists report November 11 in *Nature Materials*.

Chemist Silvia Vignolini of the University of Cambridge and colleagues whipped up a watery mixture containing cellulose fibers and poured it onto plastic. As the liquid dried into a film, the fibers settled into spiral staircase–like structures. Tweaking the steepness of the staircases changed the wavelengths of light reflected, and thus the film's color. Once the clear, plantbased slurry was transformed into shiny ribbons in a rainbow of colors, it could be peeled from the plastic and ground up to make glitter. The team needs to test the environmental impacts of this newfangled glitter, but Vignolini is optimistic that the material has a bright future. – *Maria Temming*

THE EVERYDAY EXPLAINED

Camera captures physics in a snap

New high-speed video exposes the blink-and-you'll-miss-it physics behind snapping your fingers. The footage reveals that friction plus the compressibility of the finger pads are key to humans' ability to snap properly, researchers report November 17 in *Journal of the Royal Society Interface*.

When covered with high-friction rubber or low-friction lubricant, finger snaps fell flat, indicating that bare fingers have a level of friction ideal for a speedy snap. That friction allows energy to be stored before it's suddenly unleashed. Too little friction means less pent-up energy and a slower snap. Too much friction impedes the fingers' release, also slowing the snap, the team found.

The study was inspired by a scene in the 2018 movie Avengers: Infinity War. Supervillain Thanos snaps his fingers while wearing a supernatural metal glove, destroying half of the universe's life. The team wondered if snapping while wearing a metal glove was possible. Typically, fingers in a snap compress, increasing the contact area and friction between them. In tests of fingers covered by thimbles, snaps were sluggish. Thanos' snap would have been a dud. No superheroes needed: Physics saves the day. — Emily Conover

ews

EARTH & ENVIRONMENT Key carbon caches need protection

Scientists map ecosystems vital to curbing climate change

BY JONATHAN LAMBERT

Over decades, centuries and millennia, the steady skyward climb of redwoods, the tangled march of mangroves along tropical coasts and the slow submersion of carbon-rich soil in peatlands has locked away billions of tons of carbon.

If these natural vaults get busted open, through deforestation or dredging of wetlands, it would take centuries before those redwoods or mangroves could grow back to their former fullness and reclaim all that carbon. Such carbon is "irrecoverable" on the timescale – decades. not centuries – needed to avoid the worst impacts of climate change. Keeping it locked away is crucial.

Now, through a mapping project, scientists have estimated how much irrecoverable carbon exists in peatlands, mangroves, tropical forests and elsewhere worldwide - and which areas need protection.

The estimate puts the total amount of irrecoverable carbon at 139 billion metric tons, researchers report November 18 in Nature Sustainability. That's equivalent to about 15 years of fossil fuel emissions at current levels. If all that carbon were released, it's almost certainly enough to push the planet past 1.5 degrees Celsius of warming above preindustrial levels.

"This is the carbon we must protect to avert climate catastrophe," says Monica Noon, an environmental data scientist at Conservation International in Arlington, Va. Current efforts to keep global warming below the ambitious target of 1.5 degrees C require that we reach netzero emissions by 2050, and that carbon stored in nature stays put. But agriculture and other development pressures threaten some of these carbon stores.

To map the most at-risk carbon, Noon and colleagues combined satellite data with estimates of how much total carbon is stored in ecosystems vulnerable to human incursion. That means the researchers excluded areas like permafrost, which stores lots of carbon but isn't likely to be developed for farming or other uses (though it's thawing due to warming), as well as tree plantations and other areas that have already been altered. The researchers then calculated

Irrecoverable carbon stores Researchers mapped the location and density of Earth's irrecoverable carbon – carbon locked in ecosystems that is potentially vulnerable to release from human development and, if lost, could not be restored to those ecosystems by 2050. Areas of exceptionally high density of irrecoverable carbon are shown in dark purple.



Irrecoverable carbon (metric tons per hectare)

how much carbon would get released from land conversions, such as clearing a forest.

That land might store varying amounts of carbon, depending on whether it becomes a palm oil plantation or a parking lot. To simplify, the researchers assumed cleared land was left alone, with saplings free to grow where giants once stood. That allowed the team to estimate how long it might take for the released carbon to be reintegrated into the land. Much of that carbon would remain in the air by 2050, the team reports, as many of these ecosystems take centuries to return to their former glory.

Releasing that 139 billion tons of irrecoverable carbon could have irrevocable consequences. For comparison, the U.N. Intergovernmental Panel on Climate Change estimates that humans can emit only 109 more billion tons of carbon to have a two-thirds chance of keeping global warming below 1.5 degrees C.

About half of the irrecoverable carbon sits on just 3.3 percent of Earth's total land area, equivalent to roughly the area of India and Mexico combined. Key areas are in the Amazon, the Pacific Northwest and the tropical forests and mangroves of Borneo. "The fact that it's so concentrated means we can protect it," Noon says.

About half of irrecoverable carbon falls within existing protected areas or lands managed by Indigenous peoples. Adding an additional 8 million square kilometers of protected or sustainably managed areas, which is only about 5.4 percent of the planet's land surface, would bring 75 percent of this carbon under some form of protection, Noon says.

"It's really important to have spatially explicit maps of where these irrecoverable carbon stocks are," says geographer Kate Dooley of the University of Melbourne in Australia. "It's a small percentage globally, but it's still a lot of land." Many of these dense stores are in places at high risk of development.

"It's so hard to stop this drive of deforestation," she says, but these maps will help focus the efforts of governments, civil society groups and academics on the places that matter most for the climate.



Quantum effect blocks light scattering

Pauli exclusion principle boosts some atom clouds' transparency

BY EMILY CONOVER

A cloud of ultracold atoms is like a motel with a neon "no vacancy" sign.

If a guest at the motel wants to switch rooms, they're out of luck. No vacant rooms means there's no choice but to stay put. Likewise, in new experiments, atoms boxed in by crowded conditions have no way to switch up their quantum states. That constraint means the atoms don't scatter light as they normally would, three teams of researchers report in the Nov. 19 *Science*. Predicted more than three decades ago, this light effect has now been seen for the first time.

Under normal circumstances, atoms interact readily with light. Shine a beam of light on a cloud of atoms, and they'll scatter some of that light in all directions. This type of light scattering is a common phenomenon: It happens in Earth's atmosphere. "We see the sky as blue because of scattered radiation from the sun," says physicist Yair Margalit, who was part of a team at MIT that performed one of the experiments.

But quantum physics comes to the fore in ultracold, dense atom clouds. "The way they interact with light or scatter light is different," says physicist Amita Deb of the University of Otago in Dunedin, New Zealand, a member of another team that performed one of the experiments. According to a rule called the Pauli exclusion principle, atoms in the experiments can't take on the same quantum state — namely, they can't have the same momentum as another atom in the experiment (*SN: 6/20/20, p. 13*). If atoms are packed together in a dense cloud and cooled to near absolute zero, they'll settle into the lowest-energy quantum states. Those low-energy states will be entirely filled, like a motel with no open rooms.

When an atom scatters light, it gets a kick of momentum, changing its quantum state, as it sends light off in another direction. But if the atom can't change its state due to the crowded conditions, it won't scatter the light. The atom cloud becomes more transparent, letting light through instead of scattering it.

To observe the effect, Margalit and colleagues beamed light through a cloud of lithium atoms, measuring the amount of light it scattered. Then the team decreased the temperature to make the atoms fill up the lowest energy states, suppressing the scattering of light. As the temperature dropped, the atoms scattered 37 percent less light, indicating that many atoms were prevented from scattering light. (Some atoms can still scatter light, for example if they get kicked into higher-energy quantum states that are unoccupied.) A quantum effect dictates whether a cloud of atoms (blue) scatters light (red arrows). If the cloud is cold and dense enough, quantum states may be fully occupied, meaning the atoms cannot change quantum states, so the light isn't scattered.

In another experiment, physicist Christian Sanner of the research institute JILA in Boulder, Colo., and colleagues studied a cloud of ultracold strontium atoms. The researchers measured how much light was scattered away at small angles, for which the atoms are jostled less by the scattering and therefore are even less likely to be able to find an unoccupied quantum state. At lower temperatures, the atoms scattered half as much light as at higher temperatures.

The third experiment, performed by Deb and physicist Niels Kjærgaard, also of the University of Otago, measured a similar scattering drop in an ultracold potassium atom cloud and a corresponding increase in how much light was transmitted through the cloud.

Because the Pauli exclusion principle also governs how electrons, protons and neutrons behave, it is responsible for the structure of atoms and matter as we know it. These new results reveal the wide-ranging principle in a new context, Sanner says. "It's fascinating because it shows a very fundamental principle in nature at work."

The work also suggests new ways to control light and atoms. "One could imagine a lot of interesting applications," says theoretical physicist Peter Zoller of the University of Innsbruck in Austria, who was not involved with any of the experiments. In particular, light scattering is closely related to a process called spontaneous emission, in which an atom in a high-energy state decays to a lower energy by emitting light. The results suggest that decay could be blocked, increasing the lifetime of the energetic state. Such a technique might be useful for storing quantum information for a longer period of time than is normally possible, for example in a quantum computer.

So far, these applications are still theoretical, Zoller says. "How realistic they are is something to be explored in the future."

EARTH & ENVIRONMENT

Exploding comet tied to desert glass

Atacama preserves clues to an ancient airburst, study says

BY FREDA KREIER

Scattered across a swath of the Atacama Desert in Chile lie twisted chunks of black and green glass. How the glass ended up there, sprinkled in patches along a 75-kilometer-long corridor, has been a mystery.

Now, analyses of bits of rock in the glass show that the glass probably formed when a comet, or its remnants, exploded over the desert about 12,000 years ago, researchers report November 2 in *Geology*.

This corridor is the best evidence yet of an impact from an exploding comet, says Peter Schultz, a planetary geologist at Brown University in Providence, R.I.

There are only about 190 known impact craters on Earth (*SN: 12/22/18 &* 1/5/19, p. 40). Falling space rocks carved out these sites, but none have been definitively tied to a comet. That's because scientists suspect that comets, which are made of mostly ice and some rock, tend to explode before reaching the ground, a fate they share with some small asteroids. These fiery events — known as airbursts — are dramatic, generating massive amounts of heat and strong winds. But the effects are temporary and often fail to leave lasting imprints, like craters, behind.

That's especially true in wet environments, says physicist Mark Boslough of the University of New Mexico in Albuquerque, who wasn't involved in the new research. In 1908, an airburst from an asteroid or comet over a remote part of Russia flattened trees and generated a shock wave that knocked people off their feet hundreds of kilometers away. The trees have since grown back over the site of what's now called the Tunguska blast, leaving just a marsh. "If it hadn't been observed, no one would know it happened," Boslough says.

The Atacama, one of the world's driest deserts, is better suited to preserving signs of an impact, he says. And it's full of sand — one of the raw materials for making glass when heated to high temperatures. Heat is essential for making glass; most of Earth's natural glass comes from volcanoes, forming when lava cools quickly.

The desert's glass corridor, however, isn't near a volcano, suggesting the glass formed in a different type of heating event, such as an airburst. But radiocarbon dating of remnants of ancient plants in the soil around the glass had seemed to indicate that the pieces didn't all form at the same time. This evidence led some researchers to suggest that the glass formed during several massive grass fires.

That idea, Schultz says, "seemed really weird to us because there just wasn't enough grass for fires," even long ago when the area had more greenery than it does today. After examining minerals in some of the glass, he and colleagues determined that it had formed at temperatures exceeding around 1700° Celsius — much hotter than grass fires.

Embedded within the glass is extraterrestrial material comparable to what had previously been found in a comet, the



team discovered. The most likely way for these bits of space rock to have made their way into the glass is if a chunk of space debris, such as a comet, exploded as the glass formed, Schultz says.

"It's pretty clear that this is an impact," Boslough says. "And in this case, there's no evidence for a crater, so this event was a pure airburst."

An airburst would also help explain why the glass appears twisted. "The glass had been thrown around and rolled. It was basically kneaded like bread," Schultz says. Grass fires may melt the ground, but they rarely fling it around. The airburst probably generated strong winds that flung the glass as it formed, creating the folded look.

The violence of the explosion would have scattered glass across the desert and onto sediment layers of different ages, which may have created the illusion that the glass was created during multiple events. Radiocarbon dating of burnt soil directly below the glass — presumably burned from the heat of the explosion — allowed the researchers to pin down the date of the probable comet strike to about 12,000 years ago.

That timing places the event about several hundred years after the start of a mysterious period of rapid cooling known as the Younger Dryas. During the Younger Dryas, many large animals went extinct. Some scientists have suggested that a comet exploding over the Northern Hemisphere set off a series of events that led to the frigid conditions, though the idea is controversial (*SN: 7/7/18, p. 18*).

The timing of the Atacama comet strike shows that it didn't launch the Younger Dryas event, Schultz says, but the finding does lay the groundwork for identifying other potential comet sites on Earth.

The Atacama impact would have left a strong impression on anyone who saw it, Schultz says. Archaeological evidence suggests that people lived in the region at the time and thus may have witnessed the airburst. "It would have seemed like the entire horizon was on fire," Schultz says. "If you weren't religious before, you would be after." LIFE & EVOLUTION

Amazonian birds are shrinking

Climate change may be to blame for a drop in body mass

BY JONATHAN LAMBERT

In a remote corner of Brazil's Amazon rainforest, researchers have spent decades catching and measuring birds in a large swath of forest unmarred by roads or deforestation. An exemplar of the Amazon's dazzling diversity, the experimental plot was to act as a baseline that would reveal how habitat fragmentation, from logging or roads, can hollow out rainforests' wild menagerie.

But in this pristine pocket of wilderness, a more subtle shift is happening: The birds are shrinking.

Over 40 years, dozens of Amazonian bird species have declined in mass. Many species have lost about 1 percent to 2 percent of their average body weight each decade, researchers report November 12 in *Science Advances*. What's more, some species have grown longer wings. The changes coincide with a hotter, more variable climate, which could put a premium on leaner, more efficient bodies that help birds stay cool, researchers say.

"Climate change isn't something of the future. It's happening now and has been happening and has effects we haven't thought of," says Ben Winger, an ornithologist at the University of Michigan in Ann Arbor who wasn't involved in the research but has documented similar shrinkage in migratory birds. Seeing the same patterns in so many bird species across different contexts "speaks to a more universal phenomenon," he says.

Biologists have long linked body size and temperature. In colder climates, it pays to be big. Animals with a larger mass tend to have a smaller surface area relative to volume, which reduces heat loss through the skin and keeps the body warmer. As the climate warms, "you'd expect shrinking body sizes to help organisms off-load heat better," says Vitek Jirinec, an ecologist at the Integral Ecology Research Center in Blue Lake, Calif.

Many species of North American migratory birds are getting smaller, Winger and colleagues reported in 2020 in *Ecology Letters*. Climate change is the likely culprit, Winger says, but since migrators experience a wide range of conditions while globe-trotting, other factors such as degraded habitats that birds may encounter can't be ruled out.

To see if birds that stay put have also been shrinking, Jirinec and colleagues analyzed data collected on nonmigratory birds from 1979 to 2019 in an intact part of the Amazon that spans 43 kilometers. The dataset includes measurements such as mass and wing length for over 11,000 individual birds of 77 species. The researchers also examined climate data for the region.

All the species declined in mass over this period, the researchers found, including birds as different as the Rufous-capped antthrush (*Formicarius colma*), which snatches insects off the forest floor, and the Amazonian motmot (*Momotus momota*), which scarfs down fruit up in trees. Species lost from about 0.1 percent to nearly 2 percent of their average body weight each decade. The motmot, for example, shrunk from 133 grams to about 127 grams over the study period.

These changes coincided with an overall 1 degree Celsius increase in the average temperature in the wet season and a 1.65 degree C increase in the dry season. Temperature and precipitation also became more variable over the time period, and these short-term fluctuations, such as an especially hot or dry season, better explained the size trends than the steady increase in temperature.

"The dry season is really stressful for birds," Jirinec says. Birds' mass decreased the most in the year or two after especially hot and dry spells, which tracks with the idea that birds are getting smaller to deal with heat stress.

Other factors, like decreased food availability, could also lead to smaller sizes. But since birds with widely different diets all declined in mass, a more



A smaller body size may help birds like the collared puffbird stay cool in a warming world.

pervasive force like climate change is the probable cause, Jirinec says.

For 61 of the species, wing length grew during this period, with a maximum increase of about 1 percent per decade. Jirinec thinks that longer wings make for more efficient, and thus cooler, fliers. For instance, a fighter jet, with its heavy body and compact wings, takes enormous power to maneuver. A light and long-winged glider, by contrast, can cruise along much more efficiently.

"Longer wings may be helping [birds] fly more efficiently and produce less metabolic heat," which can be beneficial in hotter conditions, Jirinec says. "But that's just a hypothesis." This body change was most pronounced in birds that spend their time higher up in the canopy, where conditions are hotter and drier than the forest floor.

Whether these changes in shape and size represent an evolutionary adaptation to climate change, or simply a physiological response to higher temperatures, remains unclear. Whichever is the case, Jirinec suggests, the change shows the pernicious power of human activity.

"The Amazon rainforest is mysterious, remote and teeming with biodiversity," he says. "This study suggests that even in places like this, far removed from civilization, you can see signatures of climate change." HUMANS & SOCIETY

Missing data make it hard to measure bias in policing

Identifying when officers don't use force is crucial information

BY SUJATA GUPTA

A team of researchers combed through 2.9 million Chicago police officer patrol records spanning the years 2012 to 2015. The team's analysis of that data, from nearly 7,000 officers, showed that Black police officers were less likely to arrest civilians than white police officers patrolling the same neighborhood (SN: 3/13/21, p. 7). Officers arrested on average eight people per shift. Black officers made about 24 percent fewer arrests on average than white officers. But an alternate analysis, one that excluded shifts where no arrests occurred, flipped the results. That made it appear as if Black officers issued 12 percent more arrests than white officers.

Failing to account for events that don't happen – police allowing a jaywalker to pass, opting not to make an arrest (usually for minor issues like possessing a small amount of drugs) or never firing a drawn gun-is problematic, says policing expert Dean Knox of the University of Pennsylvania. "Instead of drawing the conclusion that minority officers are engaging in less enforcement," he says of his Chicago study, "you could mistakenly conclude that they are engaging in more enforcement." The flip occurred because, compared with white officers, Black officers more often went out on patrols without issuing any arrests.

Nonevents of this nature are commonly excluded in policing data. Though a large body of evidence suggests that police in the United States discriminate against Black people, Knox says, many police departments collect data on only a smattering of the interactions between their officers and civilians. Cell phone videos, like those of Eric Garner in a choke hold and George Floyd struggling



Using footage from officer-worn body cameras, like the one shown, researchers are analyzing entire interactions between officers and civilians. The researchers hope to identify moments when officers averted an action, such as arresting or harming a civilian.

to breathe, tend to emerge only when encounters have spiraled out of control. That makes it difficult to measure racial bias in policing or come up with targeted solutions to reduce that bias.

So how can researchers studying policing account for nonevents? The laborious Chicago data collection by Knox and his team is not always feasible. And even that rigorous study, reported in *Science* earlier this year, still had gaps: The team had data on when police stopped, arrested or used force on civilians, but not on minor interactions that didn't meet the department's recording requirements.

When research teams accept these problematic datasets at face value, Knox writes in an essay in the Nov. 5 *Science*, they often arrive at contradictory conclusions. Disagreements in the literature allow public officials and the media to cherry-pick studies that support their viewpoint, whether arguing for or against implicit bias training to overcome unconscious stereotypes or prioritizing the recruitment of minority officers.

A long chain of events

Knox wrote the essay following the publication of a controversial, and now

retracted, study that appeared in 2019 in the *Proceedings of the National Academy of Sciences.* "White officers are not more likely to shoot minority civilians than non-White officers," the authors of that study wrote. They concluded that policies aimed at increasing police diversity would do little to stem racial disparities in police killings.

The study gained enormous traction, especially among conservative media outlets and politicians, Knox says. "This was one of the go-to pieces that people used to deny the existence of bias in policing."

But the authors' findings were mathematically baseless, says Knox, who along with Jonathan Mummolo, a policing expert at Princeton University, wrote an article debunking the study in Medium. More than 800 academics and researchers signed the piece. The authors of the study in *PNAS* failed to consider total police encounters and then measure what fraction of those encounters resulted in deadly violence, Knox says.

But that narrow focus on fatal police shootings, rare occurrences that typically happen at the culmination of a long chain of events, ignores all potential biases earlier in the chain, Knox says. The first potential bias in a chain of events starts with an officer's decision to approach a civilian or let them pass. Knox acknowledges that a separate layer of research is needed to account for societal-level disparities, such as the presence of more officers in Black, often impoverished, neighborhoods and long-standing discriminatory practices that reduce the quality of education and other services in such neighborhoods.

"Even if you can't see all the things that happened before, just acknowledging they exist is imperative," Knox says.

Consider this real-life example. On July 10, 2015, Texas state trooper Brian Encinia pulled over Sandra Bland, a Black woman, for failing to signal a lane change. The exchange grew heated and culminated with Encinia arresting Bland. Bland's subsequent death in a county jail caused public outcry.

Focusing solely on Bland's arrest, and not all that happened before, would provide little information on how Bland wound up in jail for such a minor offense, or how to prevent such an outcome in the future. But because Encinia's dashcam recorded the entire exchange, policing researchers could identify key steps leading up to her arrest, in this case by focusing on tone and language.

For instance, the researchers reported in *Law & Society Review* in 2017, Encinia's language starts off polite but becomes increasingly agitated as Bland refuses to comply with his orders. His once formal commands, such as "step out of the car," become informal and unprofessional: "I'm going to yank you out of here."

That word "yank" indicates that Encinia is losing control of the situation, says study coauthor Belén Lowrey-Kinberg, a criminologist at St. Francis College in New York City. Previous research has shown that when officers pivot from formal to informal language, violence can follow.

While this is a case study of a single event, the study provides "a great example of how situations can escalate," says criminologist Justin Nix of the University of Nebraska Omaha.

Fixing flawed data

Flawed police data do not need to be thrown out, Knox says. His team has developed an algorithm to account for gaps in the data at all points in a policecivilian interaction. The algorithm weights the various possible degrees of discrimination at each point in a chain of events - perhaps race did not factor into Encinia's decision to pull Bland over because he could not see her face, for example, or maybe race played a large role because most drivers in that area are white. The range of values resulting from the summation of those events suggests the possible amounts of discrimination in any given scenario, Knox says.

The program operates on a very general principle, Knox says.

"What are the data that you see?" and "What are the data that you don't see?"

Thinking about the whole chain of events also points to how to collect better statistics.

Consider a study by Nix and John Shjarback, a policing expert at Rowan University in Glassboro, N.J., that appeared November 10 in *PLOS ONE*. The researchers were interested in racial disparities in officers' use of force against Black and white civilians. National databases include only shootings that result

in a civilian's death. But whether someone lives or dies after being shot hinges on several factors, such as proximity to a trauma center, location of the gunshot wound and access to first aid. So the researchers sought to examine all police shootings, including those that resulted in injury but not death. To do so, they relied on records from four states — California, Colorado, Florida and Texas — that have collected this information for years.

The data revealed that some 45 percent of victims suffer nonfatal injuries. Factoring in the relative populations of Black and white civilians showed that for all four states, racial disparities in injuries were higher than racial disparities in fatalities. For example, from 2009 to 2014 in Florida, Black people were roughly three times as likely as white people to be shot and killed by police, but over five times as likely to be nonfatally shot and injured. Across all four states, and for reasons that are not entirely clear, Black people shot by the police are 7 percentage points less likely to die of their injuries than their white counterparts.

National databases that include only records of civilians who die at the hands of the police underestimate officers' use of deadly force against Black civilians, Nix says. Death "is the end of a very long sequence of events. In our paper, we

backed up one link in the chain." That is, the research-

ers looked at all instances

where officers used deadly

force and not just those that

Knox is now working with

two police departments to

break down police-civilian

encounters in more detail.

Those departments require

resulted in death.

3.12 times

Increased likelihood that a Black civilian was shot and killed by police compared with a white civilian, in Florida in 2009-2014



Increased likelihood that a Black civilian was shot and injured by police compared with a white civilian, in Florida in 2009-2014

officers to turn on their body cameras when they believe an interaction with a civilian will rise to the level of an official interaction. (Officers have discretion at this point in the process, Knox acknowledges, so as with the Chicago study, that

first link in the chain remains elusive.)

Knox and his team will analyze scripts from each encounter for language and tone, such as normal voice or shouting — a quantitative version of the approach Lowrey-Kinberg used to unpack the encounter between Encinia and Bland. Computer vision techniques will parse out gestures, such as "weapon drawn." Knox says he hopes the data will help his team get closer to reconstructing entire interactions, including identifying nonevents in any given chain.

"You don't want just the side of the story as written by an officer," Knox says. "You want the whole interaction."



How stars turn into carbon factories

Being part of a duo may up a massive star's carbon footprint

BY KEN CROSWELL

The next time you thank your lucky stars, you might want to bless the binaries. New calculations suggest that a massive star whose outer layer gets torn off by a companion star ends up shedding a lot more carbon than if the star had been born a loner.

"That star is making about twice as much carbon as a single star would make," says Rob Farmer, an astrophysicist at the Max Planck Institute for Astrophysics in Garching, Germany.

All life on Earth is based on carbon, the fourth most abundant element in the cosmos, after hydrogen, helium and oxygen. Like nearly every chemical element heavier than helium, carbon is formed in stars. For many elements, astronomers have been able to pin down the main source. For example, oxygen comes almost entirely from massive stars, most of which explode, while nitrogen is made mostly in lower-mass stars, which don't explode. In contrast, carbon arises both in massive and lower-mass stars. Astronomers would like to know exactly which types of stars forged the lion's share of this vital element.

Farmer and colleagues looked specifically at massive stars, which are at least eight times as heavy as the sun, and calculated how they behave with and without partners. Nuclear reactions at the core of a massive star first turn hydrogen into helium. When the core runs out of hydrogen, the star expands, and soon the core starts converting helium into carbon.

But massive stars usually have companion stars, adding a twist to the story line: When the star expands, the companion's gravity can tear off the larger star's outer envelope, exposing the helium core. That allows freshly minted A massive star can produce a lot of carbon, especially if another star is orbiting, research suggests. This composite, false-color image shows the remains of a massive star that exploded in the constellation Cassiopeia.

carbon to stream into space via a flow of particles.

"In these very massive stars, these winds are quite strong," Farmer says. For instance, his team's calculations suggest that the wind of a star that's born 40 times as massive as the sun and has a close companion ejects 1.1 solar masses of carbon before dying. In comparison, a single star born with the same mass ejects just 0.2 solar masses worth of carbon, the researchers report in a paper submitted October 8 to arXiv.org and in press at the *Astrophysical Journal*.

If the massive star in a binary then explodes, it also can eject more carbon than a supernova from a solo massive star. That's because, when the companion star removes the massive star's envelope, the helium core shrinks. This contraction leaves some carbon behind, outside the core. As a result, nuclear reactions can't convert that carbon into heavier elements such as oxygen, leaving more carbon to be cast into space by the explosion. Had the star been single, the core would have destroyed much of that carbon.

By analyzing the output from massive stars of different masses, Farmer's team concludes that the average massive star in a binary ejects 1.4 to 2.6 times as much carbon through winds and supernova explosions as the average massive loner star.

Given how many massive stars are in binaries, astronomer Stan Woosley says that emphasizing binary-star evolution, as the researchers have done, is helpful in pinning down the origin of a crucial element. But "I think they are making too strong a claim based on models that may be sensitive to uncertain physics," says Woosley, of the University of California, Santa Cruz. In particular, he says, mass-loss rates for massive stars are not known well enough to assert a specific difference in carbon production between single and binary stars.

Quasisatellite may be a moon chunk

Strange space rock could be wreckage of a lunar impact

BY MARIA TEMMING

The moon's violent history is written across its face. Over billions of years, space rocks have punched craters into its surface, flinging out debris. Now, astronomers may have spotted rubble from one of those impacts. The mysterious object called Kamo'oalewa appears to be a moon fragment, scientists report November 11 in *Communications Earth & Environment*.

Discovered in 2016, Kamo'oalewa, also called 2016 HO3, is one of Earth's five known quasisatellites (*SN: 7/23/16, p. 5*). These are rocks that stick fairly close to the planet as they orbit the sun. Little is known about Earth's space rock entourage because these objects are so small and faint. Kamo'oalewa, for instance, is about the size of a Ferris wheel. And it strays between 40 and 100 times as far from Earth as the moon as its orbit around the sun weaves in and out of Earth's. That has left astronomers to wonder about the nature of such tagalong rocks. "An object in a quasisatellite orbit is interesting because it's very difficult to get into this kind of orbit — it's not the kind of orbit that an object from the asteroid belt could easily find itself caught in," says Richard Binzel, a planetary scientist at MIT who was not involved in the new work. Having an orbit nearly identical to Earth's immediately raises suspicions that an object like Kamo'oalewa originated in the Earthmoon system, he says.

Researchers used the Large Binocular Telescope and the Lowell Discovery Telescope in Arizona to peer at Kamo'oalewa in visible and near-infrared wavelengths. "The real money is in the infrared," says planetary scientist Vishnu Reddy of the University of Arizona in Tucson. Light at those wavelengths con-

tains important clues about the minerals in rocky bodies, helping distinguish objects such as the moon, asteroids and terrestrial planets.

Kamoʻoalewa reflected more sunlight at longer, or redder, wavelengths. This pattern of light looked unlike any known near-Earth asteroid, Reddy and colleagues found. But it did look like grains of silicate rock from the moon

A space rock named Kamoʻoalewa has an orbit similar to Earth's and may be a moon fragment that broke off during an impact event, similar to the chunk drifting above the moon in this illustration.

brought to Earth by Apollo 14 astronauts (*SN: 2/20/71, p. 125*).

"To me," Binzel says, "the leading hypothesis is that it's an ejected fragment from the moon, from a cratering event."

Martin Connors, who was involved in the discovery of Earth's first known quasisatellites but did not participate in the new research, also suspects that Kamo'oalewa is a chip off the old moon. "This is well-founded evidence," says

Little is

known about

Earth's space

rock entourage

because these

objects are

so small

and faint.

Connors, a planetary scientist at Athabasca University in Canada. But, he cautions, "that doesn't mean it's right."

More detailed observations could help confirm Kamo'oalewa is made of moon stuff. "If you really wanted to put that nail in the coffin, you'd want to go and visit or rendezvous with this

little quasisatellite and take a lot of upclose observations," says Daniel Scheeres, a planetary scientist at the University of Colorado Boulder who was not involved in the work. "The best would be to get a sample."

China's space agency has announced plans to send a probe to Kamo'oalewa to scoop up a bit of rock and bring it to Earth later this decade.

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ATOM & COSMOS

Simulation re-creates how M87's black hole launches plasma jets

From the maw of the supermassive black hole at the center of the galaxy M87. two energetic jets stream thousands of light-years into space. Scientists still don't fully understand the physics behind the jets, which are made of a mix of electrically charged particles, or plasma (SN: 4/24/21, p. 6). But they are "really, really amazing," says astrophysicist Alejandro Cruz-Osorio of Goethe University Frankfurt. So he and colleagues created a computer simulation of M87's black hole and the swirling gas that surrounds it in an accretion disk. The aim: Figure out how this black hole – already famous for posing for a picture in 2019 (SN: 4/27/19, p. 6) – became such a jet-setter.

Under the right conditions, that simulation produces jets that match observations of M87. The black hole twists up spiraling magnetic fields that surround two high-energy beams of electrons and other charged particles. The results suggest that the black hole must be spinning rapidly, at more than half its maximum speed allowed by the laws of physics and possibly as much as 94 percent of its maximum possible speed, the researchers report November 4 in *Nature Astronomy*.

Getting the energies of the jets' electrons right turned out to be crucial. When magnetic fields in the jets rearrange in a process known as magnetic reconnection, electrons get accelerated, resulting in more of them having very high energies. This effect was not included in earlier simulations, but it was key to getting the simulated jets to act like their real-world counterparts. – *Emily Conover*

LIFE & EVOLUTION

Ancient giant orangutans evolved smaller bodies slowly

Giant orangutans that once dwelled in mainland Southeast Asia belonged to a single species that gradually shrank in size over nearly 2 million years. That conclusion comes from a study of 600 ancient orangutan teeth from 10 caves in China.

Today, orangutans live only on the islands of Sumatra and Borneo. But their ancient supersize kin roamed as far north as southern China.

From about 2 million to 111,000 years ago, the shapes of the studied teeth remained largely the same, suggesting all were from a single species. But tooth sizes progressively declined, say biological anthropologist Terry Harrison of New York University and colleagues. The ancient orangutans' average body mass started out at about 96 kilograms, close to double that of orangutans today, the team reports in the December *Journal of Human Evolution*. By about 111,000 years ago, body mass had dropped to about 80 kilograms.

Fossils of other ancient Asian animals, including rhinos and monkeys, also show declines in body size over the same period. Cooler, drier conditions that gradually reduced available food starting around 2 million years ago may have spurred a trend toward smaller bodies, Harrison says.

It's not clear when orangutans on mainland Asia died out. But climate change and possibly the arrival of humans in the region more than 60,000 years ago contributed to their demise, Harrison speculates. – *Bruce Bower*





A now-extinct orangutan species gradually shrank in size over nearly 2 million years, but still remained much larger than modern orangutans, such as this one in Sumatra.

EARTH & ENVIRONMENT

Earth's lower atmosphere is rising because of climate change

Global temperatures are rising and so, it seems, is part of the sky.

Atmosphere readings collected by weather balloons in the Northern Hemisphere over the last 40 years reveal that climate change is pushing the upper boundary of the troposphere — the slice of sky closest to the ground — steadily upward at a rate of 50 to 60 meters per decade, researchers report November 5 in *Science Advances*.

Temperature is the driving force behind this change, says environmental scientist Jane Liu of the University of Toronto. The troposphere varies in height globally; it's as high as 20 kilometers in the tropics and as low as seven kilometers near the poles. The troposphere's upper boundary, the tropopause, also rises and falls with the seasons as air expands in the heat and contracts in the cold. But as greenhouse gases trap more and more heat, the troposphere is expanding higher into the atmosphere.

The tropopause rose an average of about 200 meters in height from 1980 to 2020, Liu and colleagues found. Nearly all weather occurs in the troposphere, though the shift is unlikely to have a big effect on weather, the researchers say.

Still, this finding is a reminder of climate change's impact on our world. "We see signs of global warming around us, in retreating glaciers and rising sea levels," Liu says. "Now, we see it in the height of the troposphere." – Freda Kreier

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People show off their COVID-19 vaccine record cards at a mass vaccination site in the parking lot of a Six Flags theme park in Bowie, Md., in February.

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LESSONS LEARNED from a year of COVID-19 VACCINES

2021 was the year the COVID-19 vaccines had to prove their mettle. We started the year full of hope: With vaccines in hand in record-breaking time and their rollout ramping up, we'd get shots in arms, curb this pandemic and get life back to normal. That was too optimistic.

Roughly 200 million people in the United States — and billions globally — have now been fully vaccinated. Three vaccines — one from Pfizer and its partner BioNTech, and the other two from Moderna and Johnson & Johnson — are available in the United States. Pfizer's is even available for children as young as 5. About two dozen other vaccines have also been deployed in other parts of the world. In some higher-income countries, the United States included, people have already queued up for booster shots.

But 2021 has also been the year of learning the limits of the vaccines' superpowers. With the vaccines pitted against aggressive coronavirus variants, some people's hesitancy, inequitable distribution and the natural course of waning effectiveness, there's still a lot of work to do to bring this pandemic to an end. As if to hammer home that point, the detection of the omicron variant in late November brought new uncertainty to the pandemic's trajectory. Here are some of the top lessons we've learned in the first year of the COVID-19 vaccine. – *Macon Morehouse*

The shots work, even against emerging variants

Many COVID-19 vaccines proved effective over the last year, particularly at preventing severe disease and death (*SN: 10/9/21 & 10/23/21, p. 4*). That's true even with the emergence of more transmissible coronavirus variants.

In January, in the midst of a bleak winter surge that saw average daily cases in the United States peaking at nearly 250,000, the vaccination rollout here began in earnest. Soon after, case numbers began a steep decline.

Over the summer, though, reports of coronavirus infections in vaccinated people began to pop up. Protection against infection becomes less robust in the months following vaccination in people who received Pfizer's or Moderna's mRNA vaccines, multiple studies have shown (*SN Online: 9/21/21*). Yet the shots' original target — preventing hospitalization — has held steady, with an efficacy of about 80 percent to 95 percent. A single dose of Johnson & Johnson's vaccine is less effective at preventing symptoms or keeping people out of the hospital than the mRNA jabs. The company claims there's not yet evidence that the protection wanes. But even if that protection is not waning, some real-world data hint that the shot may not be as effective as clinical trials suggested (*SN Online; 10/19/21*).

Evidence of waning or lower protection ultimately pushed the United States and some other countries to green-light COVID -19 booster shots for adults (SN: 12/4/21, p. 6).

Much of the worry over waning immunity came amid the spread of highly contagious variants, including alpha, first identified in the United Kingdom in September 2020, and delta, first detected in India in October 2020 (*SN Online: 7/30/21*). Today, delta is the predominant variant globally.

The good news is that vaccinated people aren't unarmed against these mutated foes. The immune system launches a multipronged attack against invaders, so the response can handle small molecular tweaks to viruses, says Nina Luning Prak, an immunologist at the University of Pennsylvania. Dealing with variants "is what the immune system does."

Vaccine-prompted antibodies still attack alpha and delta, though slightly less well than they tackle the original virus that emerged in Wuhan, China, two years ago. Antibodies also still recognize more immune-evasive variants such as beta, first identified in South Africa in May 2020, and gamma, identified in Brazil in November 2020. Although protection against infection dips against many of these variants, vaccinated people remain much less likely to be hospitalized compared with unvaccinated people.

Experts will continue to track how well the vaccines are doing, especially as new variants, like omicron, emerge. In late November, the World Health Organization designated the omicron variant as the latest variant of concern after researchers in South Africa and Botswana warned that it carries several worrisome mutations. As of December 1, it was still unknown how transmissible omicron is, how well it evades the immune system or whether it can overtake delta as the predominant variant.

"This is the first time in history that we're basically monitoring virus mutations in real time," says Müge Çevik, an infectious diseases physician and virologist at the University of St. Andrews in Scotland. "This is what the viruses do. It's just that we're seeing it because we're looking for it."

But it's unlikely that any new variant will take us back to square one, Çevik

says. Because of the immune system's varied defenses, it will be difficult for a coronavirus variant to become completely resistant to vaccine-induced protection. The vaccines are giving our immune system the tools to fight back. -Erin Garcia de Jesús

The shots are safe, with few serious side effects

With billions of doses distributed around the world, the shots have proved not only effective, but also remarkably safe, with few serious side effects.

"We have so much safety data on these vaccines," says Kawsar Talaat, an infectious diseases physician at the Johns Hopkins Bloomberg School of Public Health. "I don't know of any vaccines that have been scrutinized to the same extent."

Commonly reported side effects include pain, redness or swelling at the spot of the shot, muscle aches, fatigue, fever, chills or a headache. These symptoms usually last only a day or two.

More rare and serious side effects have been noted. But none are unique to these shots; other vaccines — plus infectious diseases, including COVID-19 — also cause these complications.

One example is inflammation of the heart muscle, known as myocarditis, or of the sac around the heart, pericarditis. Current estimates are a bit squishy since existing studies have different populations and other variables (SN Online: 10/19/21). Two large studies in Israel estimated that the risk of myocarditis after an mRNA vaccine is about 4 of every 100,000 males and 0.23 to 0.46 of every 100,000 females, researchers reported in October in the New England Journal of Medicine. Yet members of Kaiser Permanente Southern California who had gotten mRNA vaccines developed myocarditis at a much lower rate: 5.8 cases for every 1 million second doses given, researchers reported, also in October, in JAMA Internal Medicine.

What all the studies have in common is that young males in their teens and 20s are at highest risk of developing the side effect, and that risk is highest after



Blood clots (one illustrated) are a potential side effect of some COVID-19 vaccines, but the risk of developing clots is much higher from the disease itself.

the second vaccine dose (*SN Online:* 6/23/21). But it's still fairly rare, topping out at about 15 cases for every 100,000 vaccinated males ages 16 to 19, according to the larger of the two Israeli studies. Males in that age group are also at the highest risk of getting myocarditis and pericarditis from any cause, including from COVID-19.

Components of the mRNA vaccines may also cause allergic reactions, including potentially life-threatening anaphylaxis. The U.S. Centers for Disease Control and Prevention calculated that anaphylaxis happens at a rate of about 0.025 to 0.047 cases for every 10,000 vaccine doses given.

But a study of almost 65,000 health care system employees in Massachusetts suggests the rate may be as high as 2.47 per 10,000 vaccinations, researchers reported in March in *JAMA*. Still, that rate is low, and people with previous histories of anaphylaxis have gotten the shots without problem. Even people who developed anaphylaxis after a first shot were able to get fully vaccinated if the second dose was broken down into smaller doses (*SN Online: 6/1/21*).

The only side effect of the COVID-19 vaccines not seen with other vaccines is a rare combination of blood clots accompanied by low numbers of blood-clotting platelets. Called thrombosis with thrombocytopenia syndrome, or TTS, it's most common among women younger than 50 who got the Johnson & Johnson vaccine or a similar vaccine made by AstraZeneca that's used around the world (*SN Online: 4/23/21*).

About 5 to 6 TTS cases were reported for every 1 million doses of the J&J vaccine, the company reported to the U.S. Food and Drug Administration. The clots may result from antibodies triggering a person's platelets to form clots (*SN Online: 4/16/21*). Such antibodies also cause blood clots in COVID-19 patients, and the risk of developing strokes or clots from the disease is much higher than with



A teenager receives a COVID-19 vaccine at a mobile vaccination clinic in Los Angeles in May. Young men have an elevated risk of developing certain forms of heart inflammation after an mRNA shot, but the risk of this side effect is still low overall, studies have found.

the vaccine, Talaat says. In one study, 42.8 of every 1 million COVID -19 patients developed one type of blood clot in the brain, and 392.3 per 1 million developed a type of abdominal blood clot, researchers reported in *EClinicalMedicine* in September.

"Your chances of getting any of these side effects, except for the sore arm, from an illness with COVID are much higher" than from the vaccines, Talaat says. — *Tina Hesman Saey*

Getting everyone vaccinated is ... complicated

The quest to vaccinate as many people as quickly as possible this year faced two main challenges: getting the vaccine to people and convincing them to take it. Strategies employed so far — incentives, mandates and making shots accessible — have had varying levels of success.

"It's an incredibly ambitious goal to try to get the large majority of the country and the globe vaccinated in a very short time period with a brand-new vaccine," says psychologist Gretchen Chapman of Carnegie Mellon University in Pittsburgh, who researches vaccine acceptance. Usually "it takes a number of years before you get that kind of coverage."

Globally, that's sure to be the case due to a lack of access to vaccines, particularly in middle- and lower-income countries. The World Health Organization set a goal to have 40 percent of people in all countries vaccinated by year's end. But dozens of countries, mostly in Africa, are likely to fall far short of that goal.

In contrast, the United States and other wealthy countries got their hands on more than enough doses. Here, the push to vaccinate started out with a scramble to reserve scarce appointments for a free shot at limited vaccination sites. But by late spring, eligible people could pop into their pharmacy or grocery store. Some workplaces offered vaccines on-site. For underserved communities that may have a harder time accessing such vaccines, more targeted approaches where shots are delivered by trusted sources at community events



The coronavirus is airborne

This year, health experts around the world revised their views about how the coronavirus spreads. Aerosol scientists, virologists and other researchers had determined in 2020 that the virus spreads through the air, but it took until 2021 for prominent public health agencies to acknowledge the fact. The admission could have wide-ranging consequences for everything from public health recommendations and building codes to marching band practices (*SN*: 8/14/21, p. 24).

For decades, doctors and many researchers have thought that respiratory viruses such as cold and flu viruses spread mainly by people touching surfaces contaminated by mucus droplets and then touching their faces. That's why, in the early days of the pandemic, disinfectant wipes flew off store shelves.

Surface-to-face transfer is still a probable route of infection for some cold-causing viruses, such as respiratory syncytial virus, or RSV. But it turns out that the coronavirus spreads mainly through fine aerosol particles that may hang in the air for hours, particularly indoors.

People spread such aerosols when coughing or sneezing, but also when talking, singing, shouting and even quietly breathing, allowing infected people to spread the disease even before they know they're sick. Some evidence suggests that the coronavirus may be evolving to spread more easily through the air (*SN:* 9/25/21, *p.* 6).

It took collecting reams of data and more than 200 scientists pushing the World Health Organization and other public health agencies to acknowledge airborne spread of the coronavirus. In April 2021, both the WHO and U.S. Centers for Disease Control and Prevention updated their recommendations to note that airborne spread is a major route of infection (SN Online: 5/18/21).

That recognition was vital to public understanding of why wearing wellfitting masks is necessary in public indoor places (*SN*: *3/13/21*, *p*. 14; *SN Online*: 7/27/21). Masking, social distancing and other measures to guard against the coronavirus are also credited with nearly wiping out flu last winter (*SN Online*: 2/2/21). Experts fear a resurgence of cold and flu this winter if those measures aren't continued (*SN Online*: 8/12/21).

Knowledge that COVID-19 is an airborne disease has led to such measures as rearranging seating in orchestras (*SN Online: 6/23/21*) and updating recommendations for proper ventilation and filtration in buildings. Some scientists and activists have also suggested that the safety of indoor air should be regulated to reduce the spread of diseases, much like safety standards for food and drinking water. — *Tina Hesman Saey* proved they could boost vaccination numbers (*SN Online: 6/18/21*).

Simply making the shot easy to get has driven much of the progress made so far, Chapman says. But getting people who are less enthusiastic has proved more challenging. Many governments and companies have tried to prod people, initially with incentives, later with mandates.

Free doughnuts, direct cash payments and entry into million-dollar lottery jackpots were among the many perks rolled out. Before the pandemic, such incentives had been shown to prompt some people to get vaccines, says Harsha Thirumurthy, a behavioral economist at the University of Pennsylvania. This time, those incentives made little difference nationwide, Thirumurthy and his colleagues reported in September in a preprint posted to SSRN, a social sciences preprint website. "It's possible they moved the needle 1 or 2 percentage

What's next for mRNA vaccines?

Tiny molecules came up big in 2021. By year's end, COVID-19 vaccines based on snippets of mRNA, or messenger RNA, proved to be safe and incredibly effective at preventing the worst outcomes of the disease.

mRNA vaccines tell our cells how to make a mimic of a viral protein, in this case the spike protein that the coronavirus uses to break into cells (see Page 22). The vaccine-generated protein then teaches the immune system what the real threat looks like should it later encounter that threat.

For decades, efforts to develop mRNA-based vaccines to fight infectious diseases like rabies have been on a slow and meandering road (*SN Online: 6/29/21*). But the urgency of the pandemic breathed new life into these attempts. The promise of mRNA technology now takes us well past this pandemic's horizon. "We're right at the beginning of a really exciting time," says Anna Blakney, a bioengineer who studies RNA technology at the University of British Columbia in Vancouver.

The dreams are big: Fighting all sorts of infections. Attacking cancer cells. Restoring specific proteins to treat genetic diseases, such as cystic fibrosis.

"It's a really amazing technology that's been proven over the past year," Blakney says. But it won't be a panacea, she cautions. "It works really well for some things. It's unknown how well it will work for other things."

Those answers might come soon. Here's a look at four research efforts that have been aided by the swift momentum for mRNA vaccines that COVID-19 generated.



Influenza Our current flu vaccines aren't so hot. In a given year, flu shots are between 40 percent and 60 percent effective at preventing the disease. mRNA might do better. Pfizer has begun enrolling about 600 people ages 65 to 85 to find out how mRNA vaccines stack up against traditional flu shots. Moderna has already dosed participants in its own trial of such a flu vaccine, slated to include 180 adults in the United States.

HIV HIV is a slippery foe, able to evade the immune system by quickly mutating and disguising itself in a coat of human proteins and sugars (*SN*: 7/3/21 & 7/17/21, p. 14). But mRNA vaccines may be able to train the body's immune system to detect HIV in its many permutations. That's the premise of a new clinical trial in the works, sponsored by the International AIDS Vaccine Initiative and including scientists from Moderna.

Zika virus There are no vaccines available to protect people against Zika virus, which can cause severe disabilities in children born to infected mothers (*SN Online: 8/7/18*). Scientists from Moderna are currently recruiting 800 adults for a clinical trial testing an mRNA vaccine for its safety and ability to prevent Zika infection.

CMV (cytomegalovirus) CMV is a common and usually harmless virus. But it can be dangerous for newborn babies who get CMV from an infected mother before they are born. An early infection can lead to premature birth, hearing loss, seizures and developmental delays. Moderna has begun testing a CMV vaccine candidate — a combination of six different mRNAs that carry instructions for proteins on the surface of CMV. The clinical trial will include nearly 7,000 people. — *Laura Sanders* points, but we've ruled out that they had a large effect," he says. Some studies of incentives offered by individual states have found a marginal benefit.

"People who are worried about side effects or safety are going to be more difficult to reach," says Melanie Kornides, an epidemiologist at the University of Pennsylvania. And with vaccination status tangled up in personal identity, "you're just not going to influence lots of people with a mass communication campaign right now; it's really about individual conversations," she says, preferably with someone trusted.

"Or," she adds, "they're going to respond to mandates." Historically, sticks such as being fired from a job or barred from school are the most effective way of boosting vaccination rates, Kornides says. For example, hospitals that require flu shots for workers tend to have higher vaccination rates than those that don't. For decades, mandates in schools have helped push vaccination rates up for diseases like measles and chickenpox, she says.

As COVID-19 mandates went into effect in the fall, news headlines often focused on protests and refusals. Yet early anecdotal evidence suggests some mandates have helped. For instance, after New York City public schools announced a vaccine requirement in late August for its roughly 150,000 employees, nearly 96 percent had received at least one shot by early November. Still, about 8,000 employees opted not to get vaccinated and were placed on unpaid leave, the *New York Times* reported.

Many people remain vehemently opposed to the vaccines, in part because of rampant misinformation that can spread quickly online. Whether more mandates, from the government or private companies, and targeted outreach will convince them remains to be seen. *— Jonathan Lambert*

Vaccines can't single-handedly end the pandemic

One year in, it's clear that vaccination is one of the best tools we have to control COVID-19. But it's also clear vaccines



A college student receives information about a \$100 gift card reward program after getting a COVID-19 shot at a drive-through facility in New Orleans. In the past, cash incentives have worked to get people vaccinated, but the strategy has been less effective in the pandemic, research finds.

alone can't end the pandemic.

While the jabs do a pretty good job preventing infections, that protection wanes over time. Still, the vaccines have "worked spectacularly well" at protecting most people from severe disease, says Luning Prak, the University of Pennsylvania immunologist. And as more people around the world get vaccinated, fewer people will die, even if they do fall ill with COVID-19.

"We have to make a distinction between the superficial infections you can get — [like a] runny nose — versus the lower respiratory tract stuff that can kill you," such as inflammation in the lungs that causes low oxygen levels, Luning Prak says. Preventing severe disease is the fundamental target that most vaccines, including the flu shot, hit, she notes. Stopping infection entirely "was never a realistic goal."

Because vaccines aren't an impenetrable barrier against the virus, we'll still need to rely on other tactics to help control spread amid the pandemic. "Vaccines are not the sole tool in our toolbox," says Saad Omer, an epidemiologist at Yale University. "They should be used with other things," such as masks to help block exposure and COVID-19 tests to help people know when they should stay home.

For now, it's crucial to have such

layered protection, Omer says. "But in the long run, I think vaccines provide a way to get back to at least a new normal." With vaccines, people can gather at school, concerts or weddings with less fear of a large outbreak.

Eventually the pandemic will end, though when is still anyone's guess. But the end certainly won't mean that COVID-19 has disappeared.

Many experts agree that the coronavirus will most likely remain with us for the foreseeable future, sparking outbreaks in places where there are pockets of susceptible people. Susceptibility can come in many forms: Young children who have never encountered the virus before and can't yet get vaccinated, people who choose not to get the vaccine and people whose immunity has waned after an infection or vaccination. Or the virus may evolve in ways that help it evade the immune system.

The pandemic's end may still feel out of reach, with the high hopes from the beginning of 2021 a distant memory. Still, hints of normalcy have returned: Kids are back in school, restaurants and stores are open and people are traveling more.

Vaccines have proved to be an invaluable tool to reduce the death and destruction that the coronavirus can leave in its wake. -Erin Garcia de Jesús

How delta took over

BY TINA HESMAN SAEY & ERIN GARCIA DE JESÚS

Illustrations by Falconieri Visuals

In late spring and early summer, a year and a half into the COVID-19 pandemic, things seemed to be looking up. In the United States, for instance, millions of people were vaccinated, cases were falling and people were resuming normal activities. Then came delta.

This variant of SARS-CoV-2, the coronavirus that causes COVID-19, hit hard. First spotted in India in October 2020, delta swept quickly around the world, supplanting other versions of the virus. It overwhelmed health care systems, tore through unvaccinated populations and showed that even the vaccinated were vulnerable, causing some breakthrough cases.

It soon became clear why delta wreaks so much havoc. People infected with delta make more of the virus and spread it for longer than people infected with other variants, researchers reported in August in *Clinical Infectious Diseases*.

As a result, delta infections are more contagious. Consider two scenarios in a community where no one has immunity to the coronavirus: A person infected with an earlier version of the virus — the one first identified in Wuhan, China, that set off the pandemic — might spread it to two or three others. But a person infected with delta may transmit it to five or six people.

Delta owes its success to mutations in some of its proteins, including some mutations that are similar to those found in the recently discovered omicron variant. Scientists don't yet know the effect that all those changes have on delta's ability to replicate or spread to others. But studies have zeroed in on the unique constellation of mutations studding the virus' spike protein (a 3-D rendering is shown, right). It's the protein that helps the virus latch onto and invade human cells. Some of these mutations help the virus more easily break into cells, where it turns cell machinery into virus-making factories. Take, for instance, a couple of mutations that are on the receptorbinding domain. This is the part of the spike protein that attaches to ACE2, a protein on the surface of host cells. One of those mutations, named L452R, switches the charge on a protein building block in a key part of the spike protein from neutral to positive. So, like a magnet attracted to metal, the mutation seems to make the spike protein bind more tightly to a part of ACE2 that has a negative charge. Other mutations stud a region of the spike protein called the N-terminal domain, which is a known target of the immune system's neutralizing antibodies. These mutations may help the virus evade those antibodies, which can stop the virus from infecting cells.

And yet two other mutations, dubbed P681R and D614G, may help prep newly made viruses to go out and conquer.

Taken together, these mutations help delta perform several tasks better than other variants do (see opposite page). As a result, delta was able to become the dominant variant in the world.

Delta's defining mutations The spike protein helps the coronavirus attach to and enter human cells. The delta variant's version carries a unique collection of mutations, marked by yellow dots in this 3-D rendering of the spike protein. Some of these mutations may help the virus more easily infect cells or hide from antibodies.







A big year for cicada science

BY SUSAN MILIUS

n one of history's weird coincidences, the second summer of a global pandemic brought Johns Hopkins biologist Ethan Allen Andrews out on a Baltimore lawn to watch the massive Brood X cicada mating frenzy. The year was 1919 and a great influenza was still spreading around the world.

In 2021, the second summer of a different pandemic with many heartbreaking parallels, Brood X cicadas again sent people in the eastern United States onto their lawns in wonder, or into hiding from the mini projectiles and their high-decibel din.

Every 17 years, big-eyed Brood X *Magicicada* bugs as fat as fingers and defenseless as gummy bears fumble out of the ground by the millions. They orient toward various trees as if mystically called, then seethe over lawns in masses to converge and climb. "Astonishing," Andrews called the view near a large tree. And that was before the mobs took their adult flying form and, after 17 asexual years, the males finally chorused for females.

"Ear drums nearly shattered by boiler-foundry din," the *Baltimore Sun* exclaimed on May 30, 1919. Yet Andrews sounded thrilled. For three years, he had dug test holes to check on the young cicadas maturing underground. When they finally crawled into daylight, he sampled and calculated. "The entire number emerging from an acre of such suburban land runs up toward one hundred thousand," he estimated.

Six Brood X cicada–lifetimes later (102 years), the most recent crop of the big, goofy bugs clambered above ground on schedule in patches scattered across 15 states. Despite the ongoing COVID-19 pandemic, researchers took to the field, or the lawn.

All together now

Magicicada species live hypercoordinated, "periodical" lives. To be considered periodical, a whole geographic population, called a brood, must live through a multiyear life cycle, synchronizing big events. North America's periodical cicadas, depending on location, emerge either every 13 or 17 years, mating only in the last month or so of life. Imagine, for a second, whole cities of humans who hit some of the big milestones of life – being born, having babies and then dying – within weeks of each other.

A periodic life cycle is rare, but not unique, says biologist Chris Simon of the University of Connecticut in Storrs. Out of the million or so named insect species, she knows of more than 50 with periodic lives — hardly an overwhelming number. Thirty-eight species of moths and butterflies live like this. So do at least four kinds of beetles and even a fly.

Among the estimated 3,000 cicada species, just a few kinds live so tightly in lockstep. For the various North American cicadas, only *Magicicada* species synchronize. Brood X may get a lot of publicity, but there are 14 other broods, all but one mixing more than one species.

Brood X mingles three species, which Simon's well-tuned ear can identify by the males' mating calls: the angry chipmunk call of *M. septendecula*, *M. cassini* with its ticking that winds up to a raspy scream and *M. septendecim*, known for its whistling spaceship drone. Females just click.

"We used to think only North America had periodical cicadas," Simon says. And that the cycles were all odd-numbered. "We" however means Western scientists. A small expanse of India has its "World Cup" cicada (*Chremistica ribhoi*), which appears on the same four-year cycle as the soccer competition. Among Fiji's cicadas, the gold-and-black nanai (*Raiateana knowlesi*) bursts out on the main island every eight years. It has replaced Queen Elizabeth on the South Pacific country's \$100 bill.

When life gives you cicadas

This year, as Simon went south for intensive Brood X mapping in North Carolina and Georgia, she bought Brewed X coffee in Washington, D.C. She's been immersed in the fascinating world of cicadas for decades, and collects instances of cicadas touching human culture. She can quote from a 1987 newspaper story reporting two men "brandishing" a cicada in a suspected robbery at the Grand Slam restaurant in Cincinnati, and she has a 2011 photo of the window of the beloved Sparky's ice cream parlor in Columbia, Mo. The shop had sold out of cicada ice cream, so the staff taped up a note: "Check back in 2024."

Looking back over her travels and worldwide research, this year Simon and long-time colleagues updated a synthesis of ideas about how *Magicicada* species evolved in three main lineages that diverged from a common ancestor

Cicada sightings Yellow marks the spot where reports of Brood X have come in over the years, compared with the blue landscape of a U.S. Forest Service map showing the counties where other cicada broods emerge on either 17- or 13-year cycles.



What's next Brood X steals the headlines, but North America offers plenty more chances to see (and hear) 17- and 13-year periodical, bumbling bugs.

	Brood	Next emergence
17-year cicadas	Brood I	2029
	Brood II	2030
	Brood III	2031
	Brood IV	2032
	Brood V	2033
	Brood VI	2034
	Brood VII	2035
	Brood VIII	2036
	Brood IX	2037
	Brood X	2038
	Brood XIII	2024
	Brood XIV	2025
13-year cicadas	Brood XIX	2024
	Brood XXII	2027
	Brood XXIII	2028

some 3.9 million years ago. The periodical lifestyle evolved along with them, the researchers wrote online October 8 in the *Annual Review of Entomology*.

One factor on the path to periodicity is what Simon calls "predator foolhardiness." *Magicicada* adults are big and weirdly easy to catch. They only halfheartedly try to escape predators. Even though birds, squirrels and plenty of other animals gorge on the easy meals, a sufficiently huge burst of cicadas can feed all the menaces and still leave enough survivors to reproduce. Reaching such mind-boggling abundance is easier when youngsters from a whole swath of countryside burst out of the ground together every 17 years.

This coordination can fit with a nutrient-skimpy diet and slow growth. Developing *Magicicada* youngsters tap tree roots for food, but ignore the higher-calorie fluid that carries sugars downward from the leaves. Instead, young cicadas drive their mouthparts into the up-sucking xylem, which carries roughly 99.9 percent water, with just a smidge of nutrients, from roots.

Feeding this way is hard work. To sip

even such weak broth means a hard fight against the plant's strong upward draw of fluids. To get the job done, cicadas, like other xylem specialists (*SN: 8/14/21, p. 14*), grow specialized power pumps in their heads.

Spreading wings

Cicadas' foolhardiness coupled with their extraordinary numbers brought a research bonanza for Mary Salcedo, a biomechanist at Virginia Tech in Blacksburg. She studies how newly adult insects quickly pump up their massive wings from the early squished-together tissue pads. Speed matters, as flightless means defenseless.

Cicadas can pump up their wings in only about 45 minutes. After studying the wings of lab locusts and grasshoppers, she enthusiastically turned to *Magicicada*: "Thousands of insects I don't have to rear or care for!"

Before the first of Brood X pushed out of the ground this year, Salcedo booked an Airbnb rental outside Washington, D.C., for 10 (fully vaccinated) people from the Virginia Tech lab of biomechanist Jake Socha. The pandemic shut Socha's lab in 2020, so the trip helped Ph.D. student Joshua Pulliam, for one, in his dramatic swerve to study cicada motion. He's finding a way to fit insect climbing into his Ph.D. project on snakes that glide so well they just about fly (*SN*: 8/1/20, p. 16).

Salcedo has long wondered how insects manage to get huge wings flightready so fast. "Most people — I found, even some entomologists — think of an insect wing as like your hair," she says. "But it's ... more like your arm."

Instead of just inert stuff, insect wings have networks with nerves, airways and insect "blood," or hemolymph. That complex system takes a lot of circulatory power, including extra hearts, says Salcedo, who is working with colleagues on a cicada wings paper. Cicadas have one central heart, plus more for the wings.

Unlike locusts and grasshoppers, which have a two-step wing reveal, the periodical cicada pulls its wings open all at once, like "pulling a sword out of a sheath," Salcedo says. She Zoom-shares



Sterilized by the pale chalky mass of a fungus called *Massospora* on its rear, a periodical cicada like this one can still fly and flirt, spreading the fungus to other cicadas.

images of Brood X cicadas she caught and photographed during the recent excursion as they stretched out their wings for the first time. The starting shapes look like small, white sails with yellow squiggles. As those squiggles expand, the wings flare wider and longer, gradually coming to life.

Mind control

Forest pathologist Matt Kasson and his students also went cicada hunting in 2021, but not just any Brood X bumbler would do. Based at West Virginia University in Morgantown, the group searched in the Shenandoah Valley and nearby mountains for cicadas infected with a fungus that renders cicadas sterile but juices up their sex drive, maximizing fungal spread by mating contact.

"You have a cicada walking around with, basically, a chalky gumdrop [of fungus] on the backside of its abdomen," Kasson says. These *Massospora* fungi drive males to mimic the flirtatious clicks of females, attracting other males. The duped males eventually catch on and clatter away, but they carry infectious fungi away with them.

Students Angie Macias and Matt Berger came up with the idea to study these fungi more than five years ago. There was no way to grow *Massospora* in labs, but the fungi attack both periodical and nonperiodical cicada species. One of the group's first projects used nonperiodical cicadas from the American West to explore what chemistry could let a fungus energize insect sexual behavior.

"I get a call one snowy night in February at 2 in the morning," Kasson remembers. It was from grad student Greg Boyce. He had a day job at a biotech company that let him use — after hours but for free — very expensive instruments to identify substances produced as an organism metabolizes. So in the dark of night, Boyce asked his adviser, "You know what psilocybin is?"

Boyce had found that the legendary ingredient in a kind of magic mushroom, of all things, turned up naturally in a *Massospora* that attacks wing-banger cicadas (*Platypedia putnami*) from New Mexico.

By daylight "we were just like, holy crap!" Kasson says. This was especially surprising because the trippy mushrooms are far, far away from *Massospora* fungi in evolutionary history. The cicada attackers are in a whole different phylum, "way lower" on the fungal tree of life. Kasson thinks the same compound must have evolved twice, maybe a couple hundred million years apart.

"We got a bunch of colleagues looped in on that, and everybody was going nuts." The big question was, did the periodical cicadas' version of *Massospora* also have psilocybin?

The answer is, no. What turns out to drive periodical cicadas to hypersexed flirtation is a different stimulant: an amphetamine called cathinone. That same ingredient puts the kick in the khat plant, popularly chewed in the Middle East and not at all related to a fungus.

Eventually it dawned on Kasson that his cicada collecting had inadvertently filled his university lab with controlled substances for which he had no permits. "I wrote the most awkward letter of my life to the DEA," he says.

In the end, the lab got squared away with the Drug Enforcement Administration. Insect mating-enhancement drugs have now become yet another tidbit of science that cicada watchers can muse over the next time their lawns start crawling.

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EVs can help navigate the climate road ahead



BY CAROLYN GRAMLING

his was another year of bleak climate news. Record heat waves baked the Pacific Northwest. Wildfires raged in California, Oregon, Washington and neighboring states. Tropical cyclones rapidly intensified in the Pacific Ocean. And devastating flash floods inundated Western Europe and China. Human-caused climate change is sending the world hurtling down a road to more extreme weather events, and we're running out of time to pump the brakes, the Intergovernmental Panel on Climate Changed warned in August (*SN: 9/11/21, p. 8*).

The world needs to dramatically reduce its greenhouse gas emissions, and fast, if there's any hope of preventing worse and more frequent extreme weather events. That means shifting to renewable sources of energy — and, importantly, decarbonizing transportation, a sector that is now responsible for about a quarter of the world's carbon dioxide emissions.

But the path to that cleaner future is daunting, clogged with political and societal roadblocks, as well as scientific obstacles. Perhaps that's one reason why the electric vehicle — already on the road, already navigating many of these roadblocks – swerved so dramatically into the climate solutions spotlight in 2021.

Just a few years ago, many automakers thought electric vehicles, or EVs, might be a passing fad, says Gil Tal, director of the Plug-in Hybrid & Electric Vehicle Research Center at the University of California, Davis. "It's now clear to everyone that [EVs are] here to stay."

Globally, EV sales surged in the first half of 2021, increasing by 160 percent compared with the previous year. Even in 2020 — when most car sales were down due to the COVID-19 pandemic — EV sales were up 46 percent relative to 2019. Meanwhile, automakers from General Motors to Volkswagen to Nissan have outlined plans to launch new EV models over the next decade: GM pledged to go all-electric by 2035, Honda by 2040. Ford introduced electric versions of its iconic Mustang and F-150 pickup truck.

Consumer demand for EVs isn't actually driving the surge in sales, Tal says. The real engine is a change in supply due to government policies pushing automakers to boost their EV production. The European Union's toughened CO_2 emissions laws for the auto industry went into effect in 2021, and automakers

have already bumped up new EV production in the region. China mandated in 2020 that EVs make up 40 percent of new car sales by 2030. Costa Rica has set official phase-out targets for internal combustion engines.

In the United States, where transportation has officially supplanted power generation as the top greenhouse gasemitting sector, President Joe Biden's administration set a goal this year of having 50 percent of new U.S. vehicle sales be electric — both plug-in hybrid and all-electric — by 2030. That's a steep rise over EVs' roughly 2.5 percent share of new cars sold in the United States today. In September, California announced that by 2035 all new cars and passenger trucks sold in the state must be zero-emission.

There are concrete signs that automakers are truly committing to EVs. In September, Ford announced plans to build two new complexes in Tennessee and Kentucky to produce electric trucks and batteries. Climate change–related energy crises, such as the February failure of Texas' power system, may also boost interest in EVs, Ford CEO Jim Farley said September 28 on the podcast Columbia Energy Exchange.

"We're seeing more extreme weather events with global warming, and so people are looking at these vehicles not just for propulsion but for ... other benefits," Farley said. "One of the most popular features of the F-150 Lightning is the fact that you can power your house for three days" with the truck's battery.

More to navigate

Although the EV market is growing fast, it's still not fast enough to meet the Paris Agreement goals, the International Energy Agency reported this year. For the world to reach net-zero emissions by 2050 — when carbon emissions added to the atmosphere are balanced by carbon removal — EVs would need to climb from the current 5 percent of global car sales to 60 percent by 2030, the agency found.

As for the United States, even if the Biden administration's plan for EVs comes to fruition, the country's transportation sector will still fall short of its emissions targets, researchers reported in 2020 in *Nature Climate Change*. To hit those targets, electric cars would need to make up 90 percent of new U.S. car sales by 2050 — or people would need to drive a lot less.

And to truly supplant fossil fuel vehicles, electric options need to meet several benchmarks. Prices for new and used EVs must come down. Charging stations must be available and affordable to all, including people who don't live in homes where they can plug in. And battery ranges must be extended. Average ranges have been improving. Just five or so years ago, cars needed a recharge after about 100 miles; today the average is about 250 miles, roughly the distance from Washington, D.C., to New York City. But limited ranges and too few charging stations remain a sticking point.

Today's batteries also require metals that are scarce, difficult to access or produced in mining operations rife with serious human rights issues. Although there, too, solutions may be on the horizon, including finding ways to recycle batteries to alleviate materials shortages (*SN*: 12/4/21, *p.* 4). EVs on their own are nowhere near enough to forestall the worst effects of climate change. But it won't be possible to slow global warming without them.

And in a year with a lot of grim climate news — both devastating extreme events and maddeningly stalled political action — EVs offered one glimmer of hope.

"We have the technology. It's not dependent on some technology that's not developed yet," Tal says. "The hope is that now we are way more willing to [transition to EVs] than at any time before."

Superlative science

BY ERIKA ENGELHAUPT

rom a record-setting black hole to the oldest animal DNA ever recovered, discoveries in 2021 stretched the limits of scientific study – and our imaginations.

Oldest behemoth black hole

More than 13 billion years ago, when the universe was a mere 670 million years old, a black hole was born. At a mass equal to 1.6 billion suns, the newly discovered supermassive black hole J0313-1806 is twice as heavy and 20 million years older than the previous record holder for oldest known black hole (SN: 2/13/21, p. 4). The ancient behemoth is so big that it challenges notions of how supermassive black holes first formed, astronomers say.

The new record holder for oldest black hole (illustrated) is called J0313-1806.



Gravity on the smallest scale

Every object with mass has gravity too, according to both Isaac Newton and Albert Einstein, even if it's barely noticeable. Scientists have now measured the gravity of a gold ball 2 millimeters wide and weighing about 90 milligrams — the smallest object ever to have its gravitational pull measured (*SN: 4/10/21, p. 5*). The tiny tug revealed that gravity behaves as predicted, even for very small masses. Researchers still want to test how gravity behaves on the even smaller quantum scale, where different rules of physics may apply.

Oldest opposable thumbs

A 160-million-year-old pterosaur nicknamed Monkeydactyl is now the earliest known animal with opposable thumbs (*SN: 5/8/21 & 5/22/21, p. 16*). The flying reptile, officially named *Kunpengopterus antipollicatus*, may have used its thumbs and flexible joints to clamber up and through trees in what is now northeastern China. The digits could have helped it capture insects and other prey, scientists say.

First-of-its-kind merger

For the first time, a black hole has been seen gobbling up a neutron star, the collapsed remains of a dead supergiant star. Astronomers detected the event by measuring gravitational waves that emanated from the collision and eventually reached Earth (*SN: 7/31/21, p. 6*). All previously identified sources of these ripples in spacetime consisted of two like objects colliding, such as two neutron stars or two black holes.

Oldest recovered animal DNA

The tooth of a Siberian mammoth that lived more than a million years ago has offered up the oldest DNA ever recovered from an animal (*SN: 3/13/21, p. 6*). The previous record holder was 700,000-year-old DNA from a fossilized horse. Scientists say the new find probably approaches the limit of how long DNA can persist. Genes from the mammoth suggest that it may have belonged to a previously unknown species.

Most Denisovan DNA

The mysterious hominid group known as the Denisovans died out long ago, but not without leaving a trace. The Indigenous Ayta Magbukon people of the Philippines get about 5 percent of their DNA from Denisovans, a genetic analysis revealed (*SN: 9/11/21, p. 16*). That's the highest level of Denisovan ancestry yet found anywhere in the world. Researchers are using the result, along with genetic clues from other groups that carry Denisovan DNA, to retrace Denisovans' movements through Southeast Asia, Papua New Guinea and Australia.

Stone Age networking

BY BRUCE BOWER

vidence that cross-continental Stone Age networking events powered human evolution ramped up in 2021.

A long-standing argument that *Homo* sapiens originated in East Africa before moving elsewhere and replacing Eurasian *Homo* species such as Neandertals has come under increasing fire over the last decade. Research this year supported an alternative scenario in which *H. sapiens* evolved across vast geographic expanses, first within Africa and later outside it.

The process would have worked as follows: Many *Homo* groups lived during a period known as the Middle Pleistocene, about 789,000 to 130,000 years ago, and were too closely related to have been distinct species. These groups would have occasionally mated with each other while traveling through Africa, Asia and Europe. A variety of skeletal variations on a human theme emerged among farflung communities. Human anatomy and DNA today include remnants of that complex networking legacy, proponents of this scenario say.

It's not clear precisely how often or when during this period groups may have mixed and mingled. But in this framework, no clear genetic or physical dividing line separated Middle Pleistocene folks usually classed as *H. sapiens* from Neandertals, Denisovans and other ancient *Homo* populations.

"Middle Pleistocene *Homo* groups were humans," says paleoanthropologist John Hawks of the University of Wisconsin–Madison. "Today's humans are a remix of those ancient ancestors."

New fossil evidence in line with that idea came from Israel. Braincase pieces and a lower jaw containing a molar tooth unearthed at a site called Nesher Ramla date to between about 140,000 and 120,000 years ago. These finds' features suggest that a previously unknown Eurasian *Homo* population lived at the site (*SN Online: 6/24/21*), a team led by paleoanthropologist Israel Hershkovitz of Tel Aviv University reported. The fossils were found with stone tools that look like those fashioned around the same time by Middle Easterners typically classified as *H. sapiens*, suggesting that the two groups culturally mingled and possibly mated.

Interactions like these may have facilitated enough mating among mobile *Homo* populations to prevent Nesher Ramla inhabitants and other Eurasian groups from evolving into separate species, Hershkovitz proposed.

But another report provided a reminder that opinions still vary about whether Middle Pleistocene *Homo* evolution featured related populations that all belonged to the same species or distinct species. Researchers studying the unusual mix of features of a roughly 146,000-year-old Chinese skull dubbed it a new species, *Homo longi* (*SN Online: 6/25/21*). After reviewing that claim, however, another investigator grouped the skull, nicknamed Dragon Man, with several other Middle Pleistocene *Homo* fossils from northern China.

If so, Dragon Man – like Nesher Ramla *Homo* – may hail from one of many closely related *Homo* lines that occasionally mated with each other as some groups moved through Asia, Africa and Europe. From this perspective, Middle Pleistocene *Homo* groups evolved unique traits during periods of isolation and shared features when crossing paths and mating.

Back-and-forth migrations by *Homo* groups between Africa and Asia started at least 400,000 years ago, discoveries in Saudi Arabia suggest (*SN: 10/9/21 & 10/23/21, p. 7*). Monsoon rains periodically turned what's now desert into a green passageway covered by lakes, wetlands and rivers, reported archaeologist Huw Groucutt of the Max Planck Institute for the Science of Human History in Jena, Germany, and colleagues. Each of five ancient lake beds identified at a

Fossil discoveries reported this year, including this partial jaw (left) and braincase (right) from Israel, support an idea that mating among many widespread but closely related *Homo* groups fostered human evolution.

Saudi site once hosted hunter-gatherers who left behind stone tools.

Occupations occurred intermittently between about 400,000 and 55,000 years ago. By about 200,000 years ago, stone tools at one of the lake beds resembled those made around the same time by *H. sapiens* in northeastern Africa. Some of those Africans may have stopped for a bit in a green Arabia before trekking into southwestern Asia, Groucutt suggests.

Either *H. sapiens* or Neandertals made stone tools unearthed in the youngest lake bed. Neandertals inhabited parts of the Middle East by around 70,000 years ago and could have reached a wellwatered Arabia by 55,000 years ago. If that's what happened, Neandertals may have mated with *H. sapiens* already there, Groucutt speculates.

Although Arabian hookups have yet to be detected in ancient DNA, European Neandertals and *H. sapiens* mated surprisingly often around 45,000 years ago (*SN: 5/8/21 & 5/22/21, p. 7*), other scientists reported. DNA extracted from *H. sapiens* fossils of that age found in Bulgaria and the Czech Republic indicates that these ancient individuals possessed between about 2 percent and 4 percent Neandertal ancestry, a large amount considering *H. sapiens* migrants had only recently arrived in Europe.

So even after the Middle Pleistocene, networking among ancient *Homo* groups may have helped make us who we are today.

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Wait, there's more

BY SCIENCE NEWS STAFF

story doesn't necessarily end once it goes to print. Here, *Science News* offers status updates on some evolving stories we reported on earlier this year.

Finally, a malaria vaccine

In June, Erin Garcia de Jesús reported that two malaria vaccine candidates showed promise in early, small clinical trials (*SN Online: 6/30/21*). One jab – tested in children in Burkina Faso – had 77 percent efficacy against malaria symptoms. The other, tested in U.S. adults, had around 87 percent efficacy against infection when paired with infection-fighting drugs. The results sparked hope that the world's first approved malaria vaccine would soon become a reality.

UPDATE: Well, it happened, but for a different vaccine. In October, the World Health Organization gave a thumbs up to a vaccine that was further along in testing, approving it for children who live in sub-Saharan Africa and other places with the deadliest species of the malaria-causing

parasite, *Plasmodium falciparum*. Of the estimated 409,000 people who died from malaria in 2019, two-thirds were under age 5. Although groundbreaking, the vaccine — called RTS,S or Mosquirix — is not a magic bullet. The four-dose regimen prevents only about 4 in 10 malaria cases and 3 in 10 severe cases. Still, RTS,S plus existing tools could "save tens of thousands of young lives each year," WHO Director-General Tedros Adhanom Ghebreyesus said in an October 6 statement.

Tulsa massacre answers

This year was the 100th anniversary of a race massacre in Tulsa, Okla., in which a mob of white people invaded the prosperous Black neighborhood of Greenwood. The death toll is estimated to be in the hundreds, though the exact number is unknown, as is the exact location where victims were buried. In June, Helen Thompson reported on a collaboration among scientists, historians and community leaders to investigate an area in Oaklawn Cemetery that may hold a mass grave of victims (*SN: 6/19/21, p. 22*).

UPDATE: In June, archaeologists announced they had found 34 coffins at Oaklawn and were analyzing remains from 19 of them. Preliminary findings suggest the remains belonged to children

Over several weeks in June, researchers excavated coffins from a site at Oaklawn Cemetery (shown from above) in their search for victims of the 1921 Tulsa race massacre.



and adults, forensic anthropology lead Phoebe Stubblefield said June 25 at a news conference. Based on skull facial features. "ancestry so far when we can detect it has been primarily of African descent," she said. One man had a bullet embedded in his shoulder, along with trauma consistent with expectations for the massacre's victims, the project's archaeology lead, Kary Stackelbeck, told Science News in November. The full analysis, expected to be released in early 2022, aims to determine the race, sex, age and any trauma patterns of all the recovered individuals. Those results will help determine the project's next steps.

GM mosquitoes hatch in Florida

After about a decade of fierce debate, genetically modified mosquitos flew free in the United States for the first time. Starting in April, modified eggs were deposited in several test spots in the Florida Keys, Susan Milius reported (SN Online: 5/14/21). Designed as living pesticides by the biotech company Oxitec, male GM Aedes aegypti mosquitoes mate with local females of this hard-toeradicate species and pass along a gene that kills daughters in the wild before they can bite. Sons grow up to trick more females into doomed mating. Eventually, the population of this spreader of dengue and Zika should dwindle.

UPDATE: GM males that hatched from eggs succeeded in wooing Floridian females, test watchers report. After two temporary stops for big storms, managers restarted periodic releases and kept tests running into November. In August, Oxitec asked the U.S. Environmental Protection Agency to allow two more years of testing in the Keys. The company also asked to start testing in "up to 84,600 total acres" in California, which identified its first *Ae. aegypti* mosquito in 2013. Today the pest is scattered throughout the state.

In California, travelers account for all of the state's dengue and Zika cases. But *Ae. aegypti* might someday spread these diseases within the state.



Confirmation, please

BY AINA ABELL

iscoveries in 2021 dared the world to consider grand possibilities in physics, space and the origins of life. Will these bold claims hold up to scrutiny?

Misbehaving muons

Nothing gets physicists more excited than evidence of a new fundamental particle. Researchers with the Muon g-2 experiment at Fermilab in Batavia, Ill., flung billions of muons around the lab's giant magnet and found that the rate at which the orientation of the muons' magnetic poles wobbled strayed from theoretical predictions. The odd behavior suggests that hidden particles are influencing the muons' magnetic properties, challenging the standard model of particle physics describing the universe's fundamental forces and elementary particles (SN: 5/8/21 & 5/21/21, p. 6). But it will take more data to convince physicists, who are still refining their predictions of muon behavior.

Antistarry night

Scientists may have spotted stars made of antimatter (*SN:* 6/5/21, *p.* 8). Finding antistars challenges a basic tenet of cosmology – that the vast majority of the universe's antimatter, matter's oppositely charged doppelgänger, was destroyed long ago. In 10 years of observations from the Fermi Gammaray Space Telescope, researchers found 14 points of light emitting gamma rays at energies that are expected when matter and antimatter meet and annihilate each other -a process that could happen on the surface of antistars. The discovery hints that substantial amounts of antimatter may have survived. But proving the existence of antistars will be extremely difficult because, aside from the studied gamma rays, the light such stars give off would look just like the light from normal stars.

Cosmic curve ball

In other news that may upend our understanding of the cosmos, scientists detected a giant arc of galaxies stretching across more than 3 billion light-years. Such a finding is counter to the assumption that matter in the universe is evenly distributed on large scales (*SN: 7/3/21 & 7/17/21, p. 9*). The arc, invisible to the human eye, came to light in an analysis of about 40,000 quasars — very bright cores of distant galaxies. But some skeptics argue that the arc may be just an artifact of the human tendency to pick up patterns where none actually exist.

Early arrival

This year brought new evidence that humans arrived in the Americas more than 15,000 years earlier than traditionally thought, throwing support behind last year's claim that humans reached North America by about 33,000 years ago (*SN: 12/19/20 & 1/2/21, p. 35*). In Fourteen celestial sources of gamma rays may come from antistars. In this map of the Milky Way, yellow indicates brighter sources; blue dots are dimmer.

May, researchers reported that animal bones excavated at a cave in Mexico date to between about 33,000 and 28,000 years ago (*SN: 7/3/21 & 7/17/21, p. 16*). Chipped and sharp-edged stones that may have functioned as tools were found near the bones, hinting that humans had been in the area. And the discovery of fossilized human footprints suggests people roamed what's now New Mexico around 23,000 to 21,000 years ago (*SN: 11/6/21, p. 12*). If the tracks' age is verified, it would show that humans were in North America during the pinnacle of the last ice age.

Oldest animal fossils?

Tiny tubes found in 890-million-year old rocks might be remnants of sea sponges. If that claim holds up, the tubes would push animal origins back by about 350 million years to an oxygen-poor period considered unsuitable for animal life (*SN: 8/28/21, p. 6*). But some researchers aren't convinced that the fossils are sea sponges. Skeptics point to the lack of mineralized skeletal parts, known as spicules, that are typical features of sea sponges, and the fact that many nonanimal organisms can make similar tubes.

Extragalactic planet

Astronomers may have detected the first known planet outside of the Milky Way, in a galaxy about 28 million light-years from Earth (SN: 11/20/21, p. 7). Traditional exoplanet-hunting techniques don't work well for such distances, so researchers looked to a type of paired star system known as an X-ray binary, which emits bright X-rays. A planet crossing, or transiting, in front of such a system would temporarily block those X-rays, alerting astronomers to the planet's presence. Some scientists are skeptical because the discovery relied, metaphorically, on many stars to align: The planet needed to transit the X-ray binary while its orbit was perfectly in line with Earth's point of view, just when a telescope was looking.



To Mars, asteroids and beyond

BY LISA GROSSMAN

hile a flurry of missions crowded around Mars this year, some lesserexplored parts of the solar system are about to get fresh eyes.

Three countries visited the Red Planet in 2021, sending orbiters, landers, rovers and even a helicopter. The United Arab Emirates successfully put its first interplanetary spacecraft, called Hope, into orbit in February, to study Mars' climate. China's Zhurong rover has been trundling around the planet's surface since May, studying the local geology and searching for underground water ice (SN Online: 5/19/21). And NASA's Perseverance rover, which landed in February, has been collaborating with a helicopter called Ingenuity to explore an ancient lake bed and collect rocks for a future delivery mission to Earth (SN Online: 4/30/21).

But while all eyes were on Mars, other missions are embarking on journeys to study even more far-flung places. After years of delays and billions of dollars over budget, the James Webb Space Telescope is set to launch, as the magazine went to press, on December 22 to probe exoplanets, the earliest galaxies and other cosmic places (*SN: 10/9/21 & 10/23/21, p. 26*).

Meanwhile, spacecraft are heading off to visit 11 asteroids in the solar system in search of clues to the origins of the planets, and water and life on Earth, as well as ways to keep our planet safe from errant space rocks.

Let's meet those rock explorers.

Lucy

NASA's Lucy spacecraft launched on October 16 on the first mission to explore Jupiter's Trojan asteroids, two groups of space rocks that share an orbit with Jupiter around the sun (*SN Online: 10/15/21*). The asteroids occupy areas known as Lagrange points, where the gravitational pulls of Jupiter and the sun cancel each other out. These regions are like cosmic dead zones and have been collecting planetary flotsam for billions of years. Those asteroids and other bits of debris are like fossils of the early solar system. (Fittingly, the mission was named for the famous hominid fossil Lucy.)

Over the next 12 years, Lucy will make five flybys to observe seven Trojan asteroids, plus one asteroid in the main belt between Mars and Jupiter for good measure. By the end of its mission, Lucy will have visited more objects than any other NASA mission.

DART

The next mission to head out was NASA's Double Asteroid Redirection Test, or DART, which launched November 24 to deliberately ram into an asteroid in an attempt to alter its orbit. That collision will test a technique for deflecting dangerous asteroids that could crash into Earth in the future.

The spacecraft's destination is a pair of asteroids called Didymos and Dimorphos (*SN: 8/15/20, p. 5*). In late September 2022, DART will crash-land on Dimorphos while moving at about 6.6 kilometers per second, which hopefully will shift its orbit around Didymos. Astronomers on Earth will be able to tell if the test worked by looking for a change in Dimorphos' orbit time, and the European Space Agency will send a follow-up probe called Hera in 2024.

Psyche

Last up is Psyche, which is set to launch in August 2022. The NASA spacecraft will visit 16 Psyche, an asteroid that seems to be made up almost entirely of metal. It may be the exposed core of a protoplanet that lost its outer mantle and crust in cosmic collisions long ago. Since scientists can't send a mission to Earth's core, a trip to 16 Psyche may be the closest we can get to a journey to the center of the Earth.

Psyche will arrive at its destination in 2026 and spend 21 months measuring the asteroid's magnetic field and composition from orbit. One question is whether the asteroid truly is a planetary core. Even if not, the asteroid is a new kind of world that no spacecraft has visited before.

SFC/NASA

Amazing animal abilities

BY ERIKA ENGELHAUPT

his year, animals of all shapes and sizes surprised us with amazing abilities we didn't know they had. From powerlifting to walking on the underside of water, these are the creature capabilities that most impressed us in 2021.

Sea slugs that grow new bodies

In a spectacular feat of whole-body regeneration, some *Elysia* sea slugs can grow a new body from just the head (*SN:* 4/10/21, *p.* 4). This feat may come in handy when animals are riddled with parasites and need a fresh start. The head simply detaches itself, crawls away and regrows an entirely new body, including the heart. These are the only animals with a heart that are known to regenerate so much of themselves.

Squirrels that parkour

We've all seen squirrels pull off deathdefying maneuvers, but now we know more about how the rodents pull off their stunts. Like masters of parkour the sport in which people leap, bounce and climb through an obstacle course — squirrels gauge the bendiness of branches when jumping. The rodents also use parkour-style jumps off of vertical surfaces to slow down and stick landings, researchers found (SN: 8/28/21, p. 14).

Animals that eat surprising animals

This year upended notions of predator and prey, revealing animals making meals of one another in surprising ways. Researchers found that more than 40 species from 11 families of spiders eat snakes, using sticky silk and venomous bites to subdue serpents up to 30 times their size (*SN Online:* 8/4/21). What's more, one Seychelles giant tortoise apparently didn't get the memo that tortoises are gentle herbivores. It was spotted stalking, catching and eating a bird chick whole, the first documented example of a tortoise hunting prey (*SN:* 9/25/21, p. 5).

A beetle that walks on water, underwater

A water strider's ability to walk on water is incredible enough, but the tiny water scavenger beetle flips the script: It walks on water upside down, clinging to the water's surface from below (*SN: 7/31/21, p. 13*). The insect may use a small air bubble to pin its belly to the underside of the water's surface, but just how it steps without breaking the water's surface tension remains a mystery for now.

A bird that mimics a flock

The male superb lyrebird lives up to its name with its excellent vocal abilities, mimicking nearly any sound it hears in its Australian forest home – even





A brown widow spider in Georgia inspects a common garter snake trapped in its web.

chainsaws and cameras. Now scientists have recorded the bird mimicking the sounds of several other bird species at once — replicating an entire soundscape. It's the only known animal with this talent (*SN: 3/27/21, p. 12*). Because the lyrebird mimics multiple alarm calls in particular, researchers aren't sure if it's also trying to sound an alarm or just showing off for mates.

Spiders that lift prey up to 50 times their own weight

In an innovative take on a pulley system, some spiders, including black widows, can hoist heavy prey up, up and into their webs using only strands of their silk. Researchers observed the spiders attaching strand after strand from their main web to large prey such as lizards, with each strand just a bit shorter than the last so that the stretchy silk slowly reeled in the prize (*SN*: 2/27/21, *p*. 13).

Polar bears that wield weapons

In a macabre example of tool use by animals, polar bears sometimes kill walrus by bashing them with large chunks of stone or ice (*SN: 8/28/21, p. 16*). Inuit hunters have long reported polar bears attacking prey this way, and a review of historical and modern documentation confirms that stone-wielding polar bears are a real phenomenon. This puts polar bears on the list of tool-using animals, including crows, chimpanzees, elephants and, of course, humans.

Water cooler-worthy news

BY TRISHLA OSTWAL

range of cool discoveries, technological milestones and downright bizarre scientific feats – cows can be potty trained? – gave us a chance to gab about something other than the pandemic.

Fusion of the future

Hopes for making nuclear fusion the clean energy source of the future got a boost in August when a fusion experiment released 1.3 million joules of energy (*SN: 9/11/21, p. 11*). A big hurdle for fusion energy has been achieving ignition — the point when a fusion reaction produces more energy than required to trigger it. The test released about 70 percent of the energy used to set off the reaction, the closest yet to the break-even milestone.

Pig-to-human kidney transplant

In a first, a pig kidney was attached to a human, and the organ functioned normally during 54 hours of monitoring (*SN: 11/20/21, p. 6*). This successful surgical experiment marks a milestone toward true animal-to-human transplants, which would broaden the supply of lifesaving organs for people in need.

Death stars

In a bone-chilling event, astronomers caught a star swallowing a nearby black hole, or perhaps a neutron star, and then getting eaten by its own meal. The resulting spectacular explosion left behind a black hole (*SN*: 10/9/21 & 10/23/21, p. 6). Astronomers had theorized that such a

star-eat-star supernova was possible, but had never observed one.

Living machines

Frog cells transformed themselves into tiny living robots (*SN: 4/24/21, p. 8*). Scientists removed skin stem cells from frog embryos and watched the cells organize into little blobs dubbed "xenobots" that could swim around and even repair themselves, plus move particles in the environment. Xenobots might someday serve a useful purpose, such as cleaning up waterways, the scientists say.

Brain teaser

Scientists got an entirely new view of the brain when they took a tiny piece of a woman's brain and mapped the varied shapes of 50,000 cells and their 100 million or so connections (*SN: 7/3/21&* 7/17/21, *p. 6*). The vast dataset may help unravel the complexities of the brain.

Pluses are minuses

People often add even when subtracting is the way to go, scientists found after asking volunteers to tackle a variety of puzzles and problems, including stabilizing a Lego structure and optimizing a travel itinerary (*SN: 5/8/21 & 5/22/21, p. 8*). The tendency to think in pluses instead of minuses could be at the root of modern-day excesses like cluttered homes, the researchers speculate.

DNA accounting

Identical twins may not be genetically identical, after all. They differ by

By inspecting a speck of human brain, researchers found examples of unusual whorled axons, message-sending nerve cell tendrils (shown below in a 3-D reconstruction) coiled like snakes.



5.2 genetic changes on average, researchers reported (*SN: 1/30/21, p. 15*). That means differences between such twins may not be solely due to environmental influences. In other DNA accounting, scientists estimated that 1.5 percent to 7 percent of modern human DNA is uniquely human, distinct from the DNA of Neandertals, Denisovans and other ancient relatives (*SN: 8/14/21, p. 7*).

Potty training cows

Can farmers reduce pollution by sending cows to the loo? The answer might very well be yes. In a unique experiment, scientists trained cows to answer nature's call by using a bathroom stall that gathers urine (*SN: 10/9/21 & 10/23/21, p. 24*). In the future, collected cow urine, which could otherwise pollute the environment, might be used to make fertilizer.

Crystal clear

The intense heat and pressure of the first atomic bomb test, in 1945, left behind a glassy substance known as trinitite — and something even stranger. Within the trinitite, scientists discovered, is a rare form of matter called a quasicrystal (SN: 6/19/21, p. 12). Quasicrystals have an orderly structure like a normal crystal, but that structure doesn't repeat. Previously, these crystals had been found only in meteorites or made in the lab.

Case of the missing genes

A foul-smelling Southeast Asian plant named *Sapria himalayana* has lost about 44 percent of the genes found in most other flowering plants (*SN: 3/13/21, p. 13*). *S. himalayana* parasitizes other plants to get nutrients, so it's not so surprising that it has entirely purged its chloroplast DNA. Chloroplasts are the structures where photosynthesis, or food making, typically occurs. *S. himalayana* appears to steal more than nutrients — more than 1 percent of its genes come from other plants, perhaps current or past hosts.

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BOOKSHELF

Our favorite books of 2021

Many of the Science News staff's favorite books of the year challenge how we understand the world, from rethinking human history to reimagining the toilet. For a satisfying read, you can't go wrong with any of these books, including a couple by our Science News colleagues.

THE DAWN OF EVERYTHING A NEW HISTORY OF HUMANITY DAVID GRAEBER DAVID WENGROW

The Dawn of Everything

David Graeber and David Wengrow This provocative history challenges the conventional wisdom that societies progressed through

a series of stages that inevitably led to inequalities – instead arguing that people have experimented with a variety of social systems since the Stone Age (SN: 11/6/21, p. 34). Farrar, Straus and Giroux, \$35



First Steps

Jeremy DeSilva It's impossible to pinpoint just one thing that makes humans human. But DeSilva, a paleoanthropologist, argues that the

emergence of upright walking led our ancestors down an evolutionary path that resulted in the features that make humans unique (SN: 4/24/21, p. 28). Harper, \$27.99



Life's Edge Carl Zimmer By considering the supposed hallmarks of life, and the exceptions to the rules, this book tackles

one of biology's thorniest questions: What makes something alive? (SN: 3/27/21, p. 28). Dutton, \$28



The Code Breaker Walter Isaacson Just after winning the Nobel Prize in chemistry, Jennifer Doudna is the subject of a biography that looks at her foundational

work on CRISPR/Cas9 and delves into the ethics of gene editing (SN: 3/27/21, p. 29). Simon & Schuster, \$35



Finding the Mother Tree Suzanne Simard In this moving memoir,

Simard recounts how she went from working at a logging company to becoming an ecologist

and uncovering the hidden underground networks that connect the trees within a forest (SN: 7/3/21 & 7/17/21, p. 36). Knopf, \$28.95



Wild Souls Emma Marris Blending science and philosophy, Marris, an environmental writer. explores the ethical dilemmas associated

with preserving wildlife, and forces readers to contemplate what humans owe other animals (SN: 7/31/21, p. 28). Bloomsbury, \$28



Pipe Dreams Chelsea Wald

In this lively tour of toilets around the world, readers meet scientists, activists and entrepreneurs who are finding creative ways

to increase access to sanitation and make the management of human waste more environmentally sustainable (SN: 4/10/21, p. 29). Avid Reader Press, \$27



Empire of Pain Patrick Radden Keefe Keefe, a staff writer at the New Yorker, investigates how the actions of three generations of the Sackler family - owners of the

pharmaceutical company that made the painkiller OxyContin - set the stage for the opioid crisis. Doubleday, \$32.50



On the Fringe Michael D. Gordin Gordin, a historian, reviews astrology, alchemy, eugenics and other subjects - many of which were once

considered mainstream science - to show how challenging it is to define pseudoscience (SN: 8/28/21, p. 30). Oxford Univ., \$18.95



Flashes of Creation

Paul Halpern In the mid-20th century, George Gamow and Fred Hoyle stood on opposite sides of a great debate over how the universe

began. By recounting the careers of these dueling physicists, this book traces how the Big Bang theory and modern cosmology came to be (SN: 8/28/21, p. 30). Basic Books, \$30



Bright Galaxies, Dark Matter, and Beyond Ashley Jean Yeager Astronomer Vera Rubin provided key evidence for the existence of dark matter, an invisible substance

now thought to account for the majority of the universe's mass. In this biography, Yeager, Science News' associate news editor, looks at how Rubin persevered in the face of skepticism of her work and the sexism that pervaded science in the mid-20th century (SN: 8/14/21, p. 29). MIT Press, \$24.95



Gory Details Erika Engelhaupt Readers with a morbid curiosity look no further. Engelhaupt, a frequent contributor to Science News, entertains with sto-

ries about topics that are not suitable for polite conversation. Everything from fecal transplants to leggy insects, face mites and other critters that just might give you the heebie-jeebies makes the cut (SN: 2/27/21, p. 29). National Geographic, \$26



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SOCIETY UPDATE

TOP MOMENTS 2021

Society for Science, which publishes Science News, had a successful 2021 in which we celebrated our centennial, held 10 virtual events and provided the public with fact-based information about the ongoing COVID-19 pandemic without hype or sensationalism.



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New Year, New Name

The Society for Science & the Public started 2021 by shortening our name to Society for Science in honor of our centennial year.



\bigtriangleup

Century of Science

In celebration of its centennial year, *Science News* launched a new online project, Century of Science, which delves into major advances across the sciences that have transformed our understanding of the world, our universe and our lives.



\bigtriangleup

New Leadership

Mariette DiChristina (above), Dean of the College of Communication at Boston University; Lance R. Collins, Vice President and Executive Director of the Virginia Tech Innovation Campus; and Charles McCabe, Chief Advisor of the Manifold Fund, have joined the Society's Board of Trustees.



Science News Now

Science News hosted a day-long event featuring panels and discussions with leading scientists, including physics Nobel laureate Andrea Ghez.



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Regeneron Science Talent Search

Yunseo Choi, 18, won the \$250,000 top award. More than \$1.8 million was awarded to the finalists, who were judged based on their projects' scientific rigor, their problem-solving abilities and their leadership potential.



New Centennial Virtual Timeline

The Society launched an online timeline, 100 Years of Impact, providing the public with an opportunity to learn about the Society's role in covering key scientific moments and discoveries, encouraging science literacy and identifying the next generation of leaders in science and engineering.



Regeneron ISEF Nearly 2,000 young scientists, engineers and innovators from 49 states and 64 countries participated in the event's first virtual competition.



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Advocate Program

The Society's Advocate Program grew to include 66 educators. Advocates support at least three to five students—who identify as a race or ethnicity historically underrepresented in STEM—in science and engineering research.



Broadcom MASTERS

Akilan Sankaran, 14, won the top \$25,000 award for his exceptional communication, critical thinking and collaboration skills. Akilan developed a computer program that can calculate highly divisible numbers, sometimes called antiprime numbers, that are over 1,000 digits long.

GET INVOLVED AT WWW.SOCIETYFORSCIENCE.ORG



SCIENCE SAVES LIVES

as we face pandemics, climate change, and other threats to our global future

> ecome a Member of the **Catalyst Circle** by making a \$10,000 gift and support the Society for Science's critical work identifying and inspiring the next generation of scientists and engineers.

In addition to publishing *Science News*, the Society is also known for our world-class student STEM competitions. Alumni of these competitions are on the forefront of fighting the COVID-19 pandemic. They are also taking on challenges ranging from world hunger to climate change to chronic disease.

JOIN THE CATALYST CIRCLE

With global challenges like climate change and the pandemic impacting lives worldwide, the Society's mission to support clear, fact-based journalism and to inspire student competitions that empower the next generation of scientists and engineers has never been more essential.

Your enthusiastic support for the Society at the Catalyst Circle level will help us with all this critical work.



Join by visiting www.societyforscience.org/CatalystCircle

FEEDBACK

Online favorites of 2021

Science News drew over 21 million visitors to our website this year. Here's a rundown of the most-read news stories and long reads of 2021.

Favorite video

Acrobatic rabbits bewitched online readers in our most-viewed YouTube video posted this year. The video – accompanying the story "A gene defect may make rabbits do handstands instead of hop" (*SN*: 4/24/21, p. 13) – shows a sauteur d'Alfort rabbit walking on its front paws (below). Such hop-less bunnies may have adopted the odd gait because of a mutation in a gene called *RORB*, scientists discovered.



Join the conversation

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Top news stories

Space station detectors found the source of weird 'blue jet' lightning Instruments on the International Space Station detected the origins of an odd type of lightning called a blue jet. The bizarre bolt is sparked by a "blue bang" — a flash of bright blue light that may be brought on by the turbulent mixing of oppositely charged regions within a thundercloud (*SN: 2/13/21, p. 14*).

A newfound quasicrystal formed in the first atomic bomb test The first atomic bomb test, in 1945, forged a peculiar, glassy material called trinitite — and within it, a rare form of matter called a quasicrystal. Quasicrystals' atoms are arranged in an orderly structure like normal crystals, but the structure's pattern doesn't repeat (see Page 36).

An Indigenous people in the Philippines have the most Denisovan DNA

The Ayta Magbukon people in the Philippines set the record for the highest known level of Denisovan ancestry – about 5 percent of their DNA comes from the ancient hominids. The finding suggests that several Denisovan populations independently reached Southeast Asia and interbred with *Homo sapiens* groups that arrived thousands of years later (Page 29).

Astronomers may have seen a star gulp down a black hole and explode

In a first, astronomers caught a glimpse of a rare double cosmic cannibalism: A star swallowed a black hole or neutron star, which then gobbled that star from within, resulting in an astonishing explosion (Page 36).

Frog skin cells turned themselves

Skin stem cells plucked from frog embryos organized themselves into miniature living robots, dubbed "xenobots," that can swim, move around debris and even self-heal. Xenobots may one day serve a useful purpose, but ethical questions need to be considered (Page 36).

Top feature stories

New drugs that block a brain chemical are game changers for some migraine sufferers A class of drugs that inhibits a neurotransmitter called calcitonin gene-related peptide is helping some patients who suffer from chronic, debilitating migraines (SN: 3/27/21, p. 16).

Einstein's theory of general relativity unveiled a dynamic and bizarre cosmos

Albert Einstein's general theory of relativity has served as the bedrock of our understanding of the cosmos. In the last 100 years, scientists have confirmed its most radical predictions, including black holes, gravitational waves and an expanding universe (*SN*: 2/13/21, p. 16).

Chemists are reimagining recycling to keep plastics out of landfills

No matter people's dedication to sorting and recycling plastics, most still end up in landfills because the materials are too difficult to transform into useful new products. Some chemists are trying to change that (*SN*: 1/30/21, p. 20).

Psychology has struggled for a century to make sense of the mind

In the last 100 years, psychologists and other social scientists have dug into the muddy "science of us" and developed conflicting theories about human thought and behavior. From the messy, contentious research bloomed insights into what makes humans tick (SN: 8/14/21, p. 18).

Fossils and ancient DNA paint a vibrant picture of human origins

From the Taung Child to Lucy, the last century of paleoanthropology has sketched a rough timeline of how humans came to be. Scientists now agree that human evolution has its roots in Africa, but many mysteries in our history remain to be solved (*SN: 9/25/21, p. 20*).





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Celebrating 50 years of CT scans

One grainy, gray-scale image of a brain changed science and medicine forever. Half a century ago, the first CT image of a patient (right) lifted the veil of invisibility that cloaks the interior of the human body, providing scientists a window on our innards unlike any before.

X-ray computed tomography, or CT, is frequently the quickest way of getting a handle on what's causing a mysterious woe in the body. CT scans can ferret out heart disease, tumors, blood clots, fractures, internal bleeding and more. The technique can give surgeons a heads-up about what they will encounter inside a patient, and guide treatment for cancer and other diseases.

"It answers so many questions quickly. That's why it's used," says medical physicist Cynthia McCollough of the Mayo Clinic in Rochester, Minn.

Over the years, scientists have improved CT scanning technology, making it faster and higher resolution. These improved CT scans have painted ever more detailed landscapes of the human body, including allowing researchers to stitch CT scans together into 3-D reconstructions of body parts including the spine, right foot and abdomen, shown in colorized images above.

And CT scans aren't just for medical professionals. Researchers in fields including archaeology, biology and physics have harnessed CT scans to better understand everything from mummified remains to how cracks form in concrete to animals such as the earless water monitor lizard, shown at top, right. That image comes from the Florida Museum of Natural History in Gainesville, where researchers are making CT scans of all vertebrate genera housed in U.S. natural history collections to reveal the animals' internal anatomy. – *Emily Conover*



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ccording to Bennet, in lieu of becoming a science teacher, donating to Society for Science is one of the best ways to help cultivate scientific thinking in future generations. Through science, we can understand the world and improve lives. That is



why Bennet gives to the Society through his donor advised fund at Vanguard Charitable.

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

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