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COVER Streams like this one in the U.S. West are getting a boost from well-placed stones and beaver dams. *JohnnyGreig/E+/Getty Images*

Living with pandemic uncertainty, Year 2

March 11, 2020, was when the coronavirus made clear it was not going to slink away. On that day, the World Health Organization officially declared the outbreak a global pandemic, married actors Tom Hanks and Rita Wilson announced they were infected and the NBA abruptly suspended the season after a Utah Jazz player tested positive. The United States closed its borders to travelers from Europe. Within two days, most public venues shuttered — even Broadway went dark. Offices and restaurants emptied and schools shut down.

But there was still hope that we would somehow avoid the worst of a pandemic; at that point, fewer than 50 people were known to have died from COVID-19 in the United States. Now, with more than 525,000 U.S. deaths and at least 2.6 million worldwide, we know that was wishful thinking.

We here at *Science News* have been looking back at the questions we were trying to answer during that chaotic, mind-bending week a year ago. How deadly the virus was and how it spread were two big ones. Data from the quarantined *Diamond Princess* cruise ship and from China gave some hints, but we really didn't know.

In that same week, senior writer Tina Hesman Saey reported on a study out of Germany showing that people were most likely to spread the virus before they had symptoms. In hindsight, that study of just nine people at one company told us so much, foreshadowing the virus's rampage. There, one person infected another by sneezing in a meeting; for others, just sitting together in front of a computer was enough.

And we reported on how social distancing would do more to rein in the virus than travel bans ever could. Back then, we were still putting "social distancing" in quotes; it was a strange new term. A year's worth of experience proves that it does effectively slow the spread of the coronavirus — and also that social, economic and political pressures make social distancing a challenge to deploy.

A year ago, a vaccine against SARS-CoV-2 was barely a hope. Now we have three effective vaccines authorized for emergency use in the United States, and more than 2 million people are getting a shot each day. But this astounding success brings many more questions, including whether the vaccines protect against new virus variants and how to interact with those who are not vaccinated.

It also raises questions about how the current approach to vaccine access might hurt in unexpected ways. Wealthy nations are monopolizing doses, buying up far more than they need. That imperils the lives of people in less affluent countries. And as staff writer Jonathan Lambert writes on Page 6, it also increases the odds that dangerous virus variants will arise that can evade vaccines. Because global supply chains are so interconnected, extreme vaccine inequity could cost the global economy more than $9 trillion this year, economists estimate.

And no matter how many vaccine doses we've bought up, no one is immune from that. — *Nancy Shute, Editor in Chief*

Science News
1719 N Street NW, Washington, DC 20036
(202) 785-2255

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Science News (ISSN 0036-8423) is published 22 times per year, bi-weekly except the first week only in May and October and the first and last weeks only in July by the Society for Science & the Public, 1719 N Street, NW, Washington, DC 20036.
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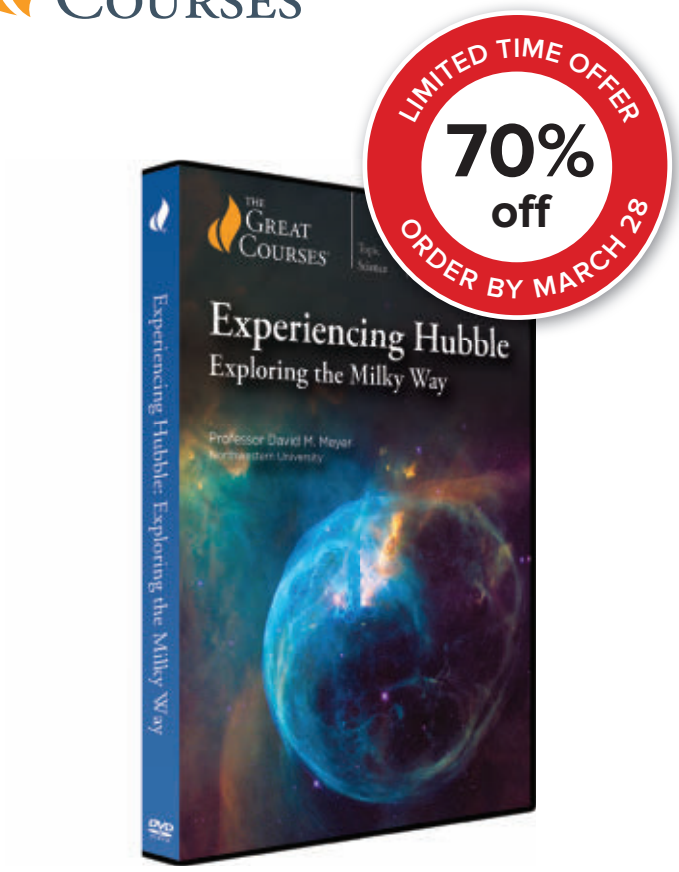

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Excerpt from the March 27, 1971 issue of *Science News*

50 YEARS AGO

Organics on Mars

[Researchers] have exposed a mixture of gases simulating conditions believed to exist on the surface of Mars to ultraviolet radiation. The reaction produced organic compounds. They conclude that the ultraviolet radiation bombarding the surface of Mars could be producing organic matter on that planet.... The fact that such organic compounds may be produced on the Martian surface increases the possibility of life on Mars.

UPDATE: In 1976, a few years after those experiments, NASA took its search for organic molecules to the Red Planet's surface. That year, the Viking landers became the first U.S. mission to land on Mars. Though the landers failed to turn up evidence in the soil, NASA has continued the hunt. In 2018, the Curiosity rover found hints of life: organic molecules in rocks and seasonal shifts in atmospheric methane. A new phase of the hunt began in February when the Perseverance rover landed on Mars (*SN Online: 2/17/21*). It will find and store rocks that might preserve signs of past life for eventual return to Earth.

RETHINK

Scientists debunk a popular birding claim

One rare bird sighting doesn't lead to spotting other rare bird species.

It was a cold, overcast Saturday morning in Salem, Ore., when Jesse Laney set out to catch a glimpse of a painted bunting. He had heard earlier that week through a birding WhatsApp message group that this vibrant, rainbow-colored bird was in the area. Painted buntings (one shown, above) are common in places like Texas and the northern parts of Mexico but are rarities in Oregon. Laney and his sons raced to the site and began searching — but the bird eluded them.

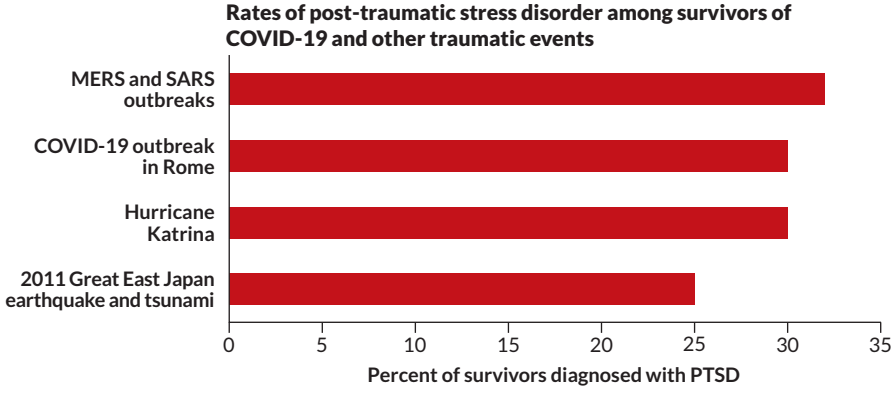
He wasn't too disappointed. Just the chance of seeing a rare bird "scratches the ever-present itch of participating in a small bit of discovery," says Laney, an ecologist at Oregon State University in Corvallis.

That itch inspired research that debunked a popular myth among birders: that a rare bird sighting leads to more

SCIENCE STATS

Some COVID-19 survivors face another foe: PTSD

The sickest of COVID-19 patients struggle to breathe. Facing a disease new to science, they're isolated from loved ones and treated by doctors and nurses in hazmat suits. Nearly a third of people who were very ill with COVID-19 developed post-traumatic stress disorder after their ordeal, a small study suggests. Psychiatrist Delfina Janiri of Agostino Gemelli University Policlinic in Rome and colleagues assessed the mental health of 381 severely ill COVID-19 patients an average of 100 days after symptoms first appeared. About 30 percent, or 115 people, were diagnosed with PTSD, the team reports February 18 in *JAMA Psychiatry*. The rate is similar to that of survivors of the coronavirus infections Middle East respiratory syndrome and severe acute respiratory syndrome, and natural disasters (see graph below). About 30 percent of New Orleans residents who survived Hurricane Katrina in 2005 developed PTSD. — *Laura Sanders*



FROM TOP: ARTHUR MORRIS/CORBIS DOCUMENTARY/GETTY IMAGES; D. JANIRI *ET AL*./*JAMA PSYCHIATRY* 2021

sightings of other rare bird species because birders flock to an area to find the initial bird. This phenomenon is called the Patagonia picnic table effect.

Its origin story dates back to sometime in the 1960s or '70s. Though details are a bit unclear, birders saw a rare black-capped gnatcatcher, or a pair of rose-throated becards, in Patagonia, Ariz., near the border with Mexico. Word got around and birders descended on the town, which led to sightings of other rare birds, including a five-striped sparrow and a yellow grosbeak, according to some accounts.

To determine if such discovery bonanzas are one-off events or a common occurrence, Laney and his colleagues analyzed data from 2008 to 2017 from the online database eBird. Avid birders typically upload their checklists — that is, birds they have spotted on an outing — to the site.

The team identified 273 "megararities," mostly in the continental United States; these are the hardest-to-find birds, either because there are so few of them or because they rarely show up in some geographic locations. The researchers then evaluated rare bird discovery rates in the two weeks before and six weeks after crowds raced to where those ultra-uncommon birds were spotted.

Ecologist Jesse Laney leads students on a birding trip. His team's research suggests that a popular birding phenomenon is a myth.

The rates remained essentially the same, the team reports January 21 in *PeerJ*, at 8 detections per 1,000 checklists. Birders had no better chance of finding a second species of rare bird in an area where there was a recent rare bird sighting than they did during routine birding.

This belief that one success can lead to more isn't limited to the birding community. When an athlete makes one shot after another, that streak is referred to as the hot hand effect (*SN: 2/11/12, p. 9*). We want to believe such patterns exist, says Andreas Wilke, a psychologist at Clarkson University in Potsdam, N.Y. Humans' ability to recognize patterns was an evolutionary advantage when it came to such survival skills as finding food, he says. "It's a very adaptive thing to do, but it can misfire in modern environments when we look at very random distributions of things and start to see patterns that don't exist."
— Anushree Dave

TEASER

A new laser generates random numbers ultrafast

The chaotic fluctuations in a new laser's light can be translated into 254 trillion random digits per second — more than 100 times faster than other laser-powered random number generators, researchers report in the Feb. 26 *Science*.

Physicist Hui Cao of Yale University and colleagues designed a laser with an hourglass-shaped cavity. This irregular shape allows light waves of various frequencies to ricochet through the laser and overlap with each other. When shined on a surface, the light contains a pattern of tiny pinpricks that brighten and dim randomly. A high-speed camera can detect the brightness at each spot in the pattern over time, and a computer can encode that data into many random series of 1s and 0s.

Cao's team measured light intensity at 254 spots about every trillionth of a second, but the camera tracked the light for only a couple of nanoseconds before its memory filled up. To encrypt information in the real world, the device would need light detectors that could send data to computers in real time, says physicist Daniel Gauthier of Ohio State University in Columbus. *— Maria Temming*

THE –EST

An Andean lizard takes the high ground

High in the Peruvian Andes, a lizard has claimed the title of world's highest-altitude reptile. Tentatively identified as a type of tree iguana, *Liolaemus tacnae*, the lizard was spotted as high as 5,400 meters in elevation. That's 100 meters higher than the previous record holder, *Phrynocephalus erythrurus*, a species of toad-headed agama lizard living on the Tibetan Plateau, researchers report February 15 in *Herpetozoa*.

In October 2020, zoologist José Cerdeña and colleagues found the Andean lizard darting between rocks as the team ascended Peru's Chachani volcano, which rises 6,057 meters above sea level. *L. tacnae* is known to survive in high-altitude areas in Peru, and at least one population near Chachani was previously spotted some 4,000 meters above sea level. Climate change could have facilitated *L. tacnae*'s status as a record holder as higher altitudes became warmer, notes Cerdeña, of the National University of Saint Augustine in Arequipa, Peru. "It is possible that this lizard species began to colonize this altitude recently," he says. Cerdeña wants to learn more about the reptile's physiology, which may hold clues to its high-altitude lifestyle. *— Jake Buehler*

A tree iguana (one shown) native to the high Andes of Peru was recently spotted setting a world altitude record for reptiles.

FROM TOP: NOELLE MOEN; AARÓN J. QUIROZ

HUMANS & SOCIETY

Vaccine inequity will prolong pandemic

Uneven distribution costs lives and harms the global economy

A worker in Ghana checks a shipment of 600,000 COVID-19 vaccines on February 24. It was the first such shipment made by COVAX, an initiative to vaccinate the globe more equitably.

FRANCIS KOKOROKO/REUTERS

BY JONATHAN LAMBERT

Months before the first COVID-19 vaccine was even approved, wealthy nations scrambled to secure hundreds of millions of doses in advance for their citizens. By the end of 2020, Canada bought up 266 million doses, enough to inoculate its population four times over. The United Kingdom snagged enough to cover a population three times its size. The United States reserved over 1 billion doses, and by early March, about 16 percent of its roughly 330 million residents had received at least one vaccine dose.

It's a drastically different story for less wealthy nations. As of March 4, more than 80 have yet to administer a single dose. In all of Africa, only 330,000 vaccines have been administered, compared with more than 350 million worldwide.

"The world is on the brink of a catastrophic moral failure, and the price of this failure will be paid with lives and livelihoods in the world's poorest countries," Tedros Adhanom Ghebreyesus, director-general of the World Health Organization, said in a January 18 speech.

COVAX, an international initiative tasked with ensuring more equitable access to COVID-19 vaccines, aims to redress this imbalance by securing shots to send to low-income countries free of charge. Despite pledges of support from some of the wealthiest nations, COVAX is off to a slow start. Its first shipment of 600,000 shots was sent February 24 to Ghana. COVAX still needs at least $2 billion to meet its goal of vaccinating 20 percent of the population of each of 92 lower-income countries by year's end.

Such stark inequities don't just raise moral questions of fairness. With vaccine demand still vastly outstripping supply, lopsided distribution could also ultimately prolong the pandemic, fuel the evolution of new, potentially vaccine-evading variants and drag down the economies of rich and poor — and vaccinated and unvaccinated — nations alike.

"The leaders of rich nations have done a very poor job explaining to their citizens why it's so important that vaccines are distributed worldwide," says Gavin Yamey, a global public health policy expert at Duke University. "No one is safe until all of us are safe, since an outbreak anywhere can become an outbreak everywhere."

Evasive maneuvers

Here's why a new coronavirus outbreak anywhere can become an outbreak everywhere: Viruses mutate.

It's normal and happens by chance as a virus replicates inside a host. Most mutations are harmless, or hurt the virus itself. But every so often, a genetic tweak makes the virus better at infecting hosts or dodging immune responses. The more a virus spreads, the more opportunity that one (or more likely a handful) of these tweaks could birth a more threatening strain.

In December, scientists detected a new variant, dubbed B.1.1.7, in the United Kingdom. It soon became clear that the variant had acquired mutations that made it more infectious. In just a few months, that variant has circled the globe, popping up in more than 90 countries, including the United States.

Another variant first detected in South Africa is also more transmissible and appears to be slightly less affected by existing vaccines. It too has spread worldwide. Variants detected in California and New York are raising concerns as well. As long as widespread viral transmission continues, new variants will emerge.

"It's uncertain at this point whether we're going to have to continually chase this virus and develop more vaccines," says William Moss, executive director of the International Vaccine Access Center at Johns Hopkins Bloomberg School of Public Health. The more the virus replicates, the more opportunity it has to evolve around existing vaccines or natural immune responses to older variants, Moss says. Large pockets of unvaccinated people can serve as incubators for new variants. The longer such pockets persist, the greater the chance of variants accumulating changes that make them resistant to vaccines. Eventually, such variants might invade well-vaccinated countries that thought themselves safe.

Barely vaccinated populations might be especially fertile grounds for vaccine-evading variants, says Abraar Karan, an internal medicine physician at Harvard Medical School. In a vaccinated person, mutations that even slightly evade an induced immune response can get a foothold. Unless that variant completely evades vaccines, which is unlikely, a

well-vaccinated population will blunt its spread. But if most of a region remains unvaccinated, that new variant could burn quickly through the population, fueling its spread to other regions.

"If we want to stop the spread we have to stop it everywhere, starting with the most vulnerable," Karan says. "Otherwise we're going to see continued outbreaks and suffering."

"No economy is an island"

Protecting people from getting sick is a big driver of the rush to vaccinate in wealthy nations, many of which have been hit hard by the virus. Vaccines are also seen as a way out of the largest global economic downturn since World War II, by some reports, roughly a 4.4 percent dip in global gross domestic product. But an inequitable distribution of vaccines could imperil a robust and quick recovery, experts say.

If extended outbreaks, lockdowns, sickness and deaths continue in countries with less access to vaccines, all economies will suffer, says Selva Demiralp, an economist at Koç University in Istanbul. "No economy is an island," she says, "and no economy will be fully recovered unless others are recovered too."

Extreme vaccine inequity could cost the global economy more than $9 trillion in 2021, up to about half of which would come from rich nations, Demiralp and colleagues reported January 25 in a study released by the National Bureau of Economic Research that has not yet gone through peer review. In that scenario, wealthy nations largely vaccinate their populations by midyear, but leave poorer nations out completely.

Everybody takes a hit thanks to the interconnectedness of the global economy. Disruptions to one link of a supply chain ripple throughout, and diminished demand for goods in countries saddled with coronavirus restrictions will affect the bottom line of companies headquartered in wealthy nations. "As infections rise in a country, both supply and demand can decrease," Demiralp says.

Her team estimated virus-induced fluctuations in supply and demand by combining a statistical model of how coronavirus spreads with economic data across 35 sectors in 65 countries. By tweaking the pace and extent of vaccination, the team estimated total costs to each country under different scenarios. The $9 trillion number represents extreme inequity. But less extreme gaps in vaccination rates are still expensive.

If rich countries vaccinate their entire populations in four months, while the lowest-income countries vaccinate half their populations by the end of 2021, global GDP this year will fall by between $1.8 trillion and $3.8 trillion, with rich countries losing up to half of that, the team calculated.

Those costs could be averted with a much smaller investment, on the order of tens to hundreds of billions of dollars, in distributing vaccines globally. "It's a no-brainer," Demiralp says. "It's not an act of charity. It's economic rationality."

Evening the playing field

COVAX is trying to even the vaccine playing field, but with limited success so far. There are a lot of hurdles, from securing scarce doses to ensuring that countries have the infrastructure to handle them. That could mean equipping some countries with more ultracold refrigerators to store certain vaccines or revamping mass vaccination programs.

COVAX uses funds from governments and charitable organizations to buy doses from pharmaceutical companies and distribute them to lower-income countries for free. The initiative intends to distribute over 330 million doses in the first half of the year, enough to vaccinate, on average, 3.3 percent of each population of 92 relatively low-income countries. Meanwhile, by June, many rich nations will be well on the way to vaccinating most of their populations.

COVAX says it's negotiated 2.27 billion doses so far, enough to vaccinate at least 20 percent of each participating country's population by year's end. But meeting that goal requires raising $8 billion. On February 19, several countries pledged further support to COVAX, including $2 billion from the United States. Still, COVAX is billions short.

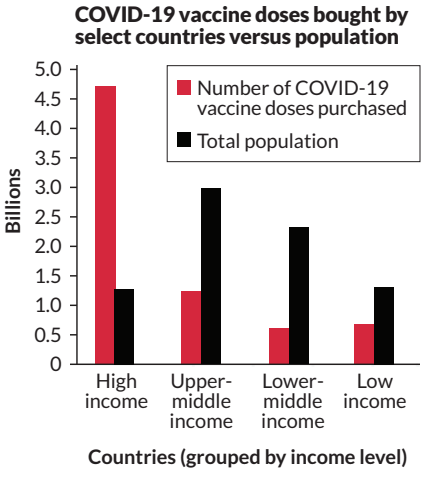
"Money is not the only challenge we face," WHO's Tedros said in a February 22 news briefing. Deals between wealthy nations and pharmaceutical companies threaten to gobble up global vaccine supply. "If there are no vaccines to buy, money is irrelevant," he said.

Vaccinating people in any country is something to celebrate, says Yamey, of Duke University, "but it should disturb us to know that low-risk people are going to get vaccinated in rich countries well ahead of high-risk people in poor countries." A more equitable rollout would prioritize health care workers and vulnerable people in all countries, he says. "I don't see that happening in any scenario."

Even if COVAX achieves its goal this year, the 92 countries will be far from reaching herd immunity, the threshold at which enough people are immune to a pathogen to slow its spread. Estimates to reach herd immunity range from 60 to 90 percent of a population.

"Many low-income nations won't have widespread vaccination until 2023 or 2024, because they can't get the doses," Yamey says. "This inequity is due to hoarding of doses by rich nations, and that me-first, me-only approach ultimately goes against their long-term interests." ■

Unequal distribution High-income countries have purchased many more vaccine doses than lower-income countries, despite having fewer people overall, according to an analysis of select countries. SOURCES: DUKE GLOBAL HEALTH INNOVATION CENTER, WORLD BANK



E. OTWELL

MATH & TECHNOLOGY

A new robot holds up under pressure

The snailfish-inspired bot flapped its fins in the Mariana Trench

BY CAROLYN GRAMLING

Inspired by a strange fish that can withstand the punishing pressures of the deep ocean, scientists have devised a soft, self-powered robot capable of keeping its fins flapping in the deepest part of the Mariana Trench.

Researchers led by roboticist Guorui Li of Zhejiang University in Hangzhou, China, field-tested the robot's ability to function at depths ranging from 70 meters to nearly 11,000 meters, the team reports in the March 4 *Nature*.

Challenger Deep is the deepest part of the Mariana Trench in the Pacific Ocean, bottoming out at about 11,000 meters below sea level. The pressure from all that overlying water is about 1,000 times the atmospheric pressure at sea level, or about 103 million pascals. "It's about the equivalent of an elephant standing on top of your thumb," says deep-sea physiologist and ecologist Mackenzie Gerringer of State University of New York at Geneseo, who was not involved in the new study.

The tremendous pressures in the deepest ocean zone, between 6,000 and 11,000 meters, present a tough engineering challenge, Gerringer says. Traditional deep-sea robots and crewed submersibles are heavily reinforced with rigid metal frames so as not to crumple. But these vessels are bulky, and the risk of structural failure remains high.

To design robots that can maneuver gracefully through shallower waters, scientists have previously looked to soft-bodied ocean creatures, such as the octopus, for inspiration (*SN: 11/1/14, p. 11*). As it happens, such a deep-sea muse also exists: the Mariana hadal snailfish (*Pseudoliparis swirei*), a mostly squishy, translucent fish that lives as deep as 8,000 meters in the Mariana Trench.

Gerringer, one of the researchers who first discovered the deep-sea snailfish in 2014, constructed a 3-D printed soft robot version of it to better understand how the snailfish swims. Her robot contained a synthesized version of the watery goo inside the fish's body that most likely adds buoyancy and allows for more efficient swimming (*SN: 2/3/18, p. 4*).

But devising a robot that can swim under extreme pressure to explore the deep-sea environment is another matter. Autonomous robots require electronics to power movement and perform tasks such as testing water chemistry, filming the denizens of deep ocean trenches and collecting samples to bring to the surface. Under intense pressure, these electronics can grind against one another.

So Li and his colleagues decided to borrow one of the snailfish's adaptations to high-pressure life: Its skull is not completely fused together with hardened bone. That extra malleability allows the pressure on the skull to equalize. In a similar vein, the scientists decided to distribute the robot fish's electronics, or "brain," far apart and encase them in soft silicone to keep them from touching.

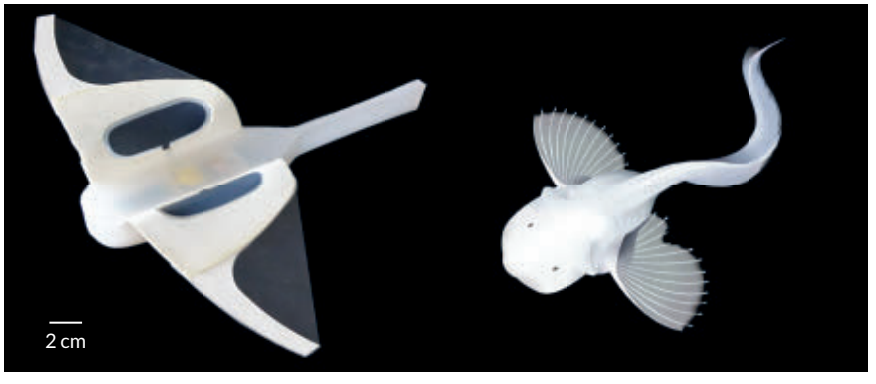
The team also designed a soft body that slightly resembles the snailfish, with two fins that the robot can use to propel itself through water. The robot's fins flap thanks to battery-powered artificial muscles: electrodes sandwiched between two membranes that deform in response to electrical charge.

The team tested the robot in several environments: 70 meters deep in a lake, about 3,200 meters deep in the South China Sea and then at the bottom of the ocean. The robot was allowed to swim freely in the first two trials. For the Challenger Deep trial, however, the researchers used the extendable arm of a deep-sea lander to keep a tight grip on the robot while it flapped its fins.

This machine "pushes the boundaries of what can be achieved" with biologically inspired soft robots, roboticists Cecilia Laschi of the National University of Singapore and Marcello Calisti of the University of Lincoln in England write in a commentary in the same issue of *Nature*. But the machine is still a long way from regular use. It swims more slowly than other underwater robots and can't yet withstand powerful underwater currents. Still, it "lays the foundations" for future robots to help answer questions about these mysterious reaches of the ocean, Laschi and Calisti write.

Deep-sea trenches are teeming with microbial life, which happily feed on organic material that sinks to the ocean bottom. That microbial activity hints that the trenches may play a significant role in Earth's carbon cycle, which is linked to the planet's regulation of its climate.

The discovery of microplastics in Challenger Deep is proof that the ocean bottom isn't that far away, Gerringer says. "We're impacting these deep-water systems before we've even found out what's down there. We have a responsibility to help connect these seemingly otherworldly systems, which are really part of our planet." ■



To withstand high pressure in the deep ocean, a new soft robot (left) takes a cue from a resident snailfish (illustrated, right). Similar to the snailfish's soft skull, which lets external and internal pressures equalize, the robot's electronics are spread apart and encased in silicone to prevent damage.

G. LI *ET AL*/*NATURE* 2021

Watch a video of the robot in action at **bit.ly/SN_SnailfishBot**

ATOM & COSMOS

Crash will follow 'Milkomeda' debut

Andromeda's and the Milky Way's black holes will collide

BY SID PERKINS

The supermassive black holes at the centers of the Milky Way and Andromeda galaxies are doomed to engulf each other in an ill-fated cosmological dance.

Astronomers have long known that Andromeda is on a collision course with our galaxy (*SN: 7/14/12, p. 10*). And now new simulations suggest the ultimate fate of the gargantuan black holes each galaxy harbors at its core.

The galaxies will coalesce into one giant elliptical galaxy — dubbed "Milkomeda" — in about 10 billion years. Then, the central black holes will begin orbiting one another and finally collide less than 17 million years later, researchers propose online February 22 at arXiv.org and in a study published in October in *Astronomy & Astrophysics*. Just before the black holes smash into each other, they'll radiate gravitational waves with the power of 10 quintillion suns. Any civilization within about 3.25 million light-years of Earth that has gravitational wave–sensing technology on par with our current abilities would be able to detect the collision, the researchers estimate.

The latest data suggest Andromeda is approaching the Milky Way at about 116 kilometers per second, says Riccardo Schiavi, an astrophysicist at the Sapienza University of Rome. Using computer simulations that include the gravitational pull of the two spiral galaxies on each other as well as the possible presence of sparse gas and other material between them, Schiavi and his colleagues played out how the galactic collision will unfold.

Previous simulations have suggested that Andromeda and the Milky Way are scheduled for a head-on collision in about 4 billion to 5 billion years. But the new study estimates that the two star groups will swoop closely past each other about 4.3 billion years from now and then fully merge about 6 billion years later.

The Milky Way galaxy and Andromeda (shown) may merge to form the Milkomeda galaxy in about 10 billion years.

The team's estimate for Milkomeda's merger date is farther into the future than what other teams have found, says Roeland van der Marel, an astronomer at the Space Telescope Science Institute in Baltimore who was not involved in the research. However, he notes, that could be due in part to uncertainty in the measurement of Andromeda's speed across the sky. ■

GENES & CELLS

How catnip repels pesky mosquitoes

The plant triggers a cellular receptor that senses irritants

BY ERIN GARCIA DE JESUS

A whiff of catnip can make mosquitoes buzz off, and now researchers know why.

The active component of catnip (*Nepeta cataria*) repels insects by triggering a chemical receptor that can spur sensations such as pain or itch, researchers report online March 4 in *Current Biology*. The sensor, TRPA1, is common in animals — from flatworms to people — and responds to irritants such as cold, heat, wasabi and tear gas. When irritants come into contact with TRPA1, the reaction can make a person cough or an insect flee.

Catnip's repellent effect on insects, and its euphoric effect on felines, has been documented for millennia. Catnip may be as effective at shooing away insects as the widely used synthetic repellent known as DEET, studies have shown. But it was unknown how the plant repelled insects.

Researchers exposed mosquitoes and fruit flies to catnip. Fruit flies were less likely to lay eggs on the side of a petri dish that was treated with catnip or its active component, nepetalactone. Mosquitoes were also less likely to try to take blood from a human hand coated with catnip. Insects that had been genetically modified to lack TRPA1, however, had no aversion to the plant. That behavior — coupled with experiments in lab-grown fruit fly cells that show catnip activates TRPA1 — suggests that insect TRPA1 senses catnip as an irritant.

Puzzling out how the plant deters insects could help scientists design potent repellents that may be easier to obtain in countries hit hard by mosquito-borne diseases. "Oil extracted from the plant or the plant itself could be a great starting point," says study coauthor Marco Gallio, a neuroscientist at Northwestern University in Evanston, Ill. That the plant's bug-off nature doesn't affect people is a good sign, he says. Human TRPA1 in lab-grown cells didn't respond to catnip.

If a plant can make a chemical that activates TRPA1 in a variety of animals, none are going to eat it, says neuroscientist Paul Garrity of Brandeis University in Waltham, Mass., who was not involved in the work. Catnip probably didn't evolve in response to predation from ancient mosquitoes or fruit flies, he says, since the plant isn't on the insects' menu. Instead, they might be collateral damage in catnip's fight with some plant-nibbling pest.

The finding "does make you wonder what the target is in cats," says neuroscientist Craig Montell of the University of California, Santa Barbara. The question is not only whether catnip targets TRPA1 in cats but also whether the plant sends signals through different cells — such as those for pleasure — in the feline nervous system, he says. ■

HUMANS & SOCIETY

Fiery burial signaled new view of death

Cremations in built structures may have hunter-gatherer roots

BY BRUCE BOWER

Middle Eastern hunter-gatherers changed their relationship with the dead nearly 20,000 years ago. Clues to that spiritual shift come from the discovery of an ancient woman's fiery burial in a hut at a seasonal campsite.

In and around the Middle East, burials of people in houses or other structures, as well as cremations, are thought to have originated in farming villages during the Neolithic Period, no earlier than about 10,000 years ago. But those treatments of the dead appear to have had roots in hunter-gatherer practices, says a team led by archaeologists Lisa Maher of the University of California, Berkeley and Danielle Macdonald of the University of Tulsa in Oklahoma.

The new find suggests that people started to associate the dead with particular structures at a time when groups of hunter-gatherers were camping for part of each year at a hunting and trading site in eastern Jordan. A budding desire to link the dead with human-built structures possibly reflected a belief that by doing so the dead would remain close to the living, the team reports in the March *Journal of Anthropological Archaeology*.

Excavations at the ancient site, called Kharaneh IV, in 2016 revealed a woman's partial, charred skeleton on the floor of a hut that had been lit on fire. Her body had been placed on its side with knees flexed. Analyses of charring patterns on her bones and nearby sediment suggest the body was placed in the hut just before the brushwood structure was intentionally burned. Charcoal- and ash-rich sediment borders where the hut stood, a sign that the fire was confined to the structure.

Radiocarbon-dated samples from the earthen floor near the woman's remains place her interment at about 19,200 years ago.

Several Neolithic sites have examples of the dead having been placed in or under burned houses, or having been intentionally burned after death, says archaeologist Peter Akkermans of Leiden University in the Netherlands. "The work at Kharaneh IV now dates these practices to more than 10,000 years earlier, in wholly different cultural settings of hunter-gatherer communities versus Neolithic farming villages."

In Jordan, archaeologists discovered the nearly 20,000-year-old charred remains of a woman whose dead body had been placed inside a hut that was then set on fire.

L. MAHER, D. MACDONALD, EFAP ARCHIVE

Other social developments traditionally attributed to Neolithic farmers, including year-round settlements and pottery making, first appeared among hunter-gatherers (*SN: 9/25/10, p. 14*; *SN: 7/28/12, p. 15*).

The new discovery "links the death of a person and the destruction or death of a building as part of a funerary rite," Maher says. Perhaps the hut was where the woman or her family lived, or perhaps she died there and the structure was deemed off-limits, Maher suggests. Either way, Kharaneh IV was occupied long after the woman's death, until about 18,600 years ago, so establishing a permanent place for her may have been considered important.

Meanings and beliefs that people attributed to burning a hut in which a dead woman's body had been placed are a mystery, Maher says. The use of fire might have signified some type of transformation, rebirth, cleansing or life-and-death cycle, she suggests. ■

GENES & CELLS

Human reference genome turns 20

Scientists still need to fill gaps and catalog more diversity

BY TINA HESMAN SAEY

As the master blueprint for building humans celebrates its 20th anniversary this year, researchers are both lauding the landmark achievement and looking for ways to bolster its shortcomings.

The Human Genome Project — which built the blueprint, called the human reference genome — has changed the way medical research is conducted, says Ting Wang, a geneticist at Washington University School of Medicine in St. Louis.

For instance, drugs were once developed through trial and error, but having the master blueprint has resulted in numerous therapies aimed at specific genes or proteins. The reference genome has also made it possible to untangle complex networks involved in regulating gene activity (*SN: 10/6/12, p. 11*) and to learn more about how chemical modifications to DNA tweak that activity (*SN: 3/21/15, p. 6*). Researchers lay out those and other accomplishments in the Feb. 11 *Nature*.

"That said, the human reference genome we use has certain limitations," Wang says.

For one thing, the reference genome, a compilation of more than 60 people's DNA, doesn't encapsulate the full range of human genetic diversity (*SN: 3/13/21, p. 24*). One way to rectify that is to decipher, or sequence, the genomes of 3 million Africans, medical geneticist Ambroise Wonkam of the University of Cape Town in South Africa proposes in a commentary also in the Feb. 11 *Nature*. Africa is where humans originated, and study after study has identified thousands to millions of new genetic variants among people of African descent.

Another problem is that the reference genome isn't really finished: Gaps remain in the more than 3-billion-DNA-letter-long template. Scientists made the

reference genome by fitting together small strings of DNA like thousands of tiny jigsaw puzzle pieces. But in some parts of the genome, the sequence of DNA letters, or bases, repeats over and over, producing identical puzzle pieces. It's hard to know exactly where all those pieces go and how many repetitions there are, so some repetitive pieces were left out.

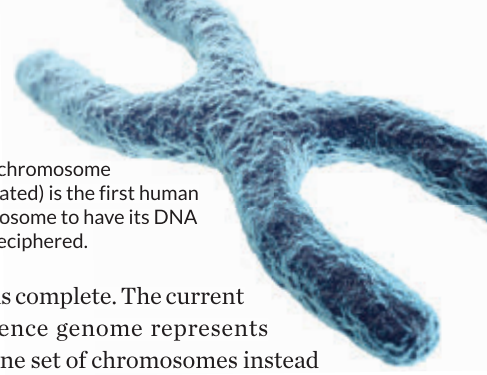
That can create problems, Wang says. For instance, doctors may sequence a patient's DNA and find a variant that might be causing a health problem. But if the suspect DNA isn't in the reference genome, there's no way to know whether the variant is harmful or not.

Wang and other scientists with the Human Pangenome Reference Consortium plan to use new DNA-deciphering technology, called long-read sequencing, to read each chromosome end to end.

Already, in July 2020, researchers reported in *Nature* the first fully complete sequence of a human chromosome, the X chromosome. That effort closed 29 gaps, including 3.1 million bases in the centromere, a region important for separating chromosomes during cell division. Learning more about centromeres may reveal why chromosome division sometimes goes wrong, leading to cancer or conditions such as Down syndrome.

That success suggests that long-read sequencing can indeed fill in the reference genome's gaps. The pangenome team hopes to assemble complete genomes for 350 people from around the world.

And when he says complete, Wang means complete. The current reference genome represents just one set of chromosomes instead of the two sets people inherit, one from each parent. With older sequencing technology, with a person's DNA cut into tiny pieces for reassembly later, there was no way to distinguish which piece came from the chromosome inherited from mom versus dad, so it was all mushed into one.



The X chromosome (illustrated) is the first human chromosome to have its DNA fully deciphered.

Sequencing each chromosome in its entirety will make it clear exactly what came from each parent. Those full pictures may allow researchers to better follow patterns of inheritance and track down genetic sources of diseases. ■

HUMANS & SOCIETY

Ardi may have had hands for swinging

Hominids evolved from a chimplike ancestor, a new study claims

BY BRUCE BOWER

One of the earliest known hominids, a 4.4-million-year-old partial skeleton of a female dubbed Ardi, had hands suited for adeptly climbing trees and swinging from branches, an investigation suggests.

These results, based on statistical comparisons of hand bones from fossil hominids and present-day primates, stoke an ongoing debate not only about how Ardi moved (*SN: 3/16/19, p. 6*), but also what the last common ancestor of humans and chimps looked like.

"The last common ancestor of humans and chimpanzees was more similar to chimps than to any other living primate," says paleoanthropologist Thomas Prang of Texas A&M University in College Station. That ancestor, who lived roughly 7 million years ago, had hands much like those of tree-adept, knuckle-walking chimps, he and colleagues say. That hand design was retained by early hominids such as Ardi's East African species, *Ardipithecus ramidus*, the team reports February 24 in *Science Advances*.

Hand fossils showing a more human-like design and grip first appeared in a later hominid, *Australopithecus afarensis*, Prang's group reports. That fossil species, best known for Lucy's partial skeleton, inhabited East Africa from around 3.9 million to 3 million years ago.

Prang's team analyzed the sizes and dimensions of four fossils from Ardi's hands and then compared those measurements with comparable ones from other fossil hominids and living primates.

Using the same statistical approach, Prang has previously argued that *Ar. ramidus* had a foot that most closely resembled those of present-day chimps and gorillas. If so, then Ardi and her compatriots, who were close in size to chimps, most likely split their time between walking on all fours and moving through trees, he argued in *eLife* in 2019.

In contrast to Prang's conclusions, the paleoanthropologists who discovered and studied Ardi's remains contend that *Ar. ramidus* was built neither like chimps nor humans (*SN: 9/19/15, p. 22*).

Ardi's finger bones look like those of chimps in some ways, says Morgan Chaney of Kent State University in Ohio. Chaney works with Owen Lovejoy, one of the scientists who originally studied Ardi's remains. But the hominid's palm and forearm were much shorter than those of chimps, Chaney says. Combined with distinctive wrists, Ardi's arms would have allowed only for grasping branches while moving slowly in trees.

Ardi's forearm structure was not that of a knuckle-walker, Chaney contends.

Prang's earlier analysis of Ardi's feet also falls short of demonstrating a chimplike design, Chaney and colleagues argue online January 10 in the *Journal of Human Evolution*. Ardi's relatively long midfoot, which was ill-suited to climbing, was not accounted for in Prang's statistical analysis, the scientists say. Similarities in body mass between Ardi and chimps, rather than a close evolutionary relationship, at least partly explain the chimplike foot measurements that Prang cites.

Based on her overall body design, Ardi walked upright, Chaney and colleagues argue. She combined a long lower pelvis that stabilized a straight-legged stance with an apelike, opposable big toe. Ardi climbed trees cautiously and rarely hung or swung from branches, those researchers hold. ■

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HUMANS & SOCIETY

Dog fossil may be oldest in America

A roughly 10,000-year-old bone fuels debate on humans' arrival

BY ANUSHREE DAVE

An ancient bone from a dog, discovered in a cave in southeast Alaska, hints at when and how humans entered the Americas toward the end of the Ice Age.

Radiocarbon dating indicates the bone, a femur fragment smaller than a dime, comes from a dog that lived about 10,150 years ago. That makes this dog fossil one of the oldest, or possibly the oldest, found in the Americas, evolutionary biologist Charlotte Lindqvist and colleagues report in the Feb. 24 *Proceedings of the Royal Society B*.

Lindqvist's team compared DNA from the bone, roughly the same age as three ancient dogs known from the Midwest (*SN: 4/28/18 & 5/12/18, p. 22*), with that from wolves, ancient dogs and modern dog breeds. The dog likely belonged to a lineage of canines that split from Siberian dogs around 16,700 years ago. The timing of that split suggests that the dog's ancestors, probably following along with humans, had left Asia by around that time.

"Dogs' movement and domestication is ... closely associated with humans," says Lindqvist, of the University at Buffalo in New York. "If you're following dogs' movement, it can tell you something about humans as well."

This finding is a big deal, says Angela Perri, an archaeologist at Durham University in England who was not involved in the study. Perri's recent genetic research suggests that domesticated dogs accompanied the first humans into the Americas, via a land bridge in Alaska, around 15,000 years ago. The new work suggests that "at least around 16,700 years ago, humans and dogs seemed to be moving into the Americas," she says. "And that would be almost 2,000 years earlier than we thought." There is currently no direct evidence of human remains in North America at that time.

ALEX MAISEY

Male superb lyrebirds (one shown) can not only copy the songs of individual birds, but also those of entire multispecies groups, new research suggests.

LIFE & EVOLUTION

One lyrebird can mimic entire flocks

Males have vocal talents previously unseen in birds

BY JAKE BUEHLER

You might be able to do a mean celebrity impression or two, but can you imitate an entire film's cast at the same time? A male superb lyrebird can — well, almost. During courtship and even while mating, the birds pull off a similar feat, mimicking the calls and wingbeat noises of several bird species at once, a new study shows.

The lyrebirds appear to be attempting to re-create the specific ecological soundscape associated with the arrival of a predator, scientists report online February 25 in *Current Biology*. Why lyrebirds do this isn't yet clear, but the finding is the first time that an individual bird has been observed mimicking the sounds of multiple bird species simultaneously.

The uncanny acoustic imitation of multispecies flocks adds a layer of complexity to the male lyrebird's courtship song and raises questions about why its remarkable vocal mimicry skills, which include sounds like chainsaws and camera shutters, evolved.

Native to forests of southeastern Australia and Tasmania, superb lyrebirds (*Menura novaehollandiae*) have a flair for theatrics. The males have exceptionally long, showy tail feathers that are shaken extensively in elaborate mating dances. The musical accompaniment to the dance is predominantly a medley of greatest hits of the songs of other bird species.

"When you hear lyrebirds, you hear this very loud, very lyrical, dramatic delivery of mimicry of lots of different species of Australian birds," says behavioral ecologist Anastasia Dalziell of the University of Wollongong in Australia. Kookaburra and parrot calls are common targets for imitation. "But when I started to record [lyrebirds] in detail and for very long periods of time, I realized that every now and then they did something completely different," Dalziell says.

The lyrebirds would transition into a shorter, quieter song made of fluttering noises and scattered chirping. Dalziell thought it sounded like mixed-species mobbing flocks — loud, aggressive contingents of prey birds that attempt

Listen to a lyrebird's uncanny call at **bit.ly/SN_Lyrebird**

The new finding also adds to an ongoing debate about what route humans took after arriving in North America. One long-held idea is that these first inhabitants traveled inland through an ice-free corridor. But around 16,700 years ago, that corridor would have been covered in ice. Thus, the existence of this ancient dog supports an alternative idea — that humans hugged the Pacific coast as they moved south.

Kelsey Witt, a geneticist at Brown University in Providence, R.I., looks forward to additional discoveries of early American dogs. By finding more ancient fossils and studying more DNA, Witt says, "I think we'll get a better picture of exactly how people migrated and exactly when dogs came through." ■

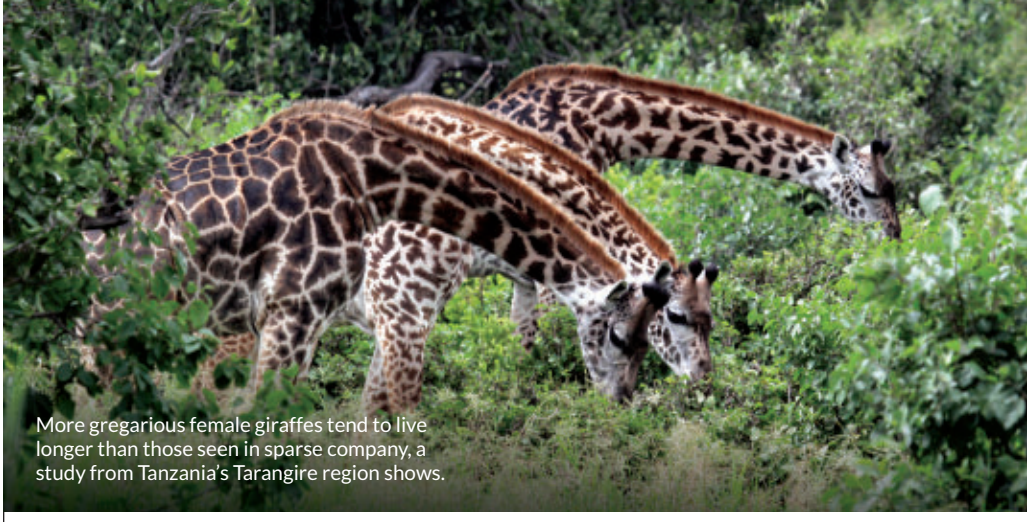
to drive away predators.

When Dalziell and her colleagues compared the acoustic signatures of the lyrebirds' strange songs with those of actual mobbing flocks, the similarities were striking. It was an accurate enough impression to fool other birds too. When the team played back the lyrebirds' fake flock noises in the wild, songbirds were attracted to the speakers to a similar degree as when the speakers played audio from a real mobbing flock. But the songbirds largely ignored the speakers when they played the lyrebirds' typical mimicked melodies.

While lyrebirds could be mimicking a mobbing flock, they might not be doing so to mimic the mobbing intention itself, says Dominique Potvin, a behavioral ecologist at the University of the Sunshine Coast in Queensland, Australia, who was not involved with the research. The calls could just be a difficult vocal feat meant to impress a mate.

Dalziell suspects the flock mimicry may be about deceiving a female into believing a predator is nearby. Such a tactic might enhance the chance of a successful mating by keeping the female close, she says. Determining if females react to the simulated mobbing flock similarly to the real version might be one way to test the deception idea. ■

DEREK LEE



More gregarious female giraffes tend to live longer than those seen in sparse company, a study from Tanzania's Tarangire region shows.

LIFE & EVOLUTION

Friends help female giraffes live longer

Being more social might mean added support and less stress

BY SUSAN MILIUS

Grown-up giraffes just aren't huggy, cuddling, demonstrative animals. So it took identity-checking software and five years of grinding data to reveal that female social life matters to survival.

The more gregarious adult female giraffes in northern Tanzania's Tarangire ecosystem tend to live longer, concludes wildlife biologist Monica Bond of the University of Zurich. Females that typically hung around at least three others of their kind were more likely to outlive those with fewer routine companions, Bond and colleagues report in the Feb. 10 *Proceedings of the Royal Society B*.

The idea that giraffes even have social lives isn't much more than a decade old, Bond says. Adult males spend most of their time in solitary searches for females willing to mate. Adult females often hang around in groups, mostly browsing shrubbery in the same vicinity. The groups may fray apart and reconfigure with different members in the fission-fusion pattern seen in many animals, such as dolphins. Yet closer looks have found that females, in their low-drama way, prefer certain neighbors and seem to avoid others.

Bond encountered giraffes in the wild in 2005 on her first trip to Africa. "I loved everything," she says, but especially giraffes looking "as fanciful and weird as a unicorn." She and colleagues have now recorded sightings for nearly 3,000 individuals in the Tarangire region. Each giraffe's spots are unique and remain identifiable throughout life, so photos of the animals' torsos make identification possible (*SN: 10/27/18, p. 13*).

Bond's team looked at how the kinds of plants eaten, soil types, closeness to humans and other factors affected females' chances of surviving from one season to the next. The most important predictor of survival for 512 adult female wild giraffes was the number of other females typically found around them.

Bond doesn't think it's just that loners or straggly groups get more easily picked off by predators. In the Tarangire region, lions don't hunt in the big prides that can readily overwhelm adult prey, and "a giraffe can kick a lion to death," she says.

Instead, gregarious females might suffer less stress, Bond speculates. Lions in the area stalk giraffe calves, for instance. In a bigger group, calves can cluster near each other in crèches that a few females watch over, letting the other moms get a break. And Bond wonders if bigger groups of giraffes also mean that some animals stay watchful at night as others rest.

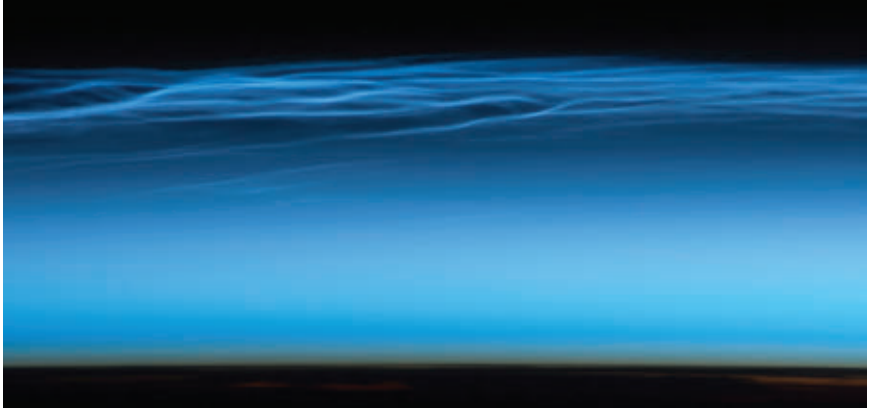
Since this analysis comes from just the Tarangire region, "it would be great for the methods to be replicated in other ecosystems to see how it holds up," says Arthur Muneza, the East Africa coordinator for the Giraffe Conservation Foundation who is based in Nairobi, Kenya. A place where giraffes need to travel farther to find water or other vital resources, for instance, might make a difference in the results. ■

EARTH & ENVIRONMENT

Why NASA made a noctilucent cloud

A rocket showed how the icy hazes form high in the sky

BY MARIA TEMMING



Noctilucent clouds (seen from the International Space Station in 2012) shimmer high in the dark sky, when sunlight from beyond the horizon illuminates ice crystals in the upper atmosphere.

NASA's Super Soaker mission was an extreme DIY project: To better understand how noctilucent, or night-shining, clouds form, researchers made one.

One predawn morning in January 2018, researchers in Alaska launched a rocket hauling a bathtub's worth of water. When the rocket was 85 kilometers off the ground, its water cargo exploded, spraying the mesosphere with vapor that froze into a cloud of ice crystals. When such high-flying hazes of ice are illuminated by sunlight from beyond the horizon before sunrise or after sunset, they are seen in the dark sky as shimmery noctilucent clouds.

In the experiment, reflections from a ground-based laser aimed at the rocket detected the ice crystals 18 seconds after the explosion. Computer simulations suggest that the only way the cloud could have formed so fast is if the vapor plume was about 25 degrees Celsius cooler than the surrounding air, researchers report in the February *Journal of Geophysical Research: Space Physics*.

The rapid cooldown, from a starting temperature of about −45° C, suggests the water vapor released by the rocket not only provided the water to make ice crystals, but also actively cooled the air to trigger cloud formation.

Water vapor can cool the atmosphere because water is good at emitting infrared radiation, and gas high in the atmosphere is sparse enough that this heat escapes easily into space, says study coauthor Richard Collins, an atmospheric scientist the University of Alaska Fairbanks.

Xinzhao Chu, a physicist at the University of Colorado Boulder, says noctilucent clouds have become brighter and more frequent in the last few decades. But it's not clear how much of that is due to climate change, which is expected to make the mesosphere colder and wetter, versus more rocket launches pumping water vapor into the air, she says. Better understanding rocket-generated clouds could help isolate climate change's impact. ■

NEWS IN BRIEF

MATTER & ENERGY

A magnetic trap captures plasma

In terms of difficulty, trapping a plasma is right up there with catching a cloud. But physicists have devised a way to magnetically bottle an ultracold plasma in the lab.

Trapping frigid plasmas, in which particles move around sluggishly, could allow for the study of plasma behavior in slow motion, the researchers report in the Feb. 26 *Physical Review Letters*. That may reveal details about how plasmas behave in hotter, more frenetic environments, like inside fusion reactors or stars.

Researchers at Rice University in Houston boiled strontium metal and channeled the resulting vapor down a tube. There, light from a laser beam slowed the atoms almost to a standstill — cooling them to three-thousandths of a degree above absolute zero (−273° Celsius). Using a second laser, the team knocked an electron off each atom, creating a plasma of negatively charged electrons and positive strontium ions.

This ionized gas couldn't be stashed inside an ordinary container. So the team created the plasma between two coils of electric current, which formed opposing magnetic fields. These equal and opposite magnetic forces on the charged particles held the plasma together for up to 500 microseconds. — *Maria Temming*

ATOM & COSMOS

Protons' antimatter is out of whack

An imbalance between two types of antiparticles that seethe within the proton is remarkably persistent, a new measurement indicates.

Protons are built from three quarks — two "up" quarks and one "down" quark. But they also contain a sea of transient quarks and antiquarks that fluctuate into existence before annihilating one another. Within that sea, down antiquarks outnumber up antiquarks. That lopsidedness persists in a realm of quark momenta previously unexplored, researchers from the SeaQuest experiment at Fermilab in Batavia, Ill., report in the Feb. 25 *Nature*.

Typically, each antiquark carries only a tiny slice of a proton's total momentum. But sometimes a single antiquark can make up a large fraction of the momentum. New tests, made by slamming protons into targets made of hydrogen and deuterium (hydrogen with an extra neutron in its nucleus), found that down antiquarks were about 50 percent more prevalent than up antiquarks — even when a single antiquark carried nearly half the proton's total momentum.

The measurements are important for studies at the Large Hadron Collider at CERN in Geneva, which slams protons together to look for new phenomena. To fully understand the collisions, physicists need a thorough accounting of the proton's constituents, says study coauthor Paul Reimer of Argonne National Laboratory in Lemont, Ill. — *Emily Conover*

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Migraine Pain Relief

A new group of drugs is helping some patients, but how is still unclear

By Karen J. Bannan

Hayley Gudgin of Sammamish, Wash., got her first migraine in 1991 when she was a 19-year-old nursing student.

"I was convinced I was having a brain hemorrhage," she says. "There was no way anything could be that painful and not be really serious."

She retreated to her bed and woke up feeling better the next day. But it wasn't long until another migraine hit. And another. Taking a pill that combines caffeine with the pain relievers acetaminophen and codeine made life manageable until she got pregnant and had to stop taking her medication. After her son was born, the migraines came back. She started taking the drugs again, but they didn't work and actually made her attacks worse.

By the time Gudgin gave birth to her second son in 1997, she was having about 15 attacks a month. Her symptoms worsened over time and included severe pain, nausea, sensitivity to light, swollen hands, difficulty speaking, vomiting and diarrhea so intense she often wound up dehydrated in the emergency room.

"It hit me [that] I had to do something when I was vomiting in the toilet, and my 3-year-old came and pulled my hair back," she says. "It was no way to live — and not just because of the pain. You go to sleep every night not knowing how you're going to wake up. You make plans knowing you might have to cancel them."

A headache specialist prescribed several preventive medicines, but each caused side effects for Gudgin, including weight gain and kidney stones. Then, in 2018, Gudgin read about a new type of treatment for frequent migraine sufferers. Her neurologist agreed it was worth a try. After much wrangling with her insurance company — the drug is costly, and she had to prove that two other drugs had failed to help her — she got approval to take it.

In August 2018, Gudgin received her first monthly injection of erenumab, sold as Aimovig. By the end of September, she was down to one or two attacks a month. "And the migraines I do get are usually gone within six hours. I don't have to go to the ER or lie in a dark room all day," she says. "It's just been life changing."

Gudgin injects the drug into her leg once a month using a device similar to an EpiPen. Erenumab is one of four monoclonal antibodies, manufactured proteins that can bind to substances in the body, that have been approved since 2018 by the U.S. Food and Drug Administration to prevent migraines. The antibodies inhibit the action of a neurotransmitter called calcitonin gene-related peptide, or CGRP, either by changing the peptide's shape or attaching to its receptors in the brain.

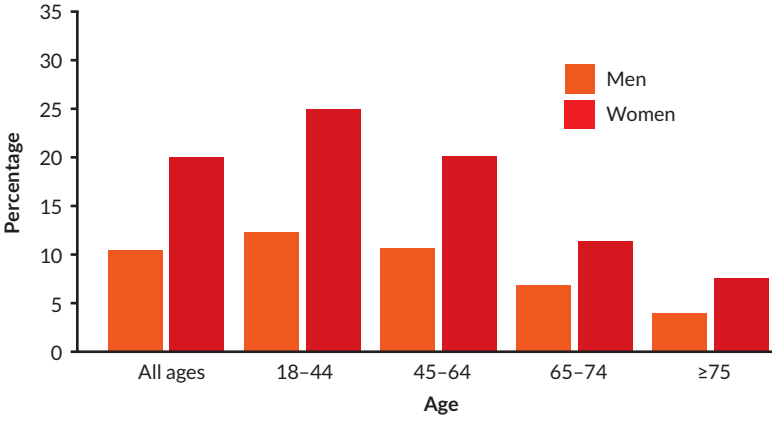
The drugs have changed the game for some migraine sufferers. Roughly half of people who took one of the four drugs in clinical trials saw at least a 50 percent reduction in monthly migraines, says neurologist David Dodick of the Mayo Clinic in

A common pain

Based on U.S. household interviews in 2018, about 1 in 5 women and 1 in 10 men reported having a migraine or severe headache in the previous three months.

SOURCE: NATIONAL HEALTH INTERVIEW SURVEY/*MMWR* 2020

U.S. adults reporting migraines or severe headaches, 2018



OPPOSITE: WOMAN: FLASHPOP/GETTY IMAGES PLUS, SMOKE: JOSE A. BERNAT BACETE/GETTY IMAGES PLUS, INJECTION PEN: SCIENCE PHOTO LIBRARY/GETTY IMAGES PLUS, PILLS: BRIAN HAGIWARA/GETTY IMAGES PLUS, T. TIBBITTS; THIS PAGE: T. TIBBITTS

Phoenix, who reported the findings at a Migraine Trust International Symposium in October. About a third of patients had a 75 percent drop in migraine days.

The CGRP-blockers appear to be an improvement over existing preventive treatments, which were developed for other disorders. The newer drugs were designed specifically to target one of the mechanisms that researchers think leads to the painful episodes.

Doctors are embracing the new drugs because they can work better and generally have much fewer side effects than other options. "It's really beneficial for improving quality of life in our patients with migraines. [The new drugs] don't cause weight gain, sleepiness, brain fog," says neurologist Nina Riggins, a headache specialist at the University of California, San Francisco.

And the options for blocking CGRP are expanding. Rimegepant, or Nurtec, is one of several drugs known as gepants that bind to the CGRP receptor. The drug, an oral tablet rather than a shot, was approved as a treatment for acute migraine in February 2020. When taken every other day, rimegepant appears to also offer some benefit as a preventive, as reported January 2 in the *Lancet*.

Hayley Gudgin suffered years of debilitating migraines. With a CGRP inhibitor, she's doing better.

Nothing typical

Migraine is the third most common disorder in the world, according to the World Health Organization. Migraines or severe headaches affect more than 15 percent of U.S. adults, striking women twice as often as men, the U.S. Centers for Disease Control and Prevention reports. In all, more than 39 million Americans get migraine attacks, which can last four to 72 hours.

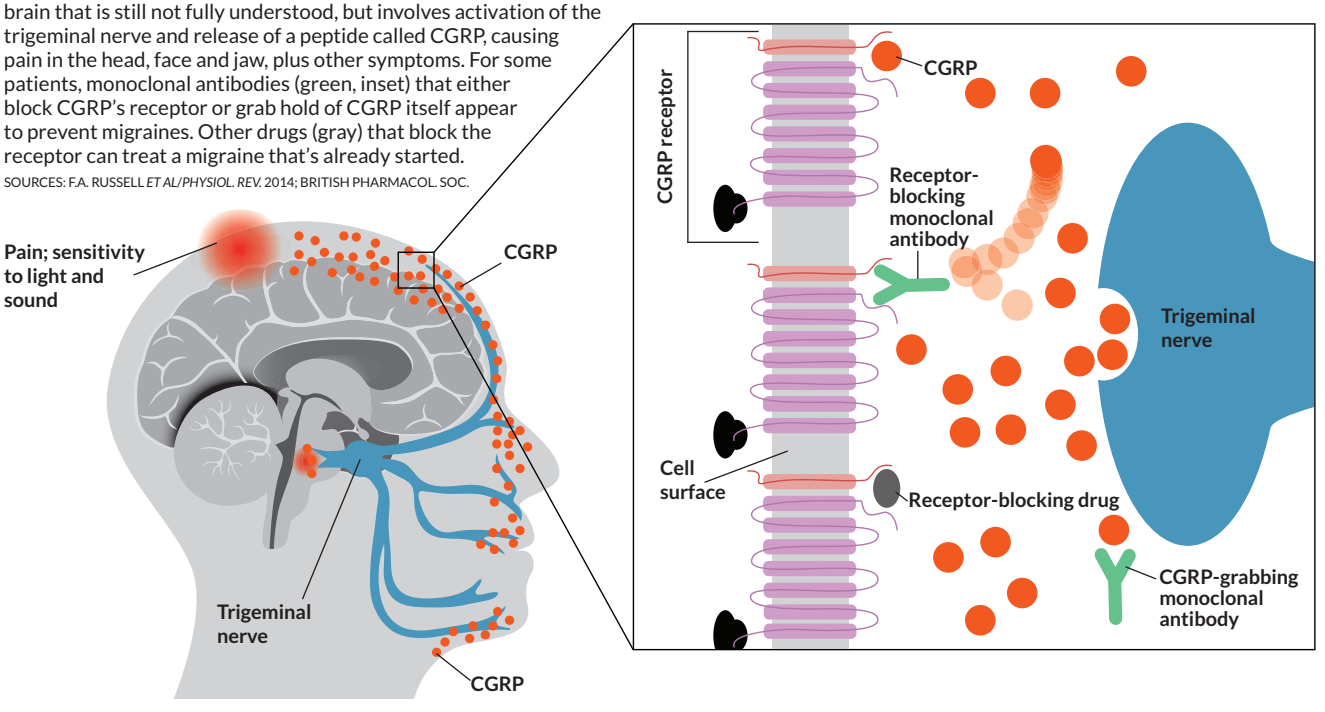
Along with the most common symptom — severe throbbing pain in the head — patients can experience sensitivity to light, smells and sound; dizziness; vomiting; numbness; and visual disturbances such as blind spots and tunnel vision.

"Migraine is probably more than one disease," says neurologist Richard Lipton of Albert Einstein College of Medicine in the Bronx, N.Y. "There are more than 40 identified genes that contribute to the risk of migraine. What that means is that there are multiple pathways that lead to migraine, and as a consequence of that, migraine is not a one-size-fits-all condition."

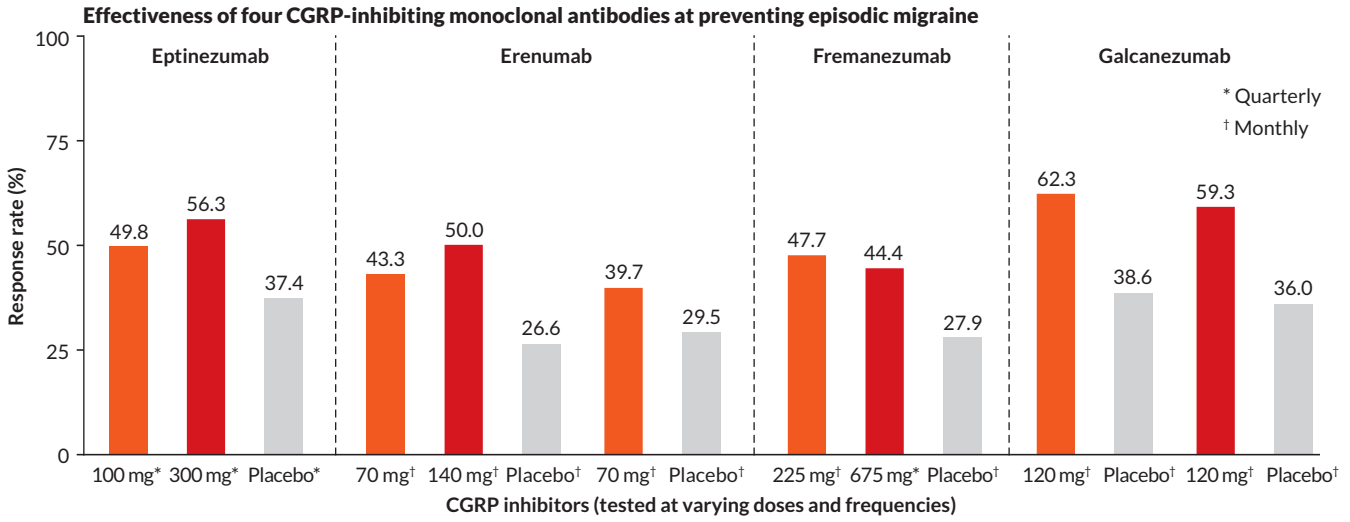
Although many genes have been identified as playing a role, researchers have not pinpointed the exact mechanisms involved with migraine. The long-held notion of blood vessel dilation

The CGRP cascade Migraines involve a series of events in the brain that is still not fully understood, but involves activation of the trigeminal nerve and release of a peptide called CGRP, causing pain in the head, face and jaw, plus other symptoms. For some patients, monoclonal antibodies (green, inset) that either block CGRP's receptor or grab hold of CGRP itself appear to prevent migraines. Other drugs (gray) that block the receptor can treat a migraine that's already started.

SOURCES: F.A. RUSSELL *ET AL*/*PHYSIOL. REV.* 2014; BRITISH PHARMACOL. SOC.



FROM TOP: MARTIN GUDGIN; T. TIBBITTS



A step forward Four approved monoclonal antibodies that work by attaching to CGRP and changing its shape or blocking its receptor showed an edge over a placebo in separate late-phase clinical trials to prevent episodic migraine. Response rate was defined as the percentage of patients with at least a 50 percent reduction in the number of migraine days per month. SOURCE: M. ASHINA/*NEJM* 2020

being to blame has even fallen out of favor, says Amaal Starling, a neurologist at the Mayo Clinic in Scottsdale, Ariz.

"We know pain is caused by ... abnormal activity in multiple parts of the brain, including the trigeminal nerve, trigeminal nucleus caudalis in the brain stem, and the pain networks," Starling says. This leads to migraine-related pain in the head, face and neck.

Some theories suggest that migraine occurs — and a cascade starts — when nerve cells in the brain get overexcited and stimulate the trigeminal nerve, which controls movement of the jaw muscle and sensations of touch, pain and temperature in the face. The trigger can be hormonal changes, stress, food, smells, sounds, a visual stimulus or some combination. The first step in the cascade releases CGRP in the brain, which causes transmission of pain signals.

The pain signals trigger an additional release of CGRP and other peptides. These molecules tell the brain to increase the dilation of blood vessels, releasing toxic chemicals. This is why, at least for some people, CGRP may be a big part of the problem.

"Most of the acute treatments that we use for migraine, if they're taken too often, cause medication overuse headaches."

RICHARD LIPTON

No easy fix

Treating chronic migraine is often a two-pronged approach: Try to prevent migraine attacks by managing the underlying cause, and stop attacks when they strike.

Part of a long-lasting problem with chronic migraine is that drugs available for prevention were developed for other diseases, such as hypertension, depression and epilepsy. For example, doctors realized that patients with high blood pressure who also had migraines reported fewer migraines after taking beta-blockers. The medicine slows down the heart by blocking the effect of adrenaline, a hormone that speeds up circulation. Similar stories led to the use of anticonvulsants, antidepressants, antianxiety medications, narcotics and antihistamines.

None of these drugs are without side effects, and they are ineffective for 40 to 50 percent of chronic migraine patients, according to a 2017 analysis of insurance claims data by Dodick and colleagues in *Cephalalgia*. Within six months of starting four commonly used migraine prevention drugs, 75 percent of patients had stopped using them. The researchers assume, based on other studies, that the main reasons for stopping were side effects and lack of efficacy.

Side effects include weight gain, nausea, brain fog, drowsiness, speech disturbance and lack of concentration. And sometimes the treatments themselves can bring on headaches. "Most of the acute treatments that we use for migraine, if they're taken too often, cause medication overuse headaches," Lipton says.

GRAPH: T. TIBBITTS; PILLS: BRIAN HAGIWARA/GETTY IMAGES PLUS

Focus on one pathway

Researchers realized about 20 years ago that CGRP plays a role in migraine. The peptide helps nerve cells communicate with each other. "[CGRP] is very heavily represented in the pathways that are involved in migraine," Lipton says.

In one study, researchers measured CGRP levels in the blood and found higher levels in people who had migraines than in people who did not. And among those who experienced migraines, CGRP blood levels went up as migraines came on. In a separate study, when an induced migraine attack was effectively treated, CGRP blood levels came down, says Deborah Friedman, a neuro-ophthalmologist at University of Texas Southwestern Medical Center in Dallas.

Researchers realized about 20 years ago that CGRP plays a role in migraine.

The work led to the creation of the four monoclonal antibodies approved for preventing migraines. One of them, erenumab, the drug that's helping Gudgin, mimics the shape of CGRP, binding to the CGRP nerve receptor so the CGRP has no place to attach when it arrives at a nerve cell. The other three drugs — galcanezumab (Emgality), fremanezumab (Ajovy) and eptinezumab (Vyepti) — attach to CGRP itself, changing its shape so it can't fit into the receptor. All four drugs are given as monthly or quarterly injections or intravenous infusions.

These monoclonal antibodies help some patients and produce fewer side effects than existing treatments. In a 2019 survey of nearly 600 people taking galcanezumab to prevent migraines, conducted by the drug's maker, Indianapolis-based Eli Lilly, nearly 80 percent reported their migraine as "better" overall since starting the medication. In a study funded by eptinezumab's manufacturer, H. Lundbeck A/S in Copenhagen, more than 80 percent of about 700 patients reported they had a 50 percent or greater drop in migraine days in at least one four-week interval, and about one-third of patients taking intravenous eptinezumab saw that same drop over the entire 24-week study.

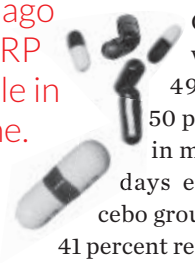
Only 20.5 percent of patients taking a placebo saw the same drop in migraine days, as reported last October in the *Journal of Headache and Pain*.

The gepants go after the same pathway, but can be taken orally because they are small molecules. Gepants are prescribed on an as-needed basis to stop acute migraines. Recent studies suggest they may have preventive benefits too, according to an April 2020 report in *Headache*.

Gepants have been studied since 2004, but earlier versions caused liver problems, so they never made it to market. In 2019 and 2020, the FDA approved two formulations — ubrogepant, or Ubrelvy, and rimegepant, or Nurtec. Overall, the gepants appear to stop migraine pain within two hours in about 20 percent of patients and do not bring on the overuse headaches that are common with other acute treatments.

Two additional gepants, atogepant and zavegepant, are still in patient trials. Atogepant is being evaluated as a preventive, while zavegepant is being looked at as an acute medication.

Lipton and colleagues reported in the *Lancet* on January 2 the results of a Phase II/III prevention study of rimegepant, funded by Biohaven Pharmaceuticals of New Haven, Conn. Of 348 participants who took the drug every day, 49 percent experienced a 50 percent or greater reduction in moderate to severe migraine days each month. But the placebo group did almost as well, with a 41 percent reduction.



The need for new ideas

Clearly, this variety of CGRP inhibitors don't work for everyone. And they cause side effects for some people, including constipation, increased risk for upper respiratory tract infections and injection-site pain.

Amy Chesney, a retired software engineer who lives in Bossier City, La., started getting migraines in 1992, tried three different CGRP drugs and found that they made her depressed and didn't do anything for her migraines.

There's also some concern about long-term effects from CGRP monoclonal antibodies, since CGRP exists in the peripheral nervous system as well as the brain. For instance, CGRP causes blood vessels to dilate in a variety of systems including the intestines.

Doctors say this is why constipation is one of the drugs' most common side effects. CGRP is also involved in hair follicles, and some patients have reported hair loss. And CGRP is important to blood vessel health, which is why researchers say it will be important to complete long-term studies to look for cardiac issues, although so far none have surfaced.

Finally, the drugs are expensive and, as Gudgin

BRIAN HAGIWARA/GETTY IMAGES PLUS

Preventing migraine

People diagnosed with chronic migraine, which means they get a migraine more than 15 days each month, are prescribed preventive drugs that work in various ways in combination with lifestyle changes, including getting more sleep, avoiding certain foods and lowering stress levels.

Drug	Action
Antidepressants	Work on brain receptors for the neurotransmitter serotonin so that the receptors pay less attention to pain signals.
Antiseizure medications	Reduce overactive sensory pathways in the brain to help prevent migraine attacks.
Beta-blockers	Stop blood vessels from dilating.
OnabotulinumtoxinA (Botox)	Injected into 30–40 places in the forehead, scalp and neck to block neurotransmitters from carrying pain signals from the brain to those areas.
CGRP-blocking monoclonal antibodies and gepants	Stop a chain reaction involved in migraine by blocking CGRP from attaching to receptors in the brain.

Stopping an acute migraine

Once a migraine attack occurs, patients have over-the-counter and prescription options to try.

Drug	Action
Gepants	Block CGRP from binding to its receptor.
Triptans	Increase the amount of serotonin in the space where nerves communicate and reduce the amount of CGRP released. Available as pills, nasal sprays and injections.
Analgesics	Over-the-counter aspirin, ibuprofen, naproxen and acetaminophen (sometimes combined with caffeine), as well as opioids and other prescription drugs can reduce migraine pain if taken soon after an attack begins.

The CGRP-inhibiting drugs, which became available starting in 2018, come in tablets, self-administered injections or infusions.

FROM LEFT: BIOHAVEN PHARMACEUTICALS; ALLISON BAILEY/ALAMY STOCK PHOTO

discovered, insurance companies can make patients and doctors jump through hoops before covering the cost, says Matthew Robbins, a neurologist at Weill Cornell Medicine and New York-Presbyterian Hospital in New York City.

When erenumab received FDA approval, its manufacturers, Novartis of Basel, Switzerland, and Amgen of Thousand Oaks, Calif., set a price of $6,900 per year for the drug. "Generally, you can't just prescribe them straight away. [Patients] have to either not tolerate established medications or [show] that they do not work first," Robbins says.

It took two denials and three months before Gudgin's insurance company would approve payment. First, she had to prove that she had tried cheaper preventive medications. Then she had to confirm that she got migraines frequently enough to classify her disease as chronic.

Gudgin says that although her insurance company finally paid for her treatment, she does have a rough time at the beginning of the year when her $4,000 deductible has not yet been met. However, it's worth it for her, she says, and she would pay out of pocket if she had to. "I'm not stuck in a darkened room. I have a life again. You can't put a price on that." ■

Explore more

- Marie Deen *et al.* "Blocking CGRP in migraine patients—a review of pros and cons." *Journal of Headache and Pain*. September 25, 2017.

Karen J. Bannan is a freelance writer and editor based in Massapequa, N.Y.

Conservation professionals gathered in Gunnison, Colo., in 2017 to learn how to build Zeedyk structures, simple rock dams that slow the flow of water in small creeks to increase surrounding plant growth.

B. RANDALL

REVIVING RIVERSCAPES

Hand-built structures can spread water across dry land

By Brianna Randall

Wearing waders and work gloves, three dozen employees from the U.S. Department of Agriculture's Natural Resources Conservation Service stood at a small creek amid the dry sagebrush of southeastern Idaho. The group was eager to learn how to repair a stream the old-fashioned way.

Tipping back his white cowboy hat, 73-year-old rancher Jay Wilde told the group that he grew up swimming and fishing at this place, Birch Creek, all summer long. But when he took over the family farm from his parents in 1995, the stream was dry by mid-June.

Wilde realized this was partly because his family and neighbors, like generations of American settlers before them, had trapped and removed most of the dam-building beavers. The settlers also built roads, cut trees, mined streams, overgrazed livestock and created flood-control and irrigation structures, all of which changed the plumbing of watersheds like Birch Creek's.

Many of the wetlands in the western United States have disappeared since the 1700s. California has lost an astonishing 90 percent of its wetlands, which includes streamsides, wet meadows and ponds. In Nevada, Idaho and Colorado, more than 50 percent of wetlands have vanished. Precious wet habitats now make up just 2 percent of the arid West — and those remaining wet places are struggling.

Nearly half of U.S. streams are in poor condition, unable to fully sustain wildlife and people, says Jeremy Maestas, a sagebrush ecosystem specialist with the NRCS who organized that workshop on Wilde's ranch in 2016. As communities in the American West face increasing water shortages, more frequent and larger wildfires (*SN: 9/26/20, p. 12*) and unpredictable floods, restoring ailing waterways is becoming a necessity.

Landowners and conservation groups are bringing in teams of volunteers and workers, like the NRCS group, to build low-cost solutions from sticks and stones. And the work is making a difference. Streams are running longer into the summer, beavers and other animals are returning, and a study last December confirmed that landscapes irrigated by beaver activity can resist wildfires.

Filling the sponge

Think of a floodplain as a sponge: Each spring, floodplains in the West soak up snow melting from the mountains. The sponge is then wrung out during summer and fall, when the snow is gone and rainfall is scarce. The more water that stays in the sponge, the longer streams can flow and plants can thrive. A full sponge makes the landscape better equipped to handle natural disasters, since wet places full of green vegetation can slow floods, tolerate droughts or stall flames.

Typical modern-day stream and river restoration methods can cost about $500,000 per mile, says Joseph Wheaton, a geomorphologist at Utah State University in Logan. Projects are often complex, and involve excavators and bulldozers to shore up streambanks using giant boulders or to construct brand-new channels.

"Even though we spend at least $15 billion per year repairing waterways in the U.S., we're hardly scratching the surface of what needs fixing," Wheaton says.

Big yellow machines are certainly necessary for restoring big rivers. But 90 percent of all U.S. waterways are small streams, the kind you can hop over or wade across.

For smaller streams, hand-built restoration solutions work well, often at one-tenth the cost, Wheaton says, and can be self-sustaining once nature takes over. These low-tech approaches include building beaver dam analogs to entice beavers to stay and get to work, erecting small rock dams or strategically mounding mud and branches in a stream. The goal of these simple structures is to slow the flow of water and spread it across the floodplain to help plants grow and to fill the underground sponge.

Fixes like these help cure a common ailment that afflicts most streams out West, including Birch Creek, Wheaton says: Human activities have altered these waterways into straightened channels largely devoid of debris. As a result, most riverscapes flow too straight and too fast.

Less than a year after workers installed this hand-built rock structure, called a Zuni bowl, in an intermittent stream in southwestern Montana, erosion stopped moving upstream, keeping the grass above the structure green and lush.

SEAN CLAFFEY/SOUTHWEST MONTANA SAGEBRUSH PARTNERSHIP

Staff from the USDA Natural Resources Conservation Service pound posts to build a beaver dam analog across Birch Creek in Idaho in 2016. The effort gave nine relocated beavers a head start to create their own dam complexes.

J. MAESTAS/USDA NRCS

"They should be messy and inefficient," he says. "They need more structure, whether it's wood, rock, roots or dirt. That's what slows down the water." Wheaton prefers the term "riverscape" over stream or river because he "can't imagine a healthy river without including the land around it."

Natural structures "feed the stream a healthy diet" of natural materials, allowing soil and water to accumulate again in the floodplain, he says.

Since as much as 75 percent of water resources in the West are on private land, conservation groups and government agencies like the NRCS are helping ranchers and farmers improve the streams, springs or wet meadows on their property.

"In the West, water is life," Maestas says. "But it's a very time-limited resource. We're trying to keep what we have on the landscape as long as possible."

Beaver benefits

In watersheds across the West, beavers can be a big part of filling the floodplain's sponge. The rodents gnaw down trees to create lodges and dams, and dig channels for transporting their logs to the dams. All this work slows down and spreads out the water.

On two creeks in northeastern Nevada, streamsides near beaver dams were up to 88 percent greener than undammed stream sections when measured from 2013 to 2016. Even better, beaver ponds helped maintain lush vegetation during the hottest summer months, even during a multiyear drought, Emily Fairfax, an ecohydrologist at California State University Channel Islands, and geologist Eric Small of University of Colorado Boulder reported in 2018 in *Ecohydrology*.

"Bringing beavers back just makes good common sense when you get down to the science of it," Wilde says. He did it on his ranch.

Using beavers to restore watersheds is not a new idea. In 1948, for instance, Idaho Fish and Game biologists parachuted beavers out of airplanes, partly to improve trout habitat on public lands.

Wilde used trucks instead of parachutes. In 2015 and 2016, he partnered with the U.S. Forest Service and Idaho Fish and Game to livetrap and relocate nine beavers to Birch Creek from public lands about 120 kilometers away. To ensure the released rodents had a few initial ponds where they could escape from predators, Wilde worked with Anabranch Solutions, a riverscape restoration company cofounded by Wheaton and colleagues, to construct 26 beaver dam analogs. Would these simple branch-and-post structures entice the beavers to stay in Birch Creek?

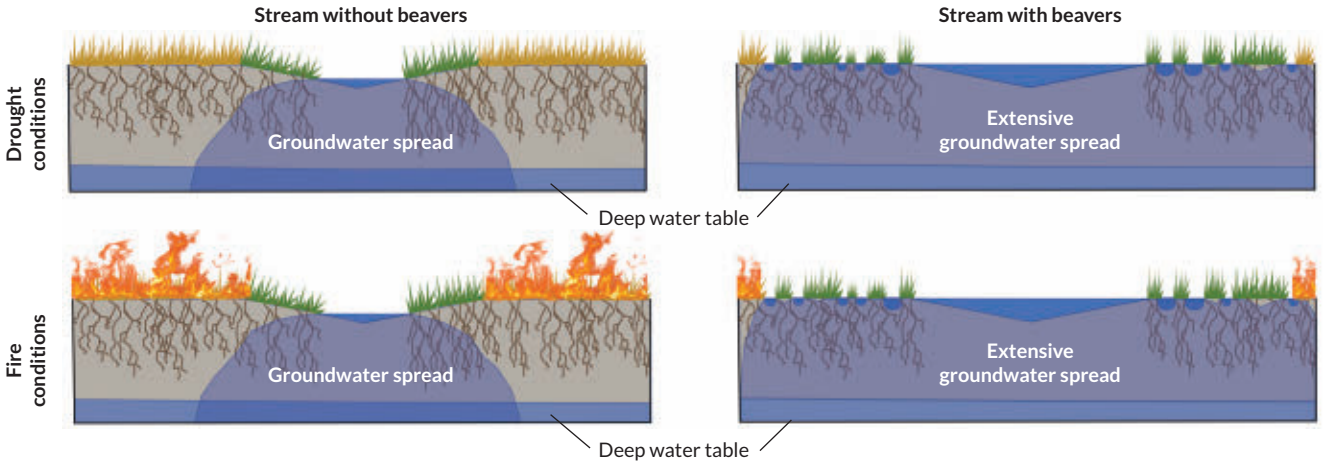
It worked like a charm. In just three years, those beavers built 149 dams, transforming the once-narrow strip of green along the stream into a wide, vibrant floodplain. Birch Creek flowed 42 days longer, through the hottest part of the summer. Fish rebounded quickly too: Native Bonneville cutthroat trout populations were up to 50 times as abundant in the ponded sections in 2019 as they were when surveyed by the U.S. Forest Service in 2000, before beavers went to work.

"When you see the results, it's almost like magic," Wilde says. Even more magical, the transformation cost Wilde only "a couple hundred bucks in fence posts" and a few days of sweat equity, thanks in part to those NRCS staffers who came in 2016 and a host of volunteers.

Rock dams in the desert

Beaver-powered restoration isn't the answer everywhere, especially in the desert where creeks are ephemeral, flowing only intermittently. In Colorado's Gunnison River basin, ranchers were looking for ways to boost water availability to ensure their cattle had enough drinking water and green grass in the face of climate change.

How beavers help in drought and fire



Meanwhile, the area's public land managers wanted to restore streams to help at-risk wildlife species like the Gunnison sage grouse, once prolific across sagebrush country.

In 2012, a group of private landowners, public agencies and nonprofit organizations launched the Gunnison Basin Wet Meadow and Riparian Restoration and Resilience-building Project to revive streams and keep meadows green. The group hired Bill Zeedyk to instruct on how to build simple, low-profile dams by stacking rocks, known widely as Zeedyk structures, to slow down the water.

Zeedyk, now 85, runs his own wetland and stream restoration firm in New Mexico, after 34 years as a wildlife biologist at the U.S. Forest Service. His 2014 book *Let the Water Do the Work* has inspired people across the West — including Maestas and Wheaton — to turn to simple, nature-based stream restoration solutions.

Over the last nine years, Zeedyk has helped the Gunnison collaborative build nearly 2,000 rock structures throughout the roughly 10,000-square-kilometer upper Gunnison watershed. The group has restored 43 kilometers of stream and improved nearly 500 hectares of wet habitat for people and wildlife. A typical project involves a dozen volunteers working for a day or two in one creek bottom where they build dozens of rock structures.

In 2017, Maestas asked Zeedyk to show more than 100 people involved in the NRCS-led Sage Grouse Initiative how to install rock structures. The white-bearded Zeedyk led them along an eroding gully near Gunnison that June.

Lifting his wooden walking staff, Zeedyk pointed out how the adjacent dirt road originally created by horses and wagons cut off the creek from its historic floodplain. The road made the channel shorter, straighter and steeper over time. "There's less growing space, and the whole system is less productive," he explained.

As participants decided where to stack rocks to spread water across the dusty sagebrush flat, Zeedyk encouraged them to "read the landscape" and "think like water." After three hours of work, participants could already see ponds forming behind their rock creations.

Watching the teams work and laugh together, Maestas called it the aha moment for the crew. "When you get your hands dirty, there's a degree of buy-in that can't come from sitting in a classroom or reading about it."

The grass is greener

The hope is that, like the beaver dam analogs, these hand-built rock structures will halt erosion, capture sediment, fill the floodplain sponge and

The water is wide

When beavers build dams, water spreads out to the surrounding vegetation. Pockets of water under the stream-side plants support the plants during drought (top row), which then repel fires much better than dry vegetation (bottom row).

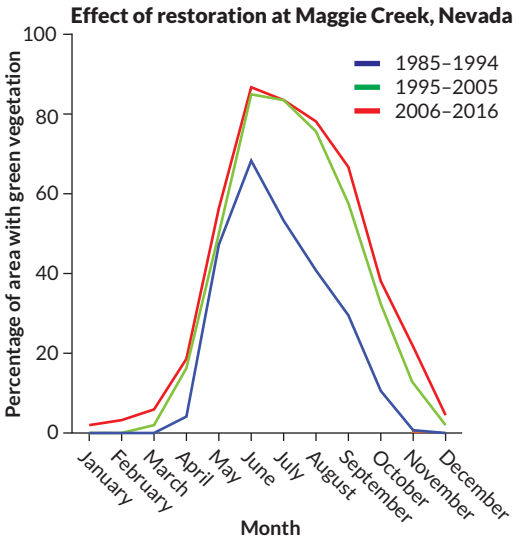
A remote camera spies Gunnison sage grouse feasting on insects and plants in a wet meadow. The area stays green long into the summer because of hand-built rock dams that spread water across the land.

FROM TOP: E. FAIRFAX/CSU CHANNEL ISLANDS; COURTESY OF NATHAN SEWARD/COLORADO PARKS AND WILDLIFE

Lasting change

In 1994, ranchers in Nevada began changing livestock grazing practices at Maggie Creek to encourage vegetation to regrow along the stream and support new beaver colonies. The graph compares average monthly greenness pre-restoration (blue) and post. In the first (green) and second decade (red) after, vegetation lasted longer into fall and winter months.

SOURCE: N.L. SILVERMAN *ET AL*/ *RESTORATION ECOLOGY* 2019



grow more water-loving plants.

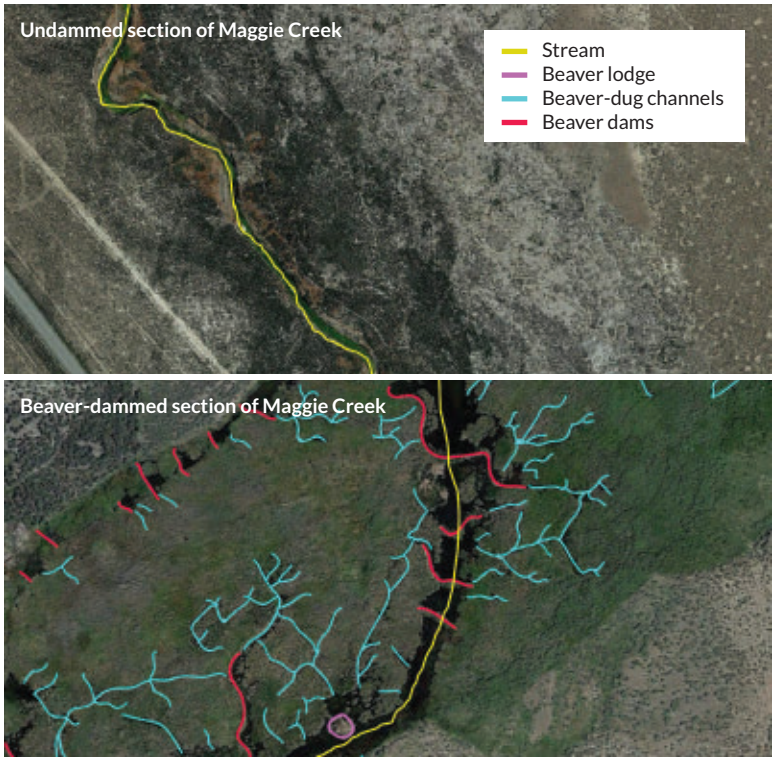
Patience, Zeedyk says, is crucial. "After we put natural processes into play in a positive direction, we have to wait for the water to do its work."

The wait isn't necessarily long. At four of the sites in the Gunnison basin restored with Zeedyk structures, wetland plant cover (including sedges, rushes, willows and wetland forbs) increased an average of 160 percent four years post-treatment, compared with a 15 percent average increase at untreated areas near each study site, according to a 2017 report by The Nature Conservancy.

"As of 2019, we had increased the wetland species cover by 200 percent in six years," says Renee Rondeau, an ecologist at the Colorado Natural Heritage Program, based in Hesperus. "So great to see this success."

Animals seem to enjoy all that fresh green growth too. Colorado Parks and Wildlife set up remote cameras to monitor whether wildlife use the restored floodplain. Since 2016, the cameras have captured more than 1.5 million images, most of which show a host of animals — from cattle and elk to sage grouse and voles — munching away in the now-lush meadows. A graduate student at Western Colorado University is classifying photos to determine whether there's a significant difference in the number of Gunnison sage grouse at the restored sites compared with adjacent untreated areas.

"Sage grouse chicks chase the green line as the desert dries up," Maestas explains. After hatching in June, hens and their broods seek out wet areas where chicks stock up on protein-rich insects and wildflowers to grow and survive the winter.



Satellite images show that when beavers settled into one part of Nevada's Maggie Creek (bottom), digging channels to ferry in logs to build dams, the floodplain was wider, wetter and greener than an area of the creek with no dams (top).

Water in the bank

The Gunnison basin is not the only place where sticks-and-stones restoration is paying dividends for people and wildlife. Nick Silverman, a hydroclimatologist and geospatial data scientist, and his colleagues at the University of Montana in Missoula used satellite imagery to evaluate changes in "greenness" at three sites that used different simple stream restoration treatments: Zeedyk's rock structures in Gunnison, beaver dam analogs in Oregon's Bridge Creek and fencing projects that kept livestock away from streambanks in northeastern Nevada's Maggie Creek.

Late summer greenness increased up to 25 percent after streams were restored compared with before, the researchers reported in 2018 in *Restoration Ecology*. Plus, the streams showed greater resilience to climate variability as time went on: Along Maggie Creek, restored more than two decades before the study, the plants stayed green even when rainfall was low, and the area had substantial increases in plant production during late summer, when vegetation usually dries out.

"It's like putting water in a piggy bank when it's wet, so plants and animals can withdraw it later

FROM TOP: C. CHANG; E. FAIRFAX/CSU CHANNEL ISLANDS

The green strip of vegetation along beaver-made ponds in Baugh Creek near Hailey, Idaho, resisted flames when a wildfire scorched the region in 2018, as shown in this drone image.

J. WHEATON/UTAH STATE UNIV.

when it's dry," Silverman says. Even more exciting, he adds, is that the impact of the low-cost options is large enough to see from space.

Water doesn't burn

The Sharps Fire that scorched south-central Idaho in July 2018 burned a wide swath of a watershed where Idaho Fish and Game had relocated beavers to restore a floodplain. A strip of wet, green vegetation stood untouched along the beavers' ponds. Wheaton sent a drone to take photos, tweeting out an image on September 5, 2018: "Why is there an impressive patch of green in the middle of 65,000 acres of charcoal? Turns out water doesn't burn. Thank you beaver!"

Fairfax, the ecohydrologist who reported that beaver dams increase streamside greenness, had been searching for evidence that beavers could help keep flames at bay. Wheaton's tweet was a "kick in the pants to push my own research on beavers and fire forward," she says.

With undergraduate student Andrew Whittle, now at the Colorado School of Mines, Fairfax got to work analyzing satellite imagery from recent wildfires. The two mapped thousands of beaver dams within wildfire-burned areas in several western states. Choosing five fires of varying severity in both shrubland and forested areas, the pair analyzed the data to see if creeks with beaver activity stayed greener than creeks without beavers during wildfires.

"Across the board, beaver-dammed areas didn't burn," Fairfax says. The study was published last December in *Ecological Applications* during one of the West's worst fire seasons. It garnered plenty of attention from land managers asking for more specifics, like how many beavers are needed to buffer a fire.

Fairfax plans to study several more burned sites with beaver ponds. She hopes to eventually create a statistical model that can help people plan nature-powered stream restoration projects.

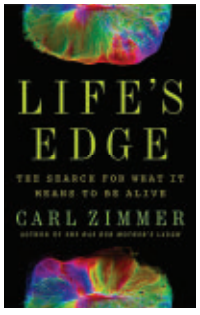
"When we're seeing hotter, more unpredictable fires that are breaking all the rules we know of," Fairfax says, "we have to figure out how to preserve critical wet habitats." ■

Explore more

- Joseph M. Wheaton *et al.* "Low-tech process-based restoration of riverscapes: design manual." March 2019.

Brianna Randall is a freelance writer based in Missoula, Mont.

What Is Life?
Paul Nurse
W.W. NORTON & CO, $20



Life's Edge
Carl Zimmer
DUTTON, $28

BOOKSHELF

Two new books search for the meaning of life

If everything in the world had to be divided into two bins — one for living things and one for nonliving — the task might seem easy. Trees, bacteria and humans are alive; rocks, smartphones and rainfall are not.

But in some cases, the distinction is murky. Where might the coronavirus responsible for the ongoing COVID-19 pandemic belong? Viruses have their own genetic material and can evolve. But without a host cell to infect, a virus can't make more copies of itself. And a virus doesn't eat food for energy, instead stealing energy from its host. So is a virus a form of life? What makes something alive?

Two new books tackle that last question. *What Is Life?* by geneticist Paul Nurse and *Life's Edge* by science journalist Carl Zimmer explore how scientists have come to understand life and probe some of the entities that push its limits.

"Asking biologists about what it means for something to be alive makes for an awkward conversation," Zimmer writes. While scientists have spent centuries contemplating the question, there is still no universally accepted definition.

In *What Is Life?* Nurse guides readers through five big scientific ideas that he argues help define living things: cells, genes, evolution, life as chemistry and life as information. He also examines how studying these aspects of life has helped us take better care of human life, such as developing heart surgery or genetically modified crops that make food more widely available. As might be expected for someone who won a Nobel Prize in physiology or medicine in 2001 for discovering how cells control growth and division, Nurse's ideas are rooted in the nuances of life as seen within a cell.

> "Asking biologists about what it means for something to be alive makes for an awkward conversation."
> **CARL ZIMMER**

Alongside personal accounts of the discoveries that inspired and guided his own career, Nurse chronicles how researchers initially revealed the cell, "biology's atom," and uncovered that strings of genetic molecules hold the instructions to make cells work.

For readers familiar with this history, the book's first few chapters might feel a little slow. Still, it's spectacular to see the concepts come together as Nurse describes the chemistry of life and how organisms manage information within their cells and from the outside world. He brings cells to life in a way that a textbook drawing can't. If one could peek inside a cell, for instance, "your senses would be assaulted by a boiling tumult of chemical activities," he writes. Some of this activity comes from a cell's enzymes, which can complete thousands to millions of precise chemical reactions per second.

Nurse shares his wonder as he contemplates evolution and our "deep relatedness to other living things," something that struck him while coming face-to-face with a gorilla — a species that shares about 96 percent of its DNA with humans — while on a trip in Uganda. "As his intelligent, deep brown eyes locked my gaze, I saw many aspects of my humanity reflected back at me," Nurse writes.

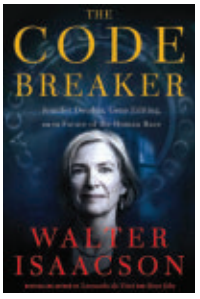
Life's Edge covers similar territory, but goes beyond the inner workings of cells. From the struggle to define when life begins and ends to the hunt for how life got started, the book offers an engaging, in-depth look at some of biology's toughest questions.

Zimmer assesses the common hallmarks of living things — reproduction, intelligence, maintaining consistent body conditions, evolution and metabolism — and what those look like using extreme examples from nature. Though the multiheaded slime mold (*Physarum polycephalum*) lacks a brain, for example, the organism can make decisions that help it navigate mazes to find food. After a python swallows a meal, the snake's metabolic rate spikes, rising to 45 times as high as its resting metabolic rate to break down the prey. A person's metabolism, on the other hand, increases to only about 0.5 times its resting rate after eating.

Once he sets the stage with these hallmarks, Zimmer delves into some scientific missteps researchers have taken while exploring the intricacies of life. A gelatinous substance found in the Atlantic Ocean in the late 1800s and thought to be a simple life-form actually turned out to be inorganic material.

Readers also get introduced to intriguing exceptions to the rules, entities lurking at the edge of life. Red blood cells don't carry their own genetic material like other cells do. Since they therefore can't make proteins or divide into new cells, red blood cells might not be considered alive.

The coronavirus is another one of those lurkers. Nurse and Zimmer both leave unanswered whether viruses should be considered alive. Nurse argues that perhaps viruses straddle the line, living when inside a cell but otherwise nonliving. Regardless of how we classify viruses, Zimmer argues, they have an enormous impact on the living world, not just by causing disease in people but also by killing bacteria and keeping their populations in check or carrying genes to new hosts. "If viruses are lifeless," he writes, "then lifelessness is stitched into our being." — *Erin Garcia de Jesus*



The Code Breaker
Walter Isaacson
SIMON & SCHUSTER, $35

BOOKSHELF

A CRISPR pioneer stars in this gene-editing story

With the slightest touch, the fernlike vine known as sleeping grass folds over on itself, like a Venus flytrap closing its flaps. "What causes the leaves to close when you touch them?" a young Jennifer Doudna wondered growing up in Hawaii. Noticing that curiosity, Doudna's father left James Watson's book *The Double Helix* on her bed one day. Doudna sped through the pages, absorbing how Watson and Francis Crick deciphered the structure of DNA. Today, she credits the book and her insatiable inquisitiveness for driving her to become a scientist and for setting the foundation for her to codiscover, nearly four decades later, a set of molecular scissors called CRISPR that can edit the genetic blueprint of life. Watson would later call CRISPR "the most important discovery since DNA's structure," Walter Isaacson writes in *The Code Breaker*.

The book, both a biography of Doudna and a deep dive into the ethics of genetic engineering, is written for people who may have heard of CRISPR but don't know much about the history of its development. The book digs into the fierce patent battles that have ensued between the University of California (Doudna is at the Berkeley campus) and the Broad Institute of MIT and Harvard, where other researchers, most notably Feng Zhang, were also developing the gene-editing tool. The tone and style of the book's first half mimic *The Double Helix*, setting up the scientific process as a detective story, one focused first on understanding how bacteria rely on CRISPR to fend off viral infections and then on how scientists transformed that natural bacterial defense system into a tool that allows humans to edit their own DNA.

While *The Code Breaker* starts off as a page-turner, the latter half is more tedious, with tangents that loosely weave together the battle over the claim to discovering CRISPR and the ethical questions around using it. Those questions came to the fore in 2018, after the birth of two babies whose genes had been edited while still embryos (*SN: 12/22/18 & 1/5/19, p. 20*). Impressively timely, Isaacson bounces from concerns over "designer" children to Doudna's shared 2020 Nobel Prize in chemistry (*SN: 11/7/20, p. 13*) to her latest race against rivals: adapting CRISPR into a tool that can quickly detect the virus that causes COVID-19, or one that could potentially thwart the virus's infection of human cells. No longer is the race for patents and prizes, Isaacson writes, but one to save humankind from the coronavirus and possibly other ills. — *Ashley Yeager*

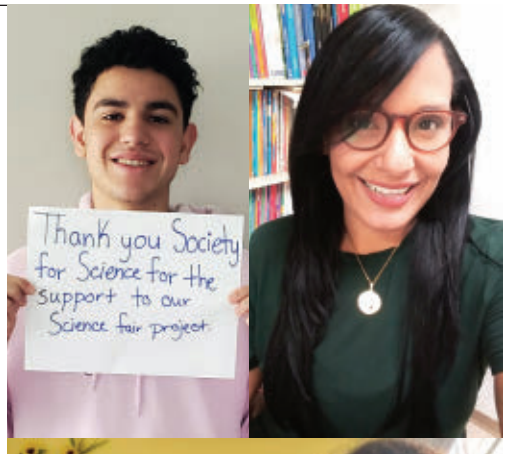
Editor's note: Feng Zhang is on the Board of Trustees of Society for Science, which publishes Science News.

COMMITTED TO STEM EDUCATION DESPITE THE ODDS

As an educator in Puerto Rico, Yajaira Torres-De Jesus (pictured far right with two of her students) is no stranger to challenges. In the 15 years she's spent teaching at Colegio Rosa-Bell in Guaynabo, the island has endured devastating natural disasters like hurricanes and earthquakes. The COVID-19 pandemic posed new difficulties for Yajaira and her students, but as a 2020 Society for Science Advocate, she found ways to keep them engaged in science research. The Advocate Program provides training, stipends, equipment (pictured above) and year-round support to mentors working with underrepresented and low-income students on entering science research competitions.

Drawing on resources available within the school community is one of the hallmarks of Yajaira's role as an Advocate. As part of her efforts to transform her school into a bustling STEM-focused center, she mentors a cohort of more than 60 students from grades seven to 12. With the new challenges brought on by the public health crisis, Yajaira worked closely with school faculty to develop lab access guidelines that would enable students to complete their scientific research safely. Additionally, she redesigned her lesson plans so that students could use materials readily available in their homes.

Yajaira is also deeply invested in getting more students involved in science. She has successfully convinced her school administration to add an agriculture elective course and even took the first steps toward creating a Future Farmers of America agricultural research chapter for private schools in Puerto Rico.

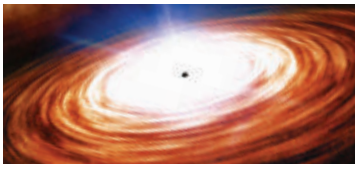


FEBRUARY 13, 2021

SOCIAL MEDIA

Oh Captain! My Captain!

Two stories in the Feb. 13 issue caught the attention of reader **Chris Evans**, the actor who plays Captain America in the Marvel Cinematic Universe. **Evans** shared **Maria Temming's** story on the source of weird "blue jet" lightning (*SN: 2/13/21, p. 14*) and her story on the most ancient black hole ever discovered (illustrated below) with his millions of followers on Twitter. Of the black hole story (see "Packing on the solar masses," right), he wrote: "Just read the first paragraph. These numbers are truly overwhelming."



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Mind readers

*Scientists are grappling with the ethical implications of new technology that aims to listen to and perhaps change brain activity, **Laura Sanders** reported in "Inside your head"* (SN: 2/13/21, p. 24).

"Interesting and provocative read," reader **Andrew Nelson** wrote. "Once the intricacies of our thoughts become recordable (or worse, reproducible), they will be misused." Linking neural activity with specific actions could establish causal relationships that could be used to control mental processes without a person's knowledge, **Nelson** wrote. "That's the scary part!"

To shape **Sanders'** story, *Science News* surveyed readers like **Nelson** about their opinions on brain science advances, editor in chief **Nancy Shute** explained in her editor's note for the issue (*SN: 2/13/21, p. 2*). Reader **Danny Otero** applauded the effort to involve the public in conversations about the thorny ethical issues surrounding neurotechnology. But "great science journalism ... rests on finding the truth from experts," he wrote. "Why not then involve professional ethicists in this discussion?"

Science News consults experts in our reporting, and **Sanders** spoke with ethicists for the story. "We would love to connect ethicists with readers and scientists for in-depth conversations about these issues," **Shute** says. "Finding out about readers' concerns so we could address them in our reporting was just the first step. We hope to be able to help encourage more connections and conversations in the future," she says.

Packing on the solar masses

*The oldest known black hole lies at the center of a galaxy 13 billion light-years from Earth and has a mass equivalent to 1.6 billion suns, **Maria Temming** reported in "Oldest known black hole mystifies scientists"* (SN: 2/13/21, p. 4).

If the black hole, dubbed J0313-1806, was that massive 13 billion years ago, reader **Arthur Silverthorn** wondered how much it weighs now.

Scientists don't know how massive the black hole is now. "Black holes ... stop growing at some point after consuming all the available gas," says astronomer **Feige Wang** of the University of Arizona in Tucson. "We do not know when that would happen," **Wang** says. But the biggest known black hole is about 66 billion solar masses. The mass of J0313-1806 would likely not be more than that, he says.

Shocking science

*Volta's electric eels can hunt in groups of more than 100, with smaller groups of about 10 eels unleashing coordinated electric attacks on prey, **Jonathan Lambert** reported in "Electric eels shock with swarm hunting tactics"* (SN: 2/13/21, p. 4).

Reader **Jerry Kerrisk** wondered if the voltage generated by a group of eels is any different from that of a single eel.

One Volta's electric eel can generate an 860-volt jolt, so in theory, a group of 10 eels could generate 8,600 volts, says evolutionary biologist **Carlos David de Santana** of the Smithsonian National Museum of Natural History in Washington, D.C. But his team has yet to measure the shock output of a group.

The total discharge from 10 joint eel strikes would probably cover a broader area and last longer than a single strike, and not exceed 860 volts, **de Santana** speculates. He hopes to gather more field observations in the fall.

Clarification

Zoologist Lee-Sim Lim of Universiti Sains Malaysia in Penang worked with Priscillia Miard, also of the university, to discover the ultrasound calls of colugos described in "A night with colugos" (*SN: 11/21/20, p. 22*).

Correction

"Solar storm preparedness" (*SN: 2/27/21, p. 16*) incorrectly stated that coronal mass ejections produce shock waves that accelerate electrons to extremely fast speeds. The shock waves accelerate protons.

An artistic take on warm-weather Neandertals

Here's a scene guaranteed to melt the popular stereotype of Ice Age Neandertals as spear-wielding mammoth hunters confined to Eurasia's frigid inner core.

New illustrations depict what's currently known about the temperate environment inhabited by Neandertals in Iberia, or what's now Spain and Portugal, a couple hundred thousand years ago. Gabriela Amorós Seller, a paleoartist at the University of Murcia in Spain, used colored pencils to illustrate an idyllic view (above) of a Neandertal man and child lounging on flat ground downslope from Bolomor Cave, near the Mediterranean coast of eastern Spain. She also illustrated the cave's Neandertal-era entrance and surrounding greenery (right).

Excavations in the cave have produced evidence of the animals, trees and other plants shown in the drawing, presented in the March 15 *Quaternary Science Reviews*. The adult munches on a hazelnut, from local hazel shrubs. Strawberry trees, Mediterranean hackberry trees, myrtle shrubs and chestnut trees — all shown — were also present, say University of Murcia botanists José Carrión and Juan Ochando. The child, meanwhile, watches a tortoise inch its way forward. Tortoises were cooked and eaten at Bolomor Cave, along with rabbits, birds and deer as well as occasional larger animals such as horses and hippos. Mild temperatures may have led the locals to wear few or no clothes, researchers suspect.

Neandertals had a largely unappreciated talent for finding and exploiting resource-rich parts of Iberia (*SN: 4/25/20, p. 12*). Amorós Seller's paintings vividly show some of that mammoth-free bounty. — *Bruce Bower*

BOTH: G. AMORÓS *ET AL/QUATERNARY SCIENCE REVIEWS* 2021

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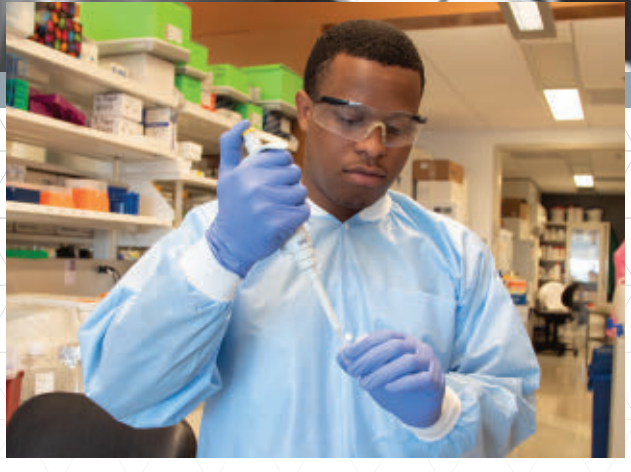

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