Electric Eels Gang Up to Kill | Einstein's Wild Universe

Science News

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ FEBRUARY 13, 2021

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New brain technology sparks privacy concerns

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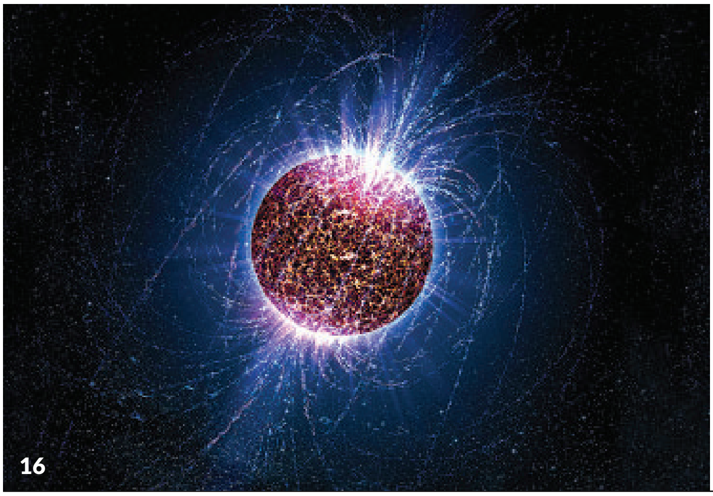

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COVER New technologies aim to listen in on — and maybe even change — your brain activity. *Julia Yellow*

FROM TOP: CASEY REED/PENN STATE; ADHI AGUS OKTAVIANA; JOHN SULLIVAN/INATURALIST.ORG (CC BY-NC 4.0)

Should corporations get access to our brains?

When the news broke in April 2019 that scientists had restored neurological functions in the brains of dead pigs, I was fascinated — and troubled. Though this groundbreaking work could lead to better treatments for stroke and other brain injuries, it also opened an eerie gray zone between the living and the dead.

Scientists are wrestling with the ethical questions posed by the pig brain experiment and other advances in brain science, as neuroscience writer Laura Sanders pointed out in her coverage of that breakthrough (*SN: 5/11/19 & 5/25/19, p. 6*). But information on scientific advances typically flows from scientists to journalists and then out to the public — there's little opportunity for the public to talk with scientists or voice concern about the implications of research before the science happens. Could we help those conversations happen? We decided to run an experiment to find out.

This issue includes the first step in our experiment. Last fall we surveyed *Science News* readers, asking what they thought about neurotechnology, including brain implants and other devices that already have the ability to listen in and change how our brains work. Of three concerns — autonomy, fairness and privacy — privacy was the biggest worry among respondents. Sanders used that information to focus her reporting for this issue's cover story (Page 24). "Asking readers what they thought directly was a great way to get perspective and find out what they're interested in," she told me, "which is something we're trying to do all the time."

Readers didn't hold back. "I have no wish/desire to be a zombie or a clone," one wrote. Others noted how giving scientists (and perhaps corporations and politicians) access to our brains could blur our sense of self. "It was so satisfying and important to get the public's perspective," Sanders said. "They're just left out in so many of these conversations."

We also asked readers to share their thoughts about genetics and race, including bias in genomic databases used for medical research and issues of genetic privacy. Senior writer Tina Hesman Saey will report on that experiment next month.

And we're eager to continue this work. Please let us know what you think by writing us at feedback@sciencenews.org. "I really do see this as the starting point; I would love to do more," Sanders said.

This project was made possible with support from the Kavli Foundation, which gave us the chance to step back from daily news coverage a bit and see if we could help more people become part of the conversations — and, ideally, decisions — about science's impact on society, our bodies and our minds.

This issue also features the second theme in our Century of Science project. Special projects editor Elizabeth Quill explores the implications of Einstein's general theory of relativity, which was considered shocking in the early 1900s (Page 16). Since then, scientists have discovered black holes and other exotic denizens of the universe that wouldn't have seemed possible before Einstein changed our view of the cosmos. — *Nancy Shute, Editor in Chief*

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Excerpt from the February 13, 1971 issue of *Science News*

50 YEARS AGO

More about partons

Experiments in which protons and neutrons were bombarded with high-energy electrons have given indications that protons and neutrons are not amorphous masses but composed of distinct subparticles. The subparticles have been named partons, and whether or not they correspond to the hypothetical quarks remains a moot question.

UPDATE: The so-called partons seen in experiments at the Stanford Linear Accelerator Center were indeed quarks — a discovery that won three researchers the 1990 Nobel Prize in physics (*SN: 10/27/90, p. 263*). Predicted by physicists Murray Gell-Mann and George Zweig in 1964, quarks are the building blocks of most of the universe's ordinary matter. Quarks were originally thought to come in three varieties: up, down and strange. But particle collider experiments have revealed three additional types: charm, bottom and top (*SN: 4/30/94, p. 276*). Quarks usually come in pairs or trios. Recently, physicists have glimpsed more elaborate tetraquarks and pentaquarks (*SN: 8/1/20, p. 14*).

RETHINK

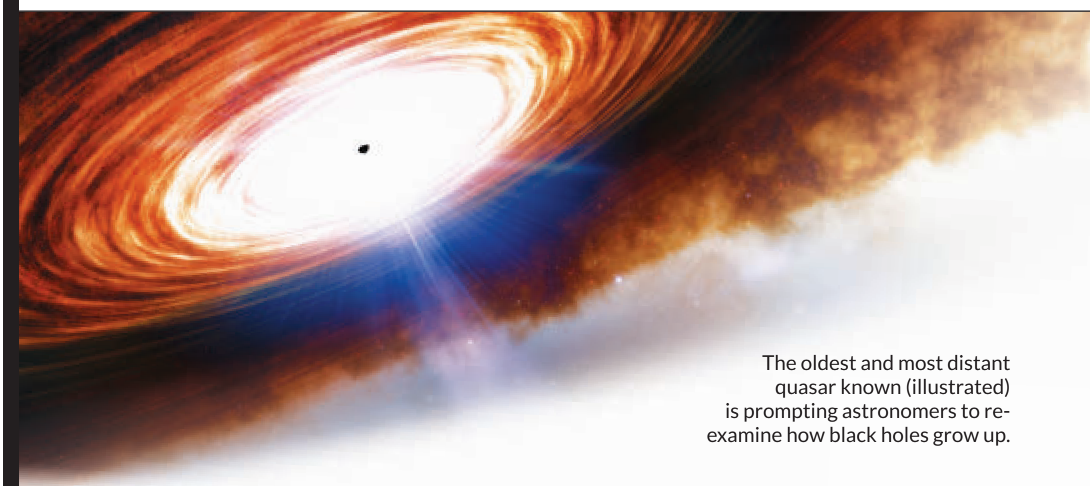
Electric eels shock with swarm hunting tactics

One Volta's electric eel — able to subdue small fish with an 860-volt jolt — is scary enough. Now imagine more than 100 eels swirling about, unleashing coordinated electric attacks.

Such a sight was assumed to be only the stuff of nightmares, at least for prey. Researchers had long thought that these eels were solitary, nocturnal hunters that use their electric sense to find smaller fish as the fish sleep (*SN: 1/10/15, p. 14*). But in a remote region of the Amazon, groups of over 100 Volta's electric eels (*Electrophorus voltai*) hunt together, corralling thousands of smaller fish together to shock and devour them, researchers report online January 14 in *Ecology and Evolution*.

"This is hugely unexpected," says Raimundo Nonato Mendes-Júnior, a biologist at the Chico Mendes Institute for Biodiversity Conservation in Brasilia, Brazil, who wasn't involved in the study. "It goes to show how very, very little we know about how electric eels behave in the wild."

Group hunting is quite rare in fishes, says Carlos David de Santana, an evolutionary biologist at the Smithsonian National Museum of Natural History in Washington, D.C. "I'd never even seen more than 12 electric eels together in the field," he says. That's why he was



The oldest and most distant quasar known (illustrated) is prompting astronomers to reexamine how black holes grow up.

NOIRLAB/NSF AND AURA, J. DA SILVA

THE –EST

Oldest known black hole mystifies scientists

The most ancient black hole ever discovered is so big it defies explanation.

This active supermassive black hole, called a quasar, lies at the heart of a galaxy over 13 billion light-years from Earth and boasts a mass of 1.6 billion suns. The quasar, dubbed J0313-1806, dates to when the universe was just 670 million years old. That makes J0313-1806 two times heavier and 20 million years older than the last record holder.

Finding such a huge quasar so early in the universe's history challenges astronomers' understanding of how these cosmic beasts first formed, researchers report in the Jan. 20 *Astrophysical Journal Letters*.

Quasars are thought to grow from smaller seed black holes that gobble up matter. Astronomer Feige Wang of the University of Arizona in Tucson and colleagues calculated that even if J0313-1806's seed formed right after the universe's first stars and grew as fast as possible, it would have needed a starting mass of at least 10,000 suns. Seed black holes typically form through the collapse of massive stars — a process that can make black holes with starting masses of only up to a few thousand suns. A gargantuan seed black hole may have formed from the collapse of primordial hydrogen gas, Wang suggests, or perhaps J0313-1806's seed started small and black holes can grow faster than scientists think. — *Maria Temming* stunned in 2012 when his colleague Douglas Bastos, now a biologist at the National Institute of Amazonian Research in Manaus, Brazil, reported seeing more than 100 eels congregating and seemingly hunting together in a small lake in northern Brazil.

Two years later, de Santana's team returned to the lake to make more detailed observations. The nearly 2-meter-long eels lethargically lay in deeper waters during much of the day, the researchers found. But at dusk and dawn, these long dark streaks swirl together to form a writhing circle more than 100 strong that herds thousands of smaller fish into shallower waters.

After corralling the prey, smaller groups of about 10 eels unleash coordinated electric attacks that can send shocked fish flying from the water. The researchers haven't yet measured the combined voltage of such attacks, but 10 Volta's electric eels firing together could, in theory, power something like 100 lightbulbs, de Santana says. The stunned, floating prey make easy pickings for the mass of eels. The whole event lasts about two hours.

So far, such aggregations have been observed in only one lake. But de Santana suspects that group hunting may be advantageous in other lakes and rivers with large shoals of small fish. Much of the eels' range remains underexplored by scientists, so de Santana and colleagues are launching a citizen science project with Indigenous communities to identify more spots where many eels live together, de Santana says. "There is still so much we don't know about these organisms." — *Jonathan Lambert*

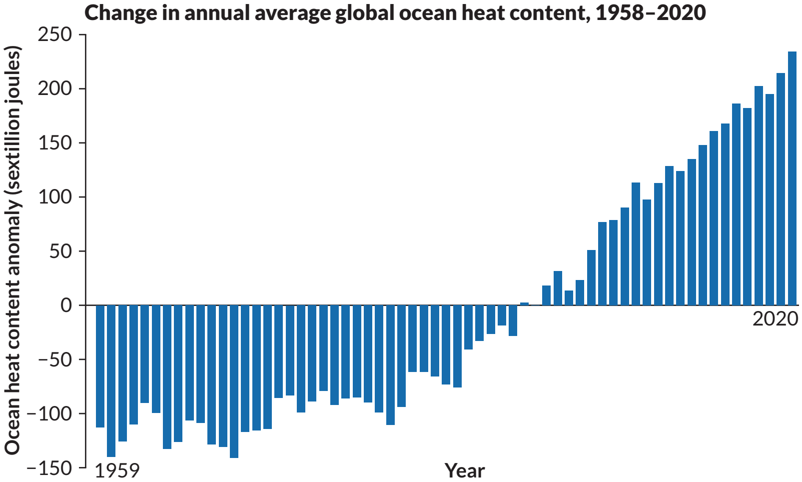
Once thought of as lone predators, Volta's electric eels (one shown) have been spotted hunting in swarms of more than 100 individuals.

SCIENCE STATS

Earth's oceans broke heat records in 2020

The total amount of heat stored in the upper oceans in 2020 was higher than in any other year on record dating back to the 1950s, researchers report online January 13 in *Advances in Atmospheric Sciences*. Climate scientist Michael Mann of Penn State and colleagues analyzed water temperature data from around the globe. The oceans' upper 2,000 meters had 234 sextillion, or 10^{21}, joules more heat energy in 2020 than the annual average from 1981 to 2010 (see graph below). Heat energy storage was up about 20 sextillion joules from 2019 — suggesting that in 2020, the oceans absorbed enough heat to boil 1.3 billion kettles of water. The two previous record holders were 2019 and 2017. "What we're seeing here is a variant on the movie *Groundhog Day*," Mann says. Overall, based on average land and sea temperature, 2020 tied with 2016 for Earth's hottest year on record (*SN Online: 1/14/21*). — *Maria Temming*

Change in annual average global ocean heat content, 1958–2020



SOURCE: L. CHENG *ET AL*/*ADVANCES IN ATMOSPHERIC SCIENCES* 2021

FROM TOP: L. SOUSA; T. TIBBITTS

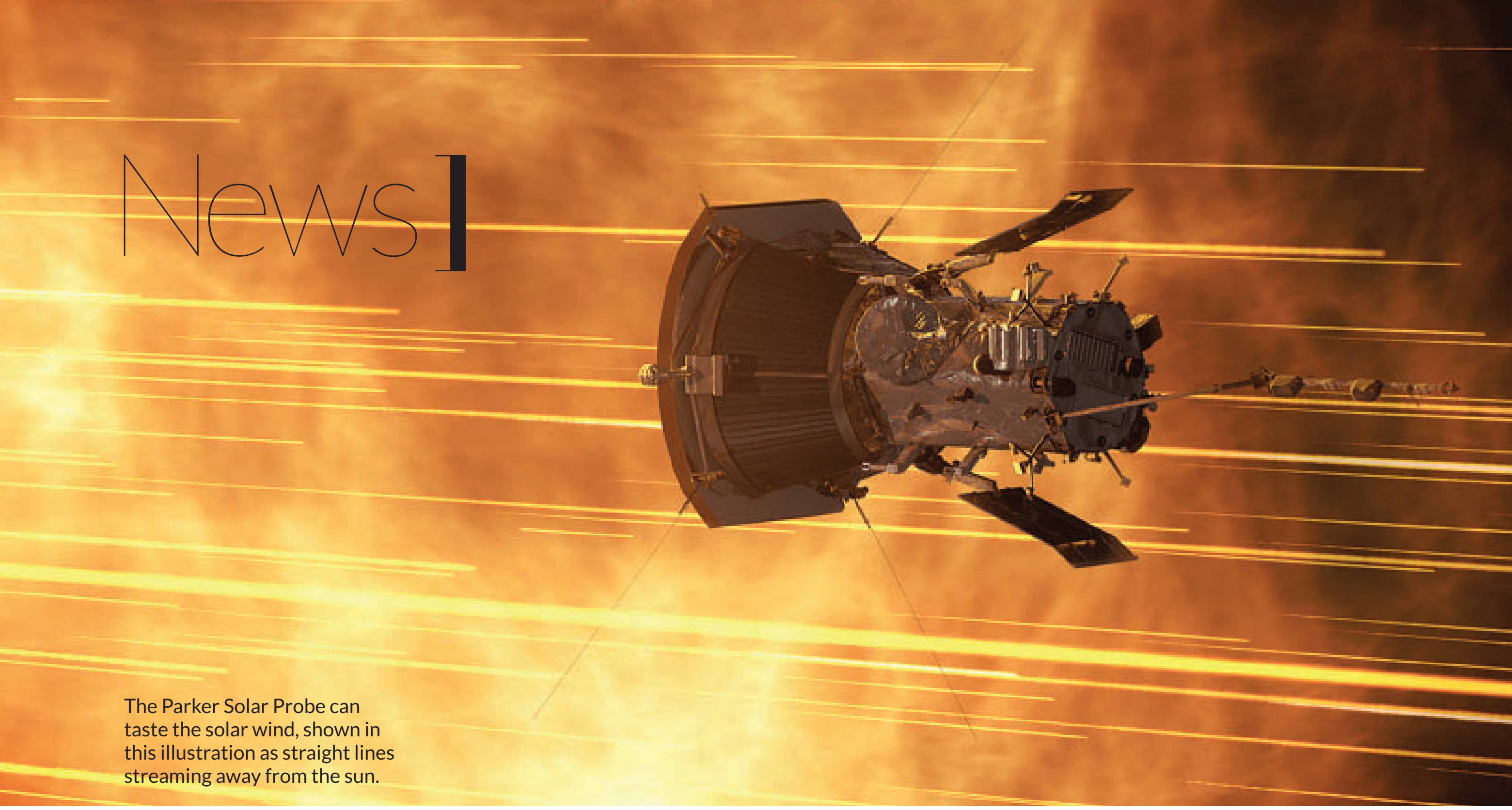
TEASER

A new zinc-air battery keeps going and going

Zinc-air batteries are lightweight and compact, but they're usually not rechargeable. By tweaking the building materials, researchers have created a prototype that could be recharged hundreds of times. Such long-lasting devices, described in the Jan. 1 *Science*, could one day power electric cars.

In a standard zinc-air battery, oxygen from the air enters the cathode and reacts with water from a liquid called an electrolyte to form hydroxide. Hydroxide travels from the cathode to an anode, and then reacts with zinc to release energy. But this reaction is not very reversible, making the battery hard to recharge. The electrolyte can also degrade the cathode and anode, shortening the battery's life span.

Materials scientist Wei Sun of the University of Münster in Germany and colleagues built a zinc-air battery using a new electrolyte. Water-repellent ions in the liquid prevent hydroxide from forming at the cathode surface. Zinc ions from the anode travel to the cathode and react directly with oxygen. Running the reaction backward recharges the battery, and the electrolyte is not corrosive. In lab tests, Sun's team recharged the prototype 320 times over 160 hours. — *Maria Temming*



The Parker Solar Probe can taste the solar wind, shown in this illustration as straight lines streaming away from the sun.

ATOM & COSMOS

NASA's Parker probe gets help from other telescopes

During a recent flyby, dozens of observatories watched the sun from every angle

BY LISA GROSSMAN

The Parker Solar Probe is no stranger to the sun. On January 17, the NASA spacecraft made its seventh close pass of our star, coming within 13.5 million kilometers of the sun's scorching surface.

And this time, Parker had plenty of company. A lucky lineup meant that dozens of other spacecraft and Earth-based observatories were trained on the sun at the same time. Together, all of these telescopes are providing unprecedented views of the sun that should help solve some of the most enduring mysteries of our star.

Parker's recent orbit was "really an amazing one," says mission project scientist Nour Raouafi of the Johns Hopkins Applied Physics Laboratory in Laurel, Md.

Chief among the spacecraft that joined the watch party was newcomer Solar Orbiter, which the European Space Agency launched in February 2020. As Parker swung by the sun in January, Solar Orbiter was watching from the other side of the star.

"This is partially luck," solar physicist Timothy Horbury of Imperial College London said December 10 at a news briefing at the virtual meeting of the American Geophysical Union. "Nobody planned to have Parker Solar Probe and Solar Orbiter operating together; it's just come out that way."

Working together, the sungazers will tackle long-standing puzzles: how the sun creates and controls the solar wind, why solar activity changes over time and how to predict powerful solar outbursts.

Teamwork

During its nearly seven-year mission, the Parker Solar Probe, which launched in 2018, will circle the sun 24 times, eventually swinging within about 6 million kilometers of the sun — roughly one-tenth the average distance between Mercury and the sun (*SN: 7/21/18, p. 12*). All of those flybys will give Parker's heavily shielded instruments the best taste yet of the plasma and charged particles of the sun's outer atmosphere, the corona (*SN: 9/15/18, p. 16*).

Because Parker gets so close, its cameras cannot take direct pictures of the solar surface. Solar Orbiter, though, will get no closer than 42 million kilometers, letting it take the highest-resolution images of the sun ever. The mission's official science phase won't begin until November 2021, but Solar Orbiter has already snapped images revealing tiny "campfire" flares that might help heat the corona (*SN: 8/15/20, p. 8*).

During Parker's seventh close encounter with the sun on January 12–23, Solar Orbiter observed the sun from a vantage point almost opposite to Parker's view. About a dozen other observers in space watched as well, including ESA and the Japan Aerospace Exploration Agency's BepiColombo spacecraft that is on its way to Mercury and NASA's veteran sun watcher STEREO-A. Both flanked Parker on either side of the sun. Telescopes on Earth were watching from a vantage point about 135 million kilometers behind Parker, making a straight line from Earth to the spacecraft to the sun.

The situation was similar to Parker's

NASA

fourth flyby in January 2020, when nearly 50 observatories watched the sun in tandem with the probe, Raouafi says. Those observations led to a special issue of *Astronomy & Astrophysics*. One of the reported results confirmed that there is a region around the sun free of dust, which was predicted in 1929. "That was amazing," says Raouafi, who hoped the recent seventh campaign would turn out to be "that good or even better."

In the wind

At the AGU meeting, researchers presented new results from Parker's second year of observations. The results deepen the mystery of magnetic kinks called "switchbacks" that Parker observed in the solar wind, a constant stream of charged particles flowing away from the sun (*SN: 12/21/19 & 1/4/20, p. 6*), Raouafi says.

Some observations support the idea that the kinks originate at the base of the corona and are carried past Parker and beyond, like a wave traveling along a jump rope. Other data suggest the switchbacks are created by turbulence within the solar wind itself.

Figuring out which idea is correct could help pinpoint how the sun produces the solar wind in the first place. "These [switchbacks] could be the key to explaining how the solar wind is heated and accelerated," Raouafi said in a talk recorded for AGU.

Meanwhile, Solar Orbiter's zoomed-in images plus simultaneous measurements of the solar wind may allow scientists to trace the wind's energetic particles back to their birthplaces on the sun's surface. Campfire flares — the "nanoflares" spotted by Solar Orbiter — might even explain the switchbacks, Horbury says.

"The goal is to connect tiny transient events like nanoflares to changes in the solar wind," Horbury said in the news briefing.

Waking up with the sun

Parker and Solar Orbiter couldn't have arrived at a better time. "The sun has been very quiet, in a deep solar minimum for the last several years," Horbury said. "But the sun is just beginning to wake up now."

13.5
million kilometers

Closest the Parker Solar Probe has gotten to the sun so far

Both spacecraft have seen solar activity building over the last year. During its sleepy period, the sun displays fewer sunspots and outbursts such as flares and coronal mass ejections, or CMEs. But as the sun wakes up, those signs of increasing magnetic activity become more common and more energetic.

On November 29, Parker observed the most powerful flare it had seen in the last three years, followed by a CME that ripped past the spacecraft at 1,400 kilometers per second.

"We got so much data from that," Raouafi says. As the Parker Solar Probe gets even closer to the sun, more CMEs should pass by the spacecraft, which will tell scientists about how the sun launches these outbursts.

Solar Orbiter caught an outburst too. On April 19, a CME passed by the spacecraft about 20 hours before its effects arrived at Earth. That's a bigger heads-up than with previous spacecraft, which give observers on Earth only about 40 minutes of warning before a CME arrives.

"We can see how that CME evolves as it travels away from the sun in a way we've never been able to do before," said Horbury.

Strong CMEs can knock out satellites and power grids, so having as much forewarning as possible is important. A future spacecraft at Solar Orbiter's distance from the sun could help give that warning.

Looking forward

Parker's recent orbit was the first time the probe and Solar Orbiter watched the sun in tandem, but not the last. "There will be plenty of opportunities like this one," Raouafi says.

He's looking forward to one in particular: the solar eclipse of 2024. On April 8, 2024, a total eclipse will cross North America from Mexico to Newfoundland. Solar scientists plan to make observations from all along the path of totality, similar to how they watched the total eclipse of 2017 (*SN Online: 8/11/17*).

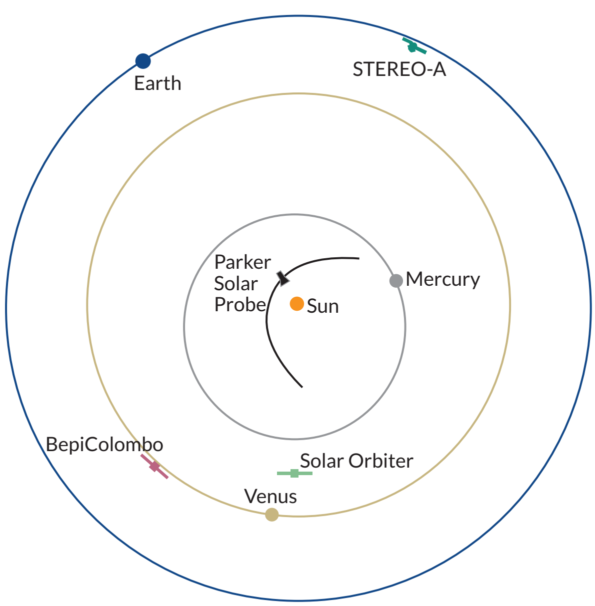
During the total eclipse, the Parker Solar Probe will be on its second-closest orbit, between 7 million and 8 million kilometers from the sun. Parker and Solar Orbiter will be "almost on top of each other," Raouafi says — both spacecraft will be together off to one side of the sun as seen from Earth. Whatever prominences and other shapes in the corona are visible to observers on Earth will be headed right at the spacecraft.

"They will be flying through the structure we will see from Earth during the solar eclipse," Raouafi says. The combined observations will tell scientists how features on the sun evolve with time.

"I think it is a new era," Horbury said. "The next few years is going to be a step change in the way we see the sun." ■

Staring at the sun

When the Parker Solar Probe flew past the sun in January, a host of other spacecraft and Earth-based telescopes were trained on our star too. This diagram shows Parker's path January 12–23 (black arc) and the relative positions of three other spacecraft: Solar Orbiter, BepiColombo and STEREO-A.



JHU-APL

LIFE & EVOLUTION

Monitor lizards engineer ecosystems

In Australia, the reptiles' burrows shelter a variety of animals

BY JAKE BUEHLER

Meters below the copper, sun-broiled dirt of northwestern Australia, an entire community hides in the dark. Geckos lay eggs as centipedes and scorpions scuttle by. A snake glides deeper underground, away from the light. This subterranean menagerie capitalizes on an old burrow, gouged into the earth by a massive lizard.

Two species of monitor lizard dig these burrows, which can have a great impact on local biodiversity by providing shelter to a wide assortment of animals, researchers report. The findings, published online December 18 in *Ecology*, reveal the lizards to be "ecosystem engineers," the researchers say, akin to beavers that flood streams with dams.

Ecologist Sean Doody of the University of South Florida in St. Petersburg started monitoring the cat-sized lizards with Australian colleagues to track how invasive cane toads harm the reptiles.

Until less than a decade ago, it wasn't clear where these monitor lizards lay eggs. While excavating burrows of the yellow-spotted monitor (*Varanus panoptes*), Doody's team found eggs at the very bottom of what turned out to be holes with a tight helical shape. These burrows plunge up to four meters into the soil — deeper than any other known vertebrate nest. The nests were part of warrens consisting of dozens of twisting burrows, each made by a single monitor lizard and arranged in the soil like dozens of cavatappi noodles set vertically.

"We kept digging these things up, and we started finding lots of animals in most of them," Doody says.

The team found other lizards, snakes, toads and arthropods in the nests of yellow-spotted monitors and Gould's monitor lizards (*V. gouldii*), which dig similar burrows. At first it was a few creatures here and there, Doody says, but then the team found 418 *Uperoleia* frogs in a single warren. In all, the team found nearly 750 individuals of 28 different vertebrate species in 16 warrens made up of many individual nesting burrows, plus about a dozen separate foraging burrows, made when monitors dig for prey.

Some animals use the burrows for overwintering, Doody says. Others use them as refuges during the hot, dry summer. Still others catch prey in there, while "some are probably hiding from predators," he says. "And some are even laying their eggs in the burrow."

Very few mammals use the burrows.

A monitor lizard like the one shown excavated this twisting tunnel for use as a nest. Burrows do double duty as refuges for other species.

LIFE & EVOLUTION

Some snakes turn into lassos to climb

The tactic allows for scaling wide tree trunks or poles

BY MARIA TEMMING

Snakes do a lot more than slither. Some swim, others sidewind across sand and some even fly. But no one has ever seen a snake move the way that a brown tree snake does. By wrapping its tail around a tree or pole in a lasso-like grip and wriggling to propel itself, the snake can shimmy up structures that would otherwise be too wide to climb.

Better understanding how brown tree snakes (*Boiga irregularis*) get around could inform strategies to control their population on Guam, where the snakes are an invasive species and have wiped out almost all of the native forest birds.

The discovery of the lasso climbing method, reported in the Jan. 11 *Current Biology*, was somewhat serendipitous. Ecologist Julie Savidge of Colorado State University in Ft. Collins and colleagues were investigating ways to keep the tree-climbing snakes away from Micronesian starlings (*Aplonis opaca*) — one of only two native forest birds left on Guam.

One approach tested whether a wide pipe, or baffle, around a pole could prevent snakes from reaching a starling nest box at the top. In reviewing hours of footage, the team saw a snake do something unexpected: It lassoed itself around the baffle and began scooting upward.

Snakes typically climb trees that are too smooth to slither up by coiling around a trunk multiple times. A snake wraps the front of its body around the trunk and then coils its back end around the tree in another loop to get a second grip. The snake then stretches its neck up and repeats the process to inch upward. But wrapping around a tree multiple times limits the width of a tree that a snake can scale. Using a single, large, lasso-like grip allows the brown tree snake to climb wider trees — or overcome baffles, says study coauthor Bruce Jayne, a biologist at the University of Cincinnati.

In lab experiments, the researchers observed brown tree snakes using this lasso-like posture when placed inside an enclosure with a wide pole topped with a dead mouse for bait. But the lasso climbing method is not very efficient. Five snakes, ranging from 1.1 to 1.7 meters long, climbed less than a millimeter per second, on average. The snakes probably save the technique for the rare occasions they encounter trees or poles too wide and smooth to scale any other way.

Gregory Byrnes, a biologist at Siena College in Loudonville, N.Y, is not entirely surprised that brown tree snakes have devised a way to deal with wide trees or baffles. "They have so

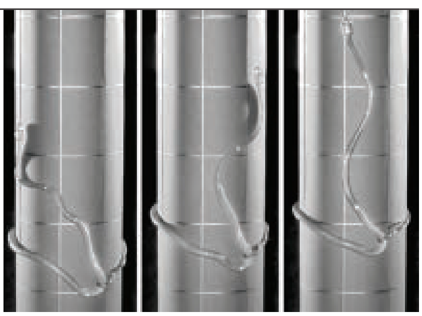
Watch a snake lasso itself up a pole at bit.ly/SN_SnakeLasso

With the “massive smell of reptile” in there, they may steer clear, Doody says.

The variety of nonmammals using the burrows is “incredible,” says Sophie Cross, an ecologist at Curtin University in Perth, Australia, who was not involved with the research. Monitors “will pretty much eat anything they can catch or dig out from the ground,” she says. “I am surprised that so many animals use these burrows, given a lot of them would be easy prey for a monitor lizard.”

If the smaller residents use the burrows at a different time than the monitors, the groups might avoid conflict. The monitors appear to lay eggs over a few weeks and leave the eggs to incubate over the eight-month dry season, Doody says.

Given the widespread use of the burrows, Doody has concerns about the ecological effects of the cane toad invasion. Monitor lizards — naïve to the toads’ potent toxins — eat the amphibians, and as a result, are rapidly dying, Doody says. Warrens are filling in, leaving less refuge for other animals. “You go from hundreds of animals using a warren system to zero.” ■



To climb a wide pole, a brown tree snake, recorded by an infrared camera, lassos itself around the pole and wriggles the loop of its tail to propel itself upward.

J. SAVIDGE ET AL/CURRENT BIOLOGY 2021

much control over their bodies that if they’re given a challenge ... they figure out a way to [overcome] it,” he says.

Testing the limits of this agility could lead to better protection of Guam’s birds, Savidge says. Already, after the researchers placed bird boxes on utility poles that are too wide for brown tree snakes to lasso up, “the birds adopted these birdhouses and have done very, very well,” she says. ■

BODY & BRAIN

Pain and relief are ‘catching’ in mice

After mingling, a rodent can mirror its companion’s feelings

BY CAROLYN WILKE

In pain and pain relief, mice may feel for each other.

Research has shown that mice can “catch” the emotions of an injured or fearful fellow. When mice are injured, healthy mice living alongside them behave as though in pain. Now, a study suggests that pain relief is contagious too.

In the last decade, researchers have done a lot of work showing that animals can pick up and share each other’s emotions, particularly fear, says Monique Smith, a neuroscientist at Stanford University. She and colleagues published the new findings on pain relief in the Jan. 8 *Science*.

Investigating these building blocks of empathy in animals can help researchers understand human empathy, Smith says, and may someday lead to treatments for disorders that affect the ability to feel empathy. “Pain isn’t just a physical experience,” Smith says. “It’s an emotional experience” as well.

> “Pain isn’t just a physical experience.”
> MONIQUE SMITH

In experiments on pairs of mice, one mouse received an injection that caused arthritis-like inflammation in one hind paw while the other mouse was unharmed. The mice then hung out together for an hour. Injected mice acted as though one paw was in pain, showing extra sensitivity to being prodded there with a wire. Uninjured companions acted as though they were in the same amount of pain, but in both hind paws. “The behavior is astounding,” says neuroscientist Jeffrey Mogil of McGill University in Montreal, who was not part of the work.

In other experiments, both mice received the injection, but one also got soothing morphine. For hours after the mice mingled, the second mouse behaved as though it also got the drug. In a control group where both mice only experienced inflammation, the animals’ touch sensitivity didn’t change after time together.

To understand how mice pick up on each other’s feelings, Smith and colleagues watched which brain regions were active after the mice spent time together. The team saw nerve cells, or neurons, firing in the anterior cingulate cortex, an area important in humans for empathy and part of the brain region responsible for memory and cognition.

The team found neurons connecting this area to other parts of the brain, including the nucleus accumbens, which deals with motivation and social behavior. When the scientists disrupted that neural connection, “the animals no longer were able to manifest empathy” for pain or pain relief, says team member and Stanford neuroscientist Robert Malenka.

The transfer of other emotions may rely on different brain connections. The researchers also examined how mice feel each other’s fear when mice saw other mice receive an electric shock. Fear transfer relied on connections from the anterior cingulate cortex to part of the amygdala, a region known to respond to fear. That suggests that different processes in the brain are involved in different types of empathy. But the differences may also be linked to how mice sense their fellows’ emotions, Mogil says. In the pain and pain relief experiments, mice spent time together sniffing each other, and odors can contain clues to mice’s feelings. But in the fear tests, visual or auditory cues conveyed emotions.

“Not surprisingly, the circuits that they’re looking at are remarkably similar to some of these processes in humans,” says Jules Panksepp, a social neuroscientist at the University of Wisconsin–Madison. Research points to a shared evolutionary basis for empathy in humans and mice.

If scientists can home in on the neurochemicals that foster empathic processes, Panksepp says, researchers may be able to design drugs to treat conditions, such as social personality disorders, that cause empathy to go awry. ■

ATOM & COSMOS

A galaxy on the verge of a shutdown

CQ 4479 has both new stars forming and an active black hole

BY LISA GROSSMAN

A distant galaxy has been caught in the act of shutting down.

The galaxy is still forming plenty of new stars. But it also has an actively feeding supermassive black hole at its center that will bring star formation to a halt within a few hundred million years, astronomers reported January 11 at the virtual meeting of the American Astronomical Society. Studying this galaxy and others like it will help astronomers figure out exactly how such shutdowns happen.

"How galaxies precisely die is an open question," says astrophysicist Allison Kirkpatrick of the University of Kansas in Lawrence. "This could give us a lot of insight into that process."

Astronomers think galaxies typically start out making stars with a passion. The stars form from pockets of cold gas that contract under their own gravity and ignite thermonuclear fusion in their centers. But at some point, something disrupts the cold star-forming fuel and sends it toward the supermassive black hole at the galaxy's core. That black hole gobbles the gas, heating it white-hot. An actively feeding black hole can be seen from billions of light-years away and is known as a quasar. Radiation from the hot gas pumps extra energy into the rest of the galaxy, blowing away or heating the remaining gas until the star-forming factory closes for good.

> "How galaxies precisely die is an open question."
> ALLISON KIRKPATRICK

That picture fits with the types of galaxies astronomers typically see: either star formers or dormant galaxies. But while examining data from large surveys of the sky, Kirkpatrick and colleagues noticed another type. The team found about two dozen galaxies that emit energetic X-rays characteristic of an actively feeding black hole, but also shine in low-energy infrared light, a sign that cold gas is still present. Kirkpatrick and colleagues dubbed these galaxies "cold quasars" in the Sept. 1 *Astrophysical Journal*.

"When you see a black hole actively accreting material, you expect that star formation has already shut down," says coauthor and astrophysicist Kevin Cooke, also of the University of Kansas. "But cold quasars are in a weird time when the black hole in the center has just begun to feed."

To investigate cold quasars in more detail, Kirkpatrick and Cooke used SOFIA, an airplane with a telescope that can see in a range of infrared wavelengths that the original cold quasar observations didn't cover. In 2019, SOFIA looked at a galaxy called CQ 4479, a cold quasar about 5.25 billion light-years from Earth.

CQ 4479 has about 20 billion times the mass of the sun in stars and is adding about 95 suns per year, the researchers found. (That's a furious rate compared with the Milky Way, which builds two or three solar masses of new stars per year.) CQ 4479's central black hole is 24 million times as massive as the sun, growing at about 0.3 solar masses per year. In terms of percentage of their total mass, the stars and black hole are growing at the same rate, Kirkpatrick says.

That "lockstep evolution" runs counter to expectations. "You should have all your stars finish growing first, and then your black hole grows," Kirkpatrick says. "This [galaxy] shows there's a period that they actually do grow together."

Cooke and colleagues estimated that in half a billion years, all the cold star-forming gas will have heated up or blown away.

Given that galaxies eventually switch off star formation, it makes sense that there should be a period of transition, says astronomer Alexandra Pope of the University of Massachusetts Amherst, who was not involved in the new work. The findings are a "confirmation of this important phase in the evolution of galaxies," she says. ■

NASA GODDARD SPACE FLIGHT CENTER, CHRIS SMITH/GESTAR/USRA

ATOM & COSMOS

Astronomers spot a flaring magnetar

The energetic outburst originated in another galaxy

BY LISA GROSSMAN

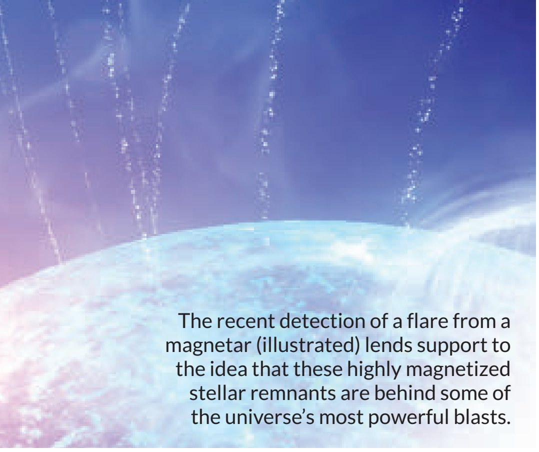
For the first time, astronomers have definitively spotted a flaring magnetar in another galaxy.

These ultramagnetic stellar corpses were thought to be responsible for some of the highest-energy explosions. But until this burst, no one could prove it, astronomers reported January 13 at the virtual meeting of the American Astronomical Society and in papers in *Nature* and *Nature Astronomy*.

Astronomers have seen flaring magnetars in the Milky Way, but their brightness makes it impossible to get a good look at them. Flaring magnetars in other galaxies may have been spotted before, but "the others were all a little circumstantial and not as rock solid," says astrophysicist Victoria Kaspi of the McGill Space Institute in Montreal, who was not involved in the new discovery. These new findings are "so incontrovertible, it's like, OK, this is it. There's no question anymore."

The first sign of the magnetar arrived as a blast of X-rays and gamma rays on April 15. Five telescopes in space, including the Fermi Gamma-ray Space Telescope, observed the blast, giving scientists enough information to track down the source: the galaxy NGC 253, also known as the Sculptor galaxy, 11.4 million light-years from Earth.

At first, astronomers thought the blast was a type of cataclysmic explosion called



The recent detection of a flare from a magnetar (illustrated) lends support to the idea that these highly magnetized stellar remnants are behind some of the universe's most powerful blasts.

a short gamma-ray burst, or GRB, which is typically caused by colliding neutron stars or other destructive cosmic events.

But the signal looked weird for a short GRB: It rose to peak brightness quickly, within two milliseconds, dimmed for another 50 milliseconds and appeared to be over by about 140 milliseconds. As the signal faded, some of the telescopes detected fluctuations in the light that changed faster than a millisecond.

Typical short GRBs don't change like that, astrophysicist Oliver Roberts of the Universities Space Research Association in Huntsville, Ala., said at a news briefing. But flaring magnetars in our own galaxy do, when the bright spot where the flare was emitted comes in and out of view as the magnetar spins.

Also surprising, the Fermi telescope caught gamma rays with energies higher than a gigaelectron volt arriving four minutes after the initial blast. There is no way for the known sources of short GRBs to do that.

"We've discovered a masquerading magnetar in a nearby galaxy, and we've unmasked it," astrophysicist Kevin Hurley of the University of California, Berkeley said at the briefing.

The researchers think that the flare was triggered by a massive starquake 1,000 trillion trillion, or 10^{27}, times as large as a magnitude 9.5 earthquake. The starquake led the magnetar to release a blob of plasma that sped away at nearly the speed of light, emitting gamma rays and X-rays as it went.

The discovery suggests that at least some signals that look like short GRBs are in fact from magnetar flares, as astronomers have long suspected. It also means that three earlier events that astronomers had flagged as possible magnetar flares probably were indeed such flares, giving astronomers a population of magnetar flares to compare with each other.

The findings could have implications for fast radio bursts, another mysterious cosmic signal that has had astronomers scratching their heads for over a decade. Several lines of evidence connect fast radio bursts to magnetars, including a signal coming from within the Milky Way that coincidentally also arrived in April 2020 (*SN: 7/4/20 & 7/18/20, p. 12*).

"That [discovery] lent extra credence to fast radio bursts being [from] magnetars," Kaspi says.

In light of the new findings, Kaspi compared the apparent frequency of magnetar flares in other galaxies with the frequency of fast radio bursts and found the rates are similar. "That argues that actually most or all fast radio bursts could be magnetars.... I don't think yet it's the total solution," but it's a good step, she says. ■

EARTH & ENVIRONMENT

Fossil fuels will stay dominant in Africa

A transition to mostly renewable energy is unlikely by 2030

BY CAROLYN GRAMLING

Africa's electricity capacity is expected to double by 2030 — and with the rapidly dropping cost of renewable energy technologies, the continent might seem poised to go green. But an analysis suggests that fossil fuels will still dominate Africa's energy mix over the next decade.

Scientists used a machine learning approach that analyzes what characteristics, such as fuel type and financing, controlled past successes and failures of power plants across Africa. The findings suggest that renewable energy sources such as wind and solar power will make up less than 10 percent of Africa's total electrical power generation by 2030, the team reports January 11 in *Nature Energy*.

In 2015, 195 nations pledged to limit global warming to "well below" 2 degrees Celsius by 2100. The world would have to reduce fossil fuel emissions by 2.7 percent each year from 2020 to 2030, but current pledges are nowhere near enough to achieve that target. And the energy demand from developing economies is expected to increase dramatically by 2030 — possibly leading to even more emissions over the next decades.

However, the price of renewable energy technologies has rapidly dropped over the last few years. So many scientists and activists have said they hope African countries might be able to take advantage of these technologies, leapfrogging past carbon-intensive coal or oil-based energy growth and straight into building renewable energy plants.

"We wanted to understand whether Africa is actually heading in the direction of making that decisive leap," says Galina Alova, a sustainability scientist at the University of Oxford.

Alova, along with Oxford sustainability scientists Philipp Trotter and Alex Money, amassed data on nearly 3,000 energy projects — both fossil fuel and renewable — commissioned over the last 20 years across Africa. The team looked at both successful and failed power plants, as well as a variety of characteristics of the plants, such as how much energy a particular plant can produce, what type of fuel it uses and how it's financed.

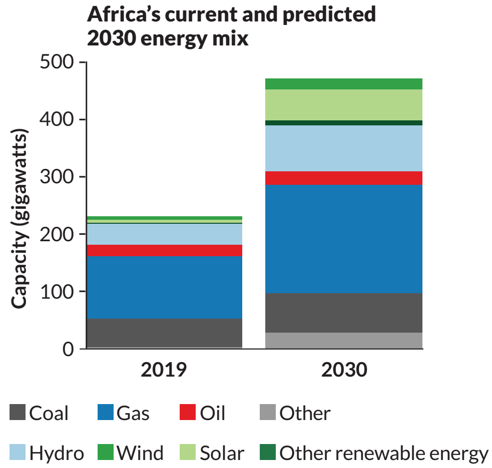
The team used a machine learning approach, creating a computer algorithm to identify the characteristics that best predicted success in the past. Then, the scientists analyzed the chances for success of almost 2,500 projects now in the pipeline, based on those features, as well as on different country characteristics, such as population density, political stability and economic strength.

Those country-level factors matter, but they weren't the biggest predictors of success, Trotter says. "We do see some truth to good governance, but project-level [factors have] been consistently more important."

Those factors include a power plant's size and whether the plant had public or private financing. Smaller renewable energy plants tend to have a better chance of success than larger projects, as do plants with financing from large public funders, such as the World Bank, which are less likely to pull out in the face of roadblocks. And though there has been a recent uptick in the chances for success for solar energy, oil and gas projects still have a much greater chance to succeed.

What this adds up to, the team says, is that by 2030, fossil fuels will still account for two-thirds of all energy generation in Africa. Renewable energy such as wind and solar will account for less than 10 percent, with the remainder coming mostly from hydropower.

The results were "both quite surprising and unsurprising to me," says Wikus Kruger, who researches the African power sector at the University of Cape Town in South Africa. Finding that project-level factors are very significant tracks with his own work. But, he says, he is less convinced that renewables' decreasing cost won't be a bigger factor.



Fixed fuels Africa's total electricity capacity, the maximum possible energy that all of the power plants could generate if running under ideal conditions, is predicted to double by 2030. Fossil fuels are expected to account for the bulk of the energy mix. SOURCE: G. ALOVA, P.A. TROTTER AND A. MONEY/*NATURE ENERGY* 2021

"We are seeing this massive disruption [to the energy market], in terms of costs of renewables. It's just completely changed the way that planning is done," Kruger says. What he finds exciting is the rise of small renewable energy projects in conflict states that have struggled to get anything done. "People are willing to put smaller amounts [of money] into [more modular] projects that spread the risks out across a wide variety of countries."

One factor that could change the renewable energy outlook, Alova says, would be a large-scale cancellation of fossil fuel plants now in the pipeline. That's key because once these plants enter production, they can stay in operation for decades.

But changing the energy mix requires more than just a drop in renewable energy costs, Trotter says. "It's something that has to happen from the top, from African governments and the international development community." Those governments face a tricky balancing act between socioeconomic development and sustainability.

"It's paramount for Africa to develop and lift people out of poverty," he says. "But what is clear from our dataset is that there is an urgency to discuss the most sustainable way to do so." ■

E. OTWELL

Bacteria blamed for sea star deaths

When microbes deplete oxygen in water, the animals suffocate

BY ERIN GARCIA DE JESUS

The mysterious culprit behind a deadly sea star disease is not an infection, as scientists once thought.

Instead, multiple types of bacteria living near sea stars deplete oxygen from the water and effectively suffocate the animals, researchers report January 6 in *Frontiers in Microbiology*. Such microbes thrive when there are high levels of organic matter in warm water and create a low-oxygen environment that can make sea stars melt into a puddle of slime.

Sea star wasting disease, which causes tissue decay and loss of limbs, first gained notoriety in 2013 when sea stars off the U.S. Pacific Coast died in massive numbers. Outbreaks of the disease had occurred before 2013, but never at such a large scale.

Scientists suspected that a virus or bacterium might be making sea stars sick. That hypothesis was supported in a 2014 study that found unhealthy animals may have been infected by a virus. But subsequent studies found no relationship between the virus and dying sea stars, leaving researchers perplexed.

Finding that a boom of nutrient-loving bacteria can drain oxygen from the water and cause the wasting disease "challenges us to think that there might not always be a single pathogen or a smoking gun," says Melissa Pespeni, a biologist at the University of Vermont in Burlington who wasn't involved in the new research. Such a complex environmental scenario "is a new kind of idea for [disease] transmission."

There were many red herrings during the hunt for why sea stars were melting into goo, says Ian Hewson, a marine biologist at Cornell University. In addition to the original hypothesis of a viral cause — which Hewson's team reported in 2014 in the *Proceedings of the National Academy of Sciences* but later disproved — he and colleagues analyzed a range of other explanations in healthy, wild-caught sea stars brought to the lab. These included things like differences in water temperature and exposing the animals to bacteria. But nothing reliably triggered wasting.

Then the researchers examined the types of bacteria living with healthy sea stars compared with those living among animals that developed wasting disease while in the lab. "That was when we had our aha moment," Hewson says.

Bacteria known as copiotrophs, which thrive in environments with a lot of organic matter, were present around the sea stars at higher levels than normal either shortly before the animals developed lesions or as they did so, Hewson and colleagues found. Bacterial species that survive only in environments with little to no oxygen were also thriving, suggesting that some copiotrophs were using up oxygen from the surrounding water. In the lab, the sea stars began wasting when the researchers added organic matter such as phytoplankton or a common bacterial-growth ingredient to the tubs of water those microbes and sea stars were living in.

Sea star wasting disease can turn a healthy sea star, such as this leather star (top), into a puddle of goo, as happened to this ochre sea star (bottom) in California.

BOTH: I. HEWSON

Experimentally depleting oxygen from the water had a similar effect, causing lesions in 75 percent of sea stars, while none succumbed in a tub where oxygen levels remained steady. Sea stars take in oxygen through small external projections called skin gills. The lack of oxygen in the wake of flourishing copiotrophs leaves sea stars struggling for air, the data suggest. It's unclear how the animals degrade in low-oxygen conditions, but it could be due to massive cell death.

Although the disease isn't caused by a contagious pathogen, it is transmissible in the sense that dying sea stars generate more organic matter that spur bacteria to grow on healthy sea stars nearby. "It's a bit of a snowball effect," Hewson says.

The team also analyzed tissues from sea stars that had succumbed in the 2013–2014 mass die-off — which followed a large algal bloom — to see if such environmental conditions might explain that outbreak. In sea stars that perished, their fast-growing appendages had high amounts of a form of nitrogen found in low-oxygen conditions — a sign that those animals may have died from a lack of oxygen.

The problem may get worse with climate change, Hewson says. "Warmer waters can't have as much oxygen [compared with colder water] just by physics alone." Bacteria, including copiotrophs, also flourish in warm water.

But pinpointing the disease's likely cause could help experts better treat sick sea stars in the lab, Hewson says. Some techniques include increasing a water tank's oxygen levels or getting rid of extra organic matter with ultraviolet light or water exchange.

"There's still a lot to figure out with this disease, but I think [this new study] gets us a long way to understanding how it comes about," Pespeni says. ■

MATTER & ENERGY

Drones could help create a quantum internet

The quantum internet may be coming to you via drone.

Scientists have used drones to transmit particles of light, or photons, that share the quantum linkage called entanglement. The photons were sent to two locations a kilometer apart, researchers at Nanjing University in China report in the Jan. 15 *Physical Review Letters*.

Entangled quantum particles can retain their interconnected properties even when separated by long distances. Such counterintuitive behavior can be harnessed to allow new types of communication. Eventually, scientists aim to build a global quantum internet that relies on transmitting quantum particles. That would enable ultrasecure communications by using the particles to create secret codes to encrypt messages. A quantum internet could also allow distant quantum computers to work together, or perform experiments that test the limits of quantum physics.

Quantum networks made with fiber-optic cables are already beginning to be used. And a quantum satellite can transmit photons across China (*SN: 8/5/17, p. 14*). Drones could serve as another technology for such networks, with the advantages of being easily movable as well as relatively quick and cheap to deploy.

The researchers used two drones to transmit the photons. One drone created pairs of entangled particles, sending one particle to a station on the ground while relaying the other to the second drone. That machine transmitted the particle it received to a second ground station a kilometer away from the first. Future fleets of drones could work together to send entangled particles to recipients in a variety of locations. *— Emily Conover*

HUMANS & SOCIETY

The oldest known abrading tool dates to 350,000 years ago

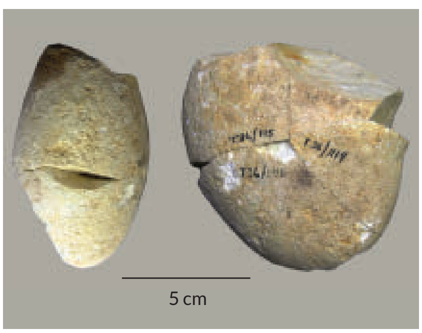
A round stone excavated at Israel's Tabun Cave in the 1960s represents the oldest known grinding or rubbing tool, say researchers who recently scrutinized the 350,000-year-old find.

The specimen marks a technological turn to manipulating objects using wide, flat stone surfaces, say Ron Shimelmitz, an archaeologist at the University of Haifa in Israel, and colleagues. Up to that time, stone implements had featured thin points or sharp edges. Microscopic wear and polish on a worn section of the Tabun stone resulted from it having been ground or rubbed against relatively soft material, such as animal hides or plants, the scientists conclude in the January *Journal of Human Evolution*.

Similar stones bearing signs of abrasion date to no more than around 200,000 years ago. Specific ways in which the Tabun stone was used remain a mystery. By around 50,000 years ago, though, human groups were using grinding stones to prepare plants and other foods, Shimelmitz says.

The team compared microscopic damage on the Tabun stone with that produced in experiments with nine similar stones collected not far from the cave site. Archaeology students forcefully ran each of the nine stones back and forth for 20 minutes over different surfaces: hard basalt rock, wood of medium hardness or a soft deer hide. Stones applied to deer hide displayed much in common with the business end of the ancient stone tool, including a wavy surface and clusters of shallow grooves.

It's unclear which evolutionary relatives of *Homo sapiens* — whose origins go back about 300,000 years — made the Tabun tool, Shimelmitz says.
— Bruce Bower



A flat surface at the top of a round stone, shown from two angles and originally found in three pieces at Israel's Tabun Cave, may have been used to grind or rub hides or other relatively soft material around 350,000 years ago.

EARTH & ENVIRONMENT

Space station detectors find the source of 'blue jet' lightning

Scientists have finally gotten a clear view of the spark that sets off an exotic type of lightning called a blue jet.

Blue jets zip upward from thunderclouds into the stratosphere. Whereas ordinary lightning excites a medley of gases in the lower atmosphere to glow white, blue jets excite mostly stratospheric nitrogen to create a signature blue hue.

These jets had been observed from the ground and aircraft, but it was hard to tell how they form without getting high above the clouds. Now, instruments on the International Space Station have spotted a blue jet emerging from a brief burst of electricity near the top of a thundercloud, researchers report in the Jan. 21 *Nature*.

Cameras and light-sensing instruments on the space station observed the blue jet in a storm over the Pacific Ocean in 2019. "The whole thing starts with what I think of as a blue bang," says Torsten Neubert, an atmospheric physicist at the Technical University of Denmark in Kongens Lyngby. From that "blue bang" — a flash of bright blue light near the top of a cloud about 16 kilometers high — a blue jet shot up into the stratosphere, climbing as high as about 52 kilometers and lasting hundreds of milliseconds.

The spark that generated the blue jet may have been a special kind of short-range electric discharge inside the thundercloud, Neubert says. Normal lightning forms from discharges between oppositely charged regions of a cloud — or a cloud and the ground — many kilometers apart. But turbulent mixing high in a cloud may bring oppositely charged regions within about a kilometer of each other, creating very short but powerful bursts of electric current, Neubert says. Scientists have seen evidence of such high-energy, short-range discharges in pulses of radio waves from thunderstorms detected by ground-based antennas. *— Maria Temming*

IRIS GROMAN-YAROSLAVSKI

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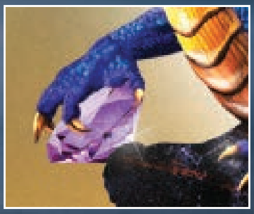

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Our Wild Universe

Einstein's general theory of relativity unveiled a dynamic and bizarre cosmos **By Elizabeth Quill**

Albert Einstein's mind reinvented space and time, foretelling a universe so bizarre and grand that it has challenged the limits of human imagination. An idea born in a Swiss patent office that evolved into a mature theory in Berlin set forth a radical new picture of the cosmos, rooted in a new, deeper understanding of gravity. Out was Newton's idea, which had reigned for nearly two centuries, of masses that appeared to tug on one another. Instead, Einstein presented space and time as a unified fabric distorted by mass and energy. Objects warp the fabric of spacetime like a weight resting on a trampoline, and the fabric's curvature guides their movements. With this insight, gravity was explained.

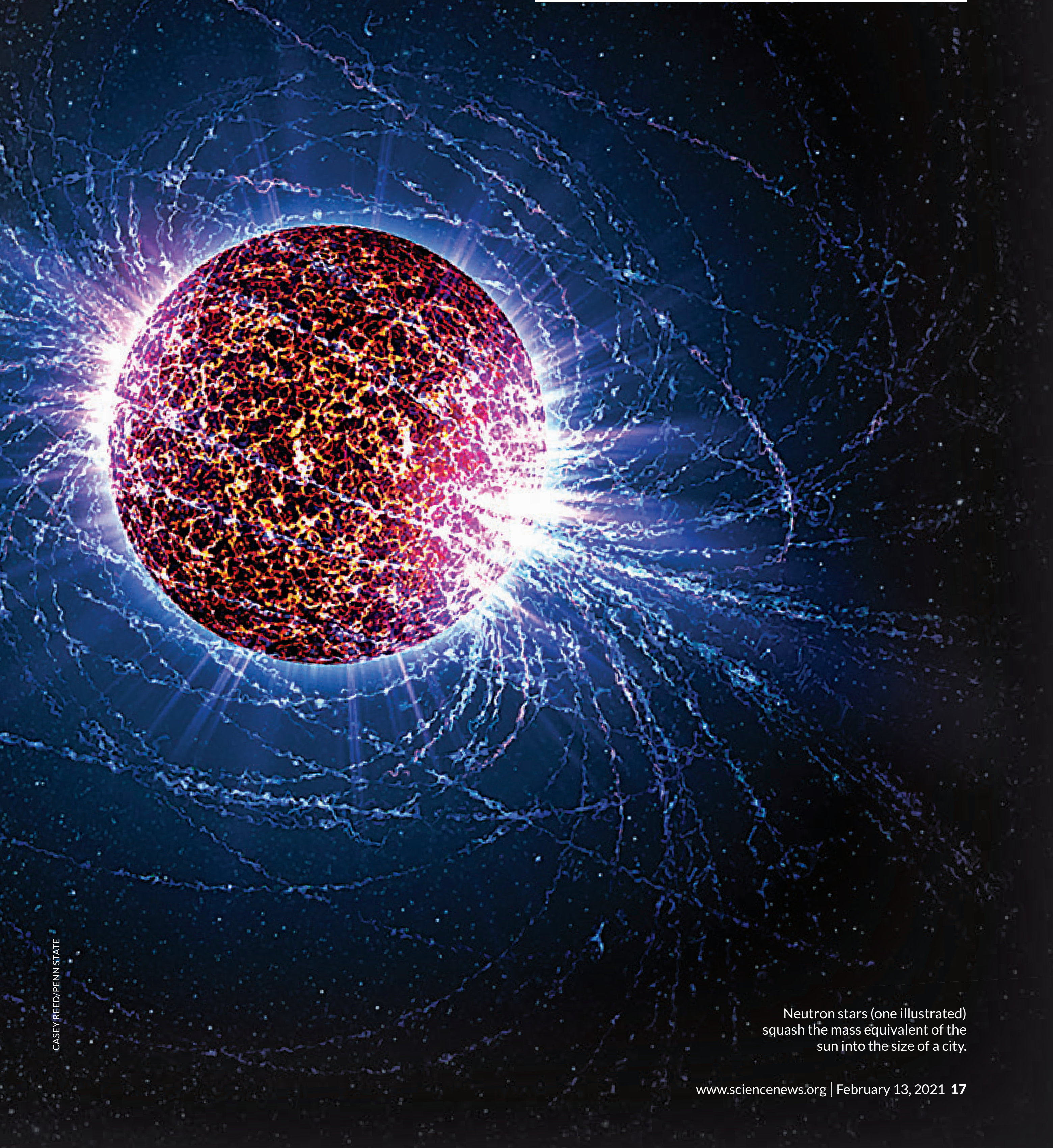
Einstein presented his general theory of relativity at the end of 1915 in a series of lectures in Berlin. But it wasn't until a solar eclipse in 1919 that everyone took notice. His theory predicted that a massive object — say, the sun — could distort spacetime nearby enough to bend light from its straight-line course. Distant stars would thus appear not exactly where expected. Photographs taken during the eclipse verified that the position shift matched Einstein's prediction. "Lights all askew in the heavens; men of science more or less agog," declared a *New York Times* headline.

Even a decade later, a story in *Science News Letter*, the predecessor of *Science News*, wrote of "Riots to understand Einstein theory" (*SN: 2/1/30, p. 79*). Apparently extra police had to be called in to control a crowd of 4,500 who "broke down iron gates and mauled each other" at the American Museum of Natural History in New York City to hear an explanation of general relativity.

By 1931, physicist Albert A. Michelson, the first American to win a Nobel Prize in the sciences, called the theory "a revolution in scientific thought unprecedented in the history of science."

ScienceNews 100

To celebrate our upcoming 100th anniversary, we've launched a series that highlights some of the biggest advances in science over the last century. For more on our changing view of the universe, and to see the rest of the series as it appears, visit the Century of Science site at **www.sciencenews.org/century**



CASEY REED/PENN STATE

Neutron stars (one illustrated) squash the mass equivalent of the sun into the size of a city.

But for all the powers of divination we credit to Einstein today, he was a reluctant soothsayer. We now know that general relativity offered much more than Einstein was willing or able to see. "It was a profoundly different way of looking at the universe," says astrophysicist David Spergel of the Simons Foundation's Flatiron Institute in New York City, "and it had some wild implications that Einstein himself didn't want to accept." What's more, says Spergel (a member of the Honorary Board of the Society for Science, publisher of *Science News*), "the wildest aspects of general relativity have all turned out to be true."

What had been masquerading as a quiet, static, finite place is instead a dynamic, ever-expanding arena filled with its own riot of space-bending beasts. Galaxies congregate in superclusters on scales vastly greater than anything experts had considered before the 20th century. Within those galaxies reside not only stars and planets, but also a zoo of exotic objects illustrating general relativity's propensity for weirdness, including neutron stars, which pack a fat star's worth of mass into the size of a city, and black holes, which pervert spacetime so strongly that no light can escape. And when these behemoths collide, they shake spacetime, blasting out ginormous amounts of energy. Our cosmos is violent, evolving and filled with science fiction–like possibilities that actually come straight out of general relativity.

"The wildest aspects of general relativity have all turned out to be true."
DAVID SPERGEL

"General relativity opened up a huge stage of stuff for us to look at and try out and play with," says astrophysicist Saul Perlmutter of the University of California, Berkeley. He points to the idea that the universe changes dramatically over its lifetime — "the idea of a lifetime of a universe at all is a bizarre concept" — and the idea that the cosmos is expanding, plus the thought that it could collapse and come to an end, and even that there might be other universes. "You get to realize that the world could be much more interesting even than we already ever imagined it could possibly be."

General relativity has become the foundation for today's understanding of the cosmos. But the current picture is far from complete. Plenty of questions remain about mysterious matter and forces, about the beginnings and the end of the universe, about how the science of the big meshes with quantum mechanics, the science of the very small. Some astronomers believe a promising route to answering some of those unknowns is another of general relativity's initially underappreciated features — the power of bent light to magnify features of the cosmos.

Today's scientists continue to poke and prod at general relativity to find clues to what they might be missing. General relativity is now being tested to a level of precision previously impossible, says astrophysicist Priyamvada Natarajan of Yale University. "General relativity expanded our cosmic view, then gave us sharper focus on the cosmos, and then turned the tables on it and said, 'now we can test it much more strongly.'" It's this testing that will perhaps uncover problems with the theory that might point the way to a fuller picture.

And so, more than a century after general relativity debuted, there's plenty left to foretell. The universe may turn out to be even wilder yet.

Ravenous beasts

Just over a century after Einstein unveiled general relativity, scientists obtained visual confirmation of one of its most impressive beasts. In 2019, a global network of telescopes revealed a mass warping spacetime with such fervor that nothing, not even light, could escape its snare. The Event Horizon Telescope released the first image of a black hole, at the center of galaxy M87 (*SN: 4/27/19, p. 6*).

"The power of an image is strong," says Kazunori Akiyama, an astrophysicist at the MIT Haystack Observatory in Westford, Mass., who led one of the teams that created the image. "I somewhat expected that we might see something exotic," Akiyama says. But after looking at the first image, "Oh my God," he recalls thinking, "it's just perfectly matching with our expectation of general relativity."

For a long time, black holes were mere mathematical curiosities. Evidence that they actually reside out in space didn't start coming in until the second half of the 20th century. It's a common story in the annals of physics. An oddity in some theorist's equation points to a previously unknown phenomenon, which kicks off a search for evidence. Once the data are attainable, and if physicists get a little lucky, the search gives way to discovery.

In the case of black holes, German physicist Karl Schwarzschild came up with a solution to Einstein's equations near a single spherical mass, such as a planet or a star, in 1916, shortly after Einstein proposed general relativity. Schwarzschild's math revealed how the curvature of spacetime would differ around stars of the same mass but increasingly smaller sizes — in other words, stars that were more and more compact. Out of the math came a limit to how small a mass could be squeezed.

Then in the 1930s, J. Robert Oppenheimer and Hartland Snyder described what would happen if a massive star collapsing under the weight of its own gravity shrank past that critical size — today known as the "Schwarzschild radius" — reaching a point from which its light could never reach us. Still, Einstein — and most others — doubted that what we now call black holes were plausible in reality.

The term "black hole" first appeared in print in *Science News Letter*. It was in a 1964 story by Ann Ewing, who was covering a meeting in Cleveland of the American Association for the Advancement of Science (*SN: 1/18/64, p. 39*). That's also about the time that hints in favor of the reality of black holes started coming in.

Just a few months later, Ewing reported the discovery of quasars — describing them in *Science News Letter* as "the most distant, brightest, most violent, heaviest and most puzzling sources of light and radio waves" (*SN: 8/15/64, p. 106*). Though not linked to black holes at the time, quasars hinted at some cosmic powerhouses needed to provide such energy. The use of X-ray astronomy in the 1960s revealed new features of the cosmos, including bright beacons that could come from a black hole scarfing down a companion star. And the motions of stars and gas clouds near the centers of galaxies pointed to something exceedingly dense lurking within.

Black holes stand out among other cosmic beasts for how extreme they are. The largest are many billion times the mass of the sun, and when they rip a star apart, they can spit out particles with 200 trillion electron volts of energy. That's some 30 times the energy of the protons that race around the world's largest and most powerful particle accelerator, the Large Hadron Collider.

As evidence built into the 1990s and up to today, scientists realized these great beasts not only exist, but also help shape the cosmos. "These objects that general relativity predicted, that were mathematical curiosities, became real, then they were marginal. Now they've become central," says Natarajan.

We now know supermassive black holes reside

In 2019, the Event Horizon Telescope Collaboration released this first-ever image of a black hole, at the heart of galaxy M87. The image shows the shadow of the monster surrounded by a bright disk of gas.

EVENT HORIZON TELESCOPE COLLABORATION

at the centers of most if not all galaxies, where they generate outflows of energy that affect how and where stars form. "At the center of the galaxy, they define everything," she says.

Though visual confirmation is recent, it feels as though black holes have long been familiar. They are a go-to metaphor for any unknowable space, any deep abyss, any endeavor that consumes all our efforts while giving little in return.

Real black holes, of course, have given plenty back: answers about our cosmos plus new questions to ponder, wonder and entertainment for space fanatics, a lost album from Weezer, numerous episodes of *Doctor Who*, the Hollywood blockbuster *Interstellar*.

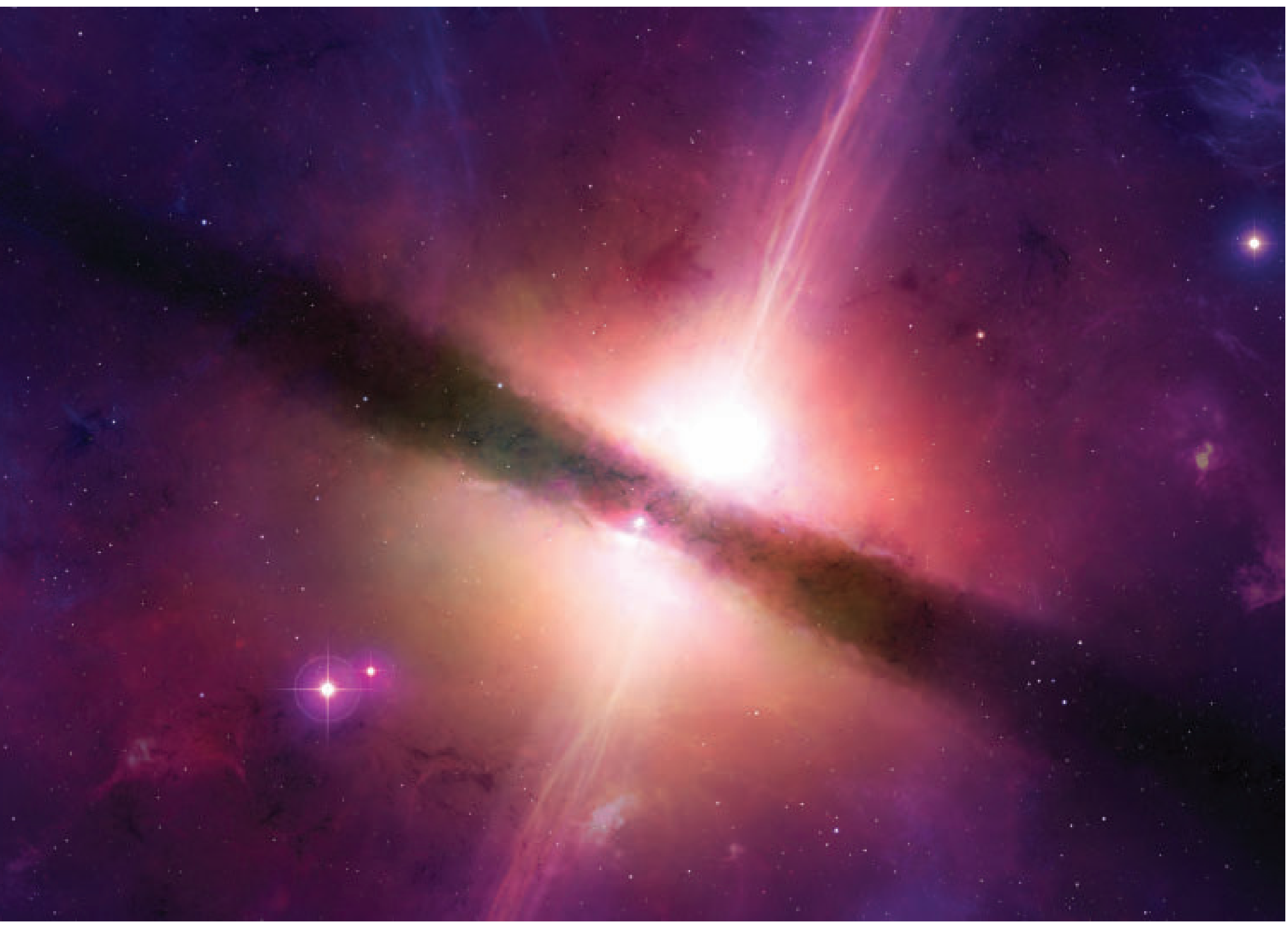
For physicist Nicolas Yunes of the University of Illinois at Urbana-Champaign, black holes and other cosmic behemoths continue to amaze. "Just thinking about the dimensions of these objects, how large they are, how heavy they are, how dense they are," he says, "it's really breathtaking."

Spacetime waves

When general relativity's behemoths collide, they disrupt the cosmic fabric. Ripples in spacetime called gravitational waves emanate outward, a calling card of a tumultuous and most energetic tango.

Einstein's math predicted such waves could be created, not only by gigantic collisions but also by explosions and other accelerating bodies. But for a long time, spotting any kind of spacetime ripple was a dream beyond measure. Only the most dramatic cosmic doings would create signals that were large enough for direct detection. Einstein, who called the waves *gravitationswellen*, was unaware that any such big events existed in the cosmos.

Beginning in the 1950s, when others were still arguing whether gravitational waves existed in reality, physicist Joseph Weber sunk his career into trying to detect them. After a decade-plus effort, he claimed detection in 1969, identifying an apparent signal perhaps from a supernova or

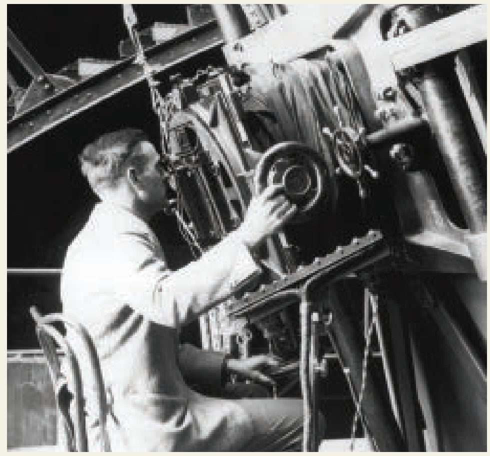


Quasars (one illustrated) are so bright that they can outshine their home galaxies. Though baffling when first discovered, these outbursts are powered by massive, feeding black holes.

MARK GARLICK/SCIENCE SOURCE

An expanding picture

Einstein's equations of general relativity were a wellspring from which our current view of the cosmos has flowed. That the theory continues to supply so many rich questions is part of what makes it "just incredible," says David Spergel, an astrophysicist at the Simons Foundation's Flatiron Institute in New York City. Over the last century, we've detected cosmic beasts that defy the imagination. We've also learned some crucial facts about our cosmos: The universe is expanding, and at an accelerating rate. The universe began with a bang 13.8 billion years ago. And mysterious forms of matter and energy are shaping the cosmos in unexpected and largely unknown ways. Here are some of the milestones in our expanding picture. *— Elizabeth Quill*



Clockwise from left: Astronomer Vera Rubin's measurements suggested the existence of dark matter in the 1970s. In the 1920s, astronomer Edwin Hubble offered evidence that the universe is expanding. In 1990, the Cosmic Background Explorer, or COBE (illustrated), team reported measurements of the oldest light in the universe, remnants of the Big Bang.

CLOCKWISE FROM TOP: PICTORIAL PRESS LTD/ALAMY STOCK PHOTO; COBE SCIENCE TEAM/NASA; RUBIN COLLECTION/AIP EMILIO SEGRÈ VISUAL ARCHIVES

1929 Edwin Hubble reports that distant galaxies appear to be flying away from us faster than nearby galaxies, crucial evidence that the universe is expanding.

1933 Fritz Zwicky examines galaxies in the Coma cluster and determines that there is unseen mass, what scientists now call "dark matter."

1964 Arno Penzias and Robert Wilson discover the cosmic microwave background radiation, the relic radiation left over from the Big Bang (*SN: 6/15/68, p. 575*).

1978 Vera Rubin, Kent Ford and Norbert Thonnard measure the rotation rates of stars in outer parts of galaxies, strongly implying the existence of dark matter.

1986 Margaret Geller, John Huchra and Valérie de Lapparent map a section of the observable universe, revealing a structure that encompasses large walls and giant voids.

1990 Based on just nine minutes of data, the Cosmic Background Explorer, or COBE, reveals that the cosmic microwave background radiation aligns with what is expected from blackbody radiation, good evidence that it is an afterglow of the Big Bang (*SN: 1/20/90, p. 36*).

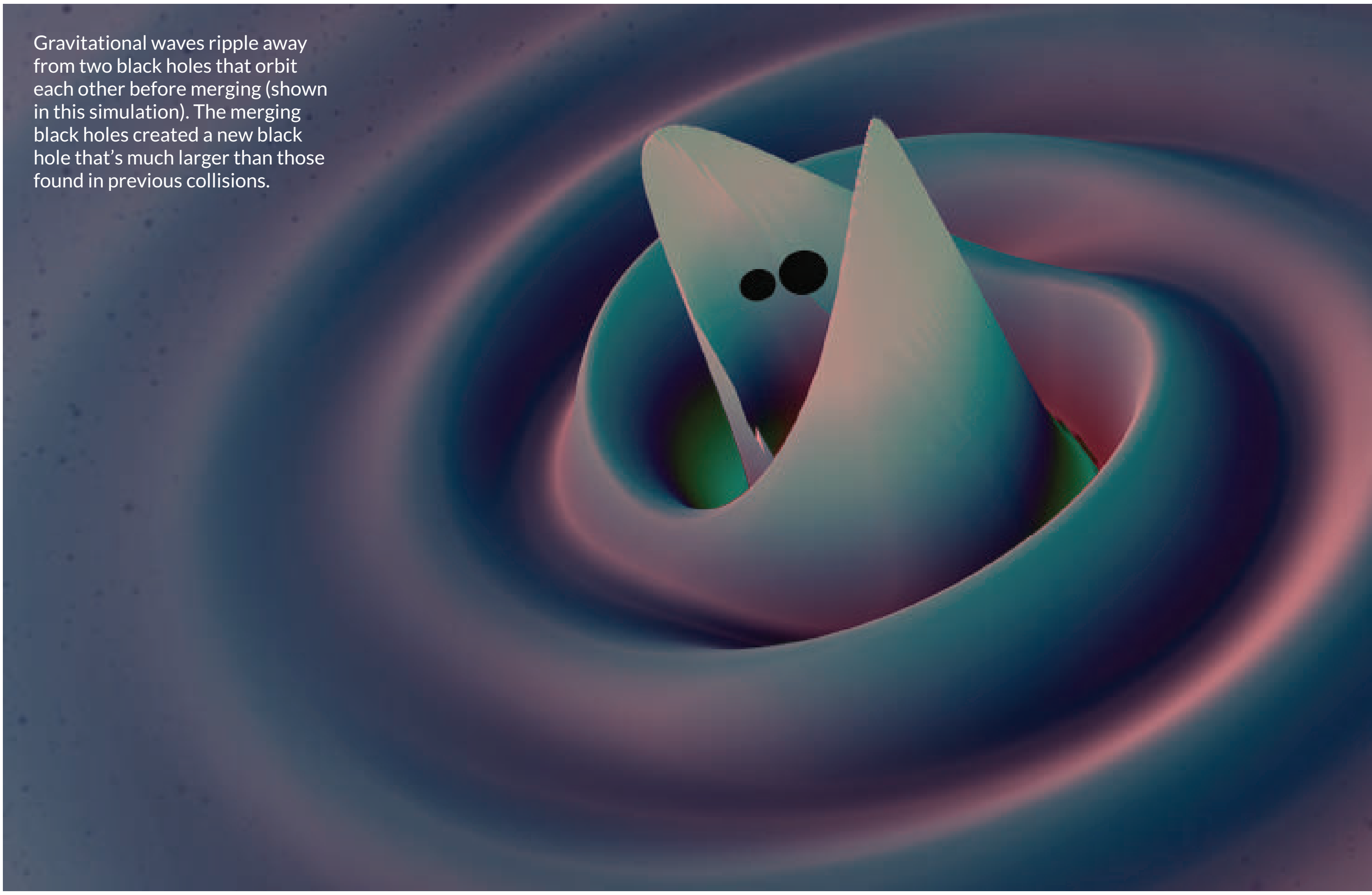
1992 Cosmologists detect temperature fluctuations in the cosmic microwave background, variations that correspond to ripples in the density of matter shortly after the Big Bang, as expected from the theory of inflation (*SN: 5/2/92, p. 292*).

1993 Astronomers report evidence of Massive Compact Halo Objects at the outskirts of the Milky Way (*SN: 9/25/93, p. 199*). These MACHOs account for some but not all of galactic dark matter.

1998 Astronomers uncover data indicating that the expansion of the universe is picking up speed (*SN: 3/21/98, p. 185*).

2002 Astronomers put the age range of the universe at between 13 billion and 14 billion years (*SN: 5/4/02, p. 277*).

2006 By studying an intergalactic collision, researchers report compelling evidence of dark matter's presence in space (*SN: 8/26/06, p. 31*).



Gravitational waves ripple away from two black holes that orbit each other before merging (shown in this simulation). The merging black holes created a new black hole that's much larger than those found in previous collisions.

DEBORAH FERGUSON, KARAN JANI, DEIRDRE SHOEMAKER AND PABLO LAGUNA/GEORGIA TECH, MAYA COLLABORATION

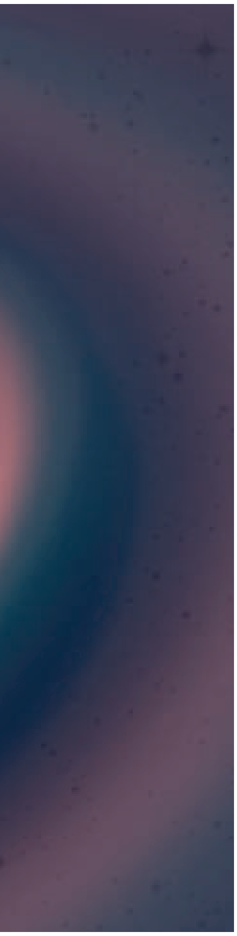
from a newly discovered type of rapidly spinning star called a pulsar. In the few years after reporting the initial find, *Science News* published more than a dozen stories on what it began calling the "Weber problem" (*SN: 6/21/69, p. 593*). Study after study could not confirm the results. What's more, no sources of the waves could be found. A 1973 headline read, "The deepening doubt about Weber's waves" (*SN: 5/26/73, p. 338*).

Weber stuck by his claim until his death in 2000, but his waves were never verified. Nonetheless, scientists increasingly believed gravitational waves would be found. In 1974, radio astronomers Russell Hulse and Joseph Taylor spotted a neutron star orbiting a dense companion. Over the following years, the neutron star and its companion appeared to be getting closer together by the distance that would be expected if they were losing energy to gravitational waves. Scientists soon spoke not of the Weber problem, but of what equipment could possibly pick up the waves. "Now, although they have not yet seen, physicists believe," Dietrick E. Thomsen wrote in *Science News* in 1984 (*SN: 8/4/84, p. 76*).

It was a different detection strategy, decades in the making, that would provide the needed sensitivity. The Advanced Laser Interferometry Gravitational-wave Observatory, or LIGO, which reported the first confirmed gravitational waves in 2016, relies on two detectors, one in Hanford, Wash., and one in Livingston, La. Each detector splits the beam of a powerful laser in two, with each beam traveling down one of the detector's two arms. In the absence of gravitational waves, the two beams recombine and cancel each other out. But if gravitational waves stretch one arm of the detector while squeezing the other, the laser light no longer matches up.

The machines are an incredible feat of engineering. Even spacetime ripples detected from colliding black holes might stretch an arm of the LIGO detector by as little as one ten-thousandth of the width of a proton.

When the first detection, from two colliding black holes, was announced, the discovery was heralded as the beginning of a new era in astronomy. It was *Science News*' story of the year in 2016, and such a big hit that the pioneers of the



LIGO detector won the Nobel Prize in physics the following year.

Scientists with LIGO and another gravitational wave detector, Virgo, based in Italy, have by now logged dozens more detections (*SN: 1/30/21, p. 30*). Most of the waves have emanated from mergers of black holes, though a few events have featured neutron stars. Smashups so far have revealed the previously unknown birthplaces of some heavy elements and pointed to a bright jet of charged subatomic particles that could offer clues to mysterious flashes of high-energy light known as gamma-ray bursts. The waves also have revealed that midsize black holes, between 100 and 100,000 times the sun's mass, do in fact exist — along with reconfirming that Einstein was right, at least so far.

Just five years in, some scientists are already eager for something even more exotic. In a *Science News* article about detecting black holes orbiting wormholes via gravitational waves, physicist Vítor Cardoso of Instituto Superior Técnico in Lisbon, Portugal, suggested a coming shift to more unusual phenomena: "We need to look for strange but exciting signals," he said (*SN: 8/29/20, p. 12*).

Gravitational wave astronomy is truly only at its beginnings. Improved sensitivity at existing Earth-based detectors will turn up the volume on gravitational waves, allowing detections from less energetic and more distant sources. Future detectors, including the space-based LISA, planned for launch in the 2030s, will get around the troublesome noise that interferes when Earth's surface shakes.

"Perhaps the most exciting thing would be to observe a small black hole falling into a big black hole, an extreme mass ratio inspiraling," Yunes says. In such an event, the small black hole would zoom back and forth, back and forth, swirling in different directions as it followed wildly eccentric orbits, perhaps for years. That could offer the ultimate test of Einstein's equations, revealing whether we truly understand how spacetime is warped in the extreme. ■

Explore more

■ Clifford M. Will and Nicolas Yunes. *Is Einstein Still Right?* Oxford University Press, 2020.

Researchers at two gravitational wave observatories, LIGO in the United States and Virgo in Italy (shown above), have reported dozens of detections of black hole smashups, as well as neutron star mergers, in the last five years.

THE VIRGO COLLABORATION

JULIA YELLOW

Inside Your Head

Privacy questions swirl around new brain technology

By Laura Sanders

Gertrude the pig rooted around a straw-filled pen, oblivious to the cameras and onlookers — and the 1,024 electrodes eavesdropping on her brain signals. Each time the pig's snout found a treat in a researcher's hand, a musical jingle sounded, indicating activity in her snout-controlling nerve cells.

Those beeps were part of the big reveal on August 28 by Elon Musk's company Neuralink. "In a lot of ways, it's kind of like a Fitbit in your skull with tiny wires," said Musk, founder of Tesla and SpaceX, of the new technology.

Neuroscientists have been recording nerve cell activity from animals for decades. But the ambitions of Musk and others to link humans with computers are shocking in their reach. Future-minded entrepreneurs and researchers aim to listen in on our brains and perhaps even reshape thinking. Imagine being able to beckon our Teslas with our minds, Jedi-style.

Some scientists called Gertrude's introduction a slick publicity stunt, full of unachievable promises. But Musk has surprised people before. "You can't argue with a guy who built his own electric car and sent it to orbit around Mars," says Christof Koch, a neuroscientist at the Allen Institute for Brain Science in Seattle.

Whether Neuralink will eventually merge brains and Teslas is beside the point. Musk isn't the only dreamer chasing neurotechnology. Advances are coming quickly and span a variety of approaches, including external headsets that may be able to distinguish between hunger and boredom; implanted electrodes that translate intentions to speak into real words; and bracelets that use nerve impulses for typing without a keyboard.

Today, paralyzed people are already testing brain-computer interfaces, a technology that connects brains to the digital world (*SN: 11/16/13, p. 22*). With brain signals alone, users have been able to shop online, communicate and even use a prosthetic arm to sip from a cup (*SN: 6/16/12, p. 5*). The ability to hear neural chatter, understand it and perhaps even modify it could change and improve people's lives in ways that go well beyond medical treatments. But these abilities also raise questions about who gets access to our brains and for what purposes.

Because of neurotechnology's potential for both good and bad, we all have a stake in shaping how it's created and, ultimately, how it is used. But most people don't have the chance to weigh in, and only find out about these advances after they're a fait accompli. So we asked *Science News* readers their views about recent neurotechnology advances. We described three main ethical issues — fairness, autonomy and privacy. Far and away, readers were most concerned about privacy.

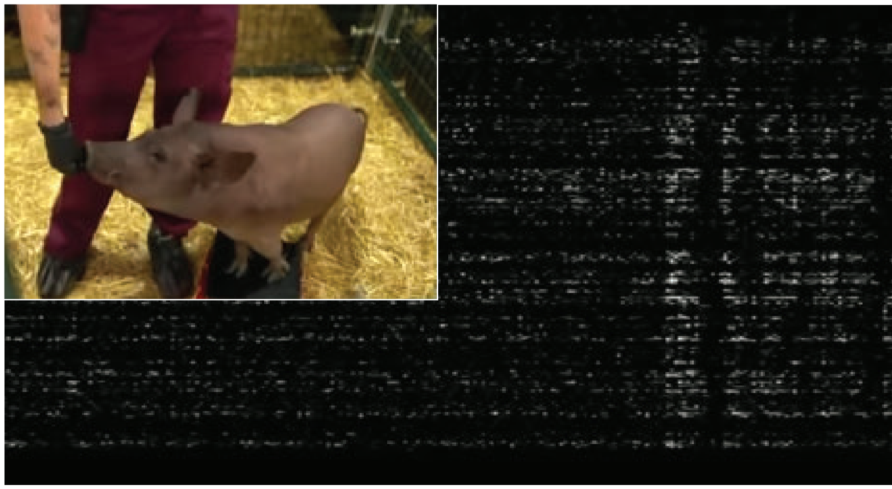
The idea of allowing companies, or governments, or even health care workers access to the brain's inner workings spooked many respondents. Such an intrusion would be the most important breach in a world where privacy is already rare. "My brain is the only place I know is truly my own," one reader wrote.

Technology that can change your brain — nudge it to think or behave in certain ways — is especially worrisome to many of our readers. A nightmare scenario raised by several respondents: We turn into zombies controlled by others.

When these types of brain manipulations get discussed, several sci-fi scenarios come to mind, such as memories being wiped clean in the poignant 2004 film *Eternal Sunshine of the Spotless Mind*; ideas implanted into a person's mind, as in the 2010 movie *Inception*; or people being tricked into thinking a virtual world is the real thing, as in the mind-bending 1999 thriller *The Matrix*.

Today's tech capabilities are nowhere near any of those fantasies. Still, "the here and now is just as interesting ... and just as morally problematic," says neuroethicist Timothy Brown of the University of Washington in Seattle. "We don't need *The Matrix* to get our dystopia."

Today, codes of ethics and laws govern research, medical treatments and certain aspects of our privacy. But we have no comprehensive way to handle the privacy violations that might arise with future advances in brain science. "We are all flying by



Whenever Gertrude's snout touched something, nerve cells in her brain fired electrical signals detected by an implanted device (signals shown as wavy lines on black). Similar technology may one day help people with paralysis or brain disorders.

NEURALINK

the seat of our pants here," says Rafael Yuste, a neurobiologist at Columbia University.

For now, ethics questions are being taken up in a piecemeal way. Academic researchers, bioethicists and scientists at private companies, such as IBM and Facebook, are discussing these questions among themselves. Large brain-research consortiums, such as the U.S. BRAIN Initiative (*SN: 2/22/14, p. 16*), include funding for projects that address privacy concerns. Some governments, including Chile's national legislature, are starting to address concerns raised by neurotechnology.

With such disjointed efforts, it's no surprise that no consensus has surfaced. The few answers that exist are as varied as the people doing the asking.

Reading thoughts

The ability to pull information directly from the brain — without relying on speaking, writing or typing — has long been a goal for researchers and doctors intent on helping people whose bodies can no longer move or speak. Already, implanted electrodes can record signals from the movement areas of the brain, allowing people to control robotic prostheses.

Readers' thoughts

We asked members of the public for their take on the ethics of new brain technology. A sampling of their quotes are on the following pages.

"The thoughts of someone accessing a person's brain is absolutely terrifying."

"I have no wish/desire to be a zombie or a clone."

Robert "Buz" Chmielewski, who has had quadriplegia since his teens, uses brain signals to feed himself some cake. Via electrodes implanted in both sides of his brain, he controls two robotic arms: One manipulates the knife and the other holds the fork.

JHU-APL

In January 2019, researchers at Johns Hopkins University implanted electrodes in the brain of Robert "Buz" Chmielewski, who was left quadriplegic after a surfing accident. With signals from both sides of his brain, Chmielewski controlled two prosthetic arms to use a fork and a knife simultaneously to feed himself, researchers announced in a press release on December 10.

Other research has decoded speech from the brain signals of a paralyzed man who is unable to speak. When the man saw the question, "Would you like some water?" on a computer screen, he responded with the text message, "No, I am not thirsty," using only signals in his brain. This feat, described November 19 at a symposium hosted by Columbia University, is another example of the tremendous progress under way in linking brains to computers.

"Never before have we been able to get that kind of information without interacting with the periphery of your body, that you had to voluntarily activate," says Karen Rommelfanger, a neuroethicist at Emory University in Atlanta. Speaking, sign language and writing, for instance, "all require several steps of your decision making," she says.

> "Imagine walking into McDonald's and suddenly you have an irresistible urge for a cheeseburger (or 10)."

Today, efforts to extract information from the brain generally require bulky equipment, intense computing power and, most importantly, a willing participant, Rommelfanger says. For now, an attempt to break into your mind could easily be thwarted by closing your eyes, or wiggling fingers, or even getting drowsy.

What's more, Rommelfanger says, "I don't believe that any neuroscientist knows what a mind is or what a thought is," she says. "I am not concerned about mind reading, from the existing terrain of technologies."

But that terrain may change quickly. "We are getting very, very close" to having the ability to pull private information from people's brains, Yuste says, pointing to studies that have decoded what a person is looking at and what words they hear. Scientists from Kernel, a neurotech company near Los Angeles, have invented a helmet, just now hitting the market, that is essentially a portable brain scanner that can pick up activity in certain brain areas (see Tech in action, Page 28).

For now, companies have only our behavior — our likes, our clicks, our purchase histories — to build eerily accurate profiles of us and estimate what we'll do next. And we let them. Predictive algorithms make good guesses, but guesses all the same. "With this neural data gleaned from neurotechnology, it may not be a guess anymore," Yuste says. Companies will have the real thing, straight from the source.

Even subconscious thoughts might be revealed with further technological improvements, Yuste says. "That is the ultimate privacy fear, because what else is left?"

Rewrite, revise

Technology that can change the brain's activity already exists today, as medical treatments. These tools can detect and stave off a seizure in a person with epilepsy, for instance, or stop a tremor before it takes hold.

Researchers are testing systems for obsessive-compulsive disorder, addiction and depression (*SN: 2/16/19, p. 22*). But the power to precisely change a functioning brain directly — and as a result, a person's behavior — raises worrisome questions.

The desire to persuade, to change a person's mind, is not new, says Marcello Ienca, a bioethicist at ETH Zurich. Winning hearts and minds is at the core of advertising and politics. Technology capable of changing your brain's activity with just a subtle nudge, however, "brings current manipulation risks to the next level," Ienca says.

What happens if such influence finds a place outside the medical arena? A doctor might use precise brain-modifying technology to ease anorexia's grip on a young person, but the same might be used for money-making purposes: "Imagine walking into McDonald's and suddenly

you have an irresistible urge for a cheeseburger (or 10)," one of our readers wrote.

Is the craving caused by real hunger? Or is it the result of a tiny neural nudge just as you drove near the golden arches? That neural intrusion could spark uncertainty over where that urge came from, or perhaps even escape notice altogether. "This is super dangerous," Yuste says. "The minute you start stimulating the brain, you are going to be changing people's minds, and they will never know about it, because they will interpret it as 'that's me.' "

Precise brain control of people is not possible with existing technology. But in a hint of what may be possible, scientists have already created visions inside mouse brains (*SN: 8/17/19, p. 10*). Using a technique called optogenetics to stimulate small groups of nerve cells, researchers made mice "see" lines that weren't there. Those mice behaved exactly as if their eyes had actually seen the lines, says Yuste, whose research group performed some of these experiments. "Puppets," he calls them.

What to do?

As neurotechnology marches ahead, scientists, ethicists, companies and governments are looking for answers on how, or even whether, to regulate brain technology. For now, those answers depend entirely on who is asked. And they come against a backdrop of increasingly invasive technology that we've become surprisingly comfortable with.

JULIA YELLOW

We allow our smartphones to monitor where we go, what time we fall asleep and even whether we've washed our hands for a full 20 seconds. Couple that with the digital breadcrumbs we actively share about the diets we try, the shows we binge and the tweets we love, and our lives are an open book.

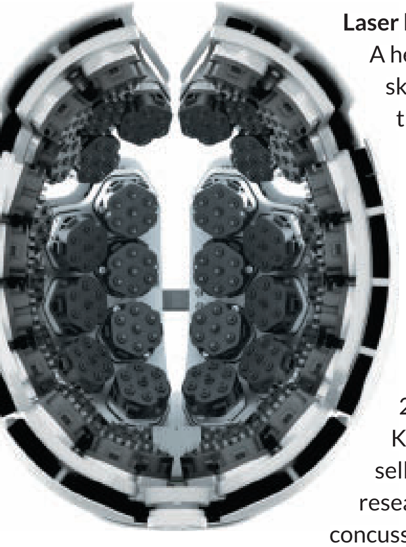
"How would we know that what we thought or felt came from our own brains, or whether it was put there by someone else?"

Those details are more powerful than brain data, says Anna Wexler, an ethicist at the University of Pennsylvania. "My e-mail address, my notes app and my search engine history are more reflective of who I am as a person — my identity — than our neural data may ever be," she says.

It's too early to worry about privacy invasions from neurotechnology, Wexler argues, a position that makes her an outlier. "Most of my colleagues would tell me I'm crazy."

At the other end of the spectrum, some researchers, including Yuste, have proposed strict regulations around privacy that would treat a person's neural data like their organs. Much like a liver can't be taken out of a body without approval for medical purposes, neural data shouldn't be removed either. That viewpoint has found purchase in Chile, which is now considering whether to classify neural data with new protections that would not allow companies to get at it.

Tech in action



Laser helmets

A helmet sends laser beams through the skull and into the brain. After bouncing off tissue and blood, the particles of light return to detectors that measure oxygen levels. Those levels indicate where in the brain nerve cells are active, thus giving clues about mental processes. This technology, called functional near-infrared spectroscopy, is the same that allows pulse oximeters to measure oxygen levels in the blood. In early 2021, the neurotechnology company Kernel, based near Los Angeles, began selling Kernel Flow helmets (shown) to researchers who are using the tools to study concussions, language and even dreaming.

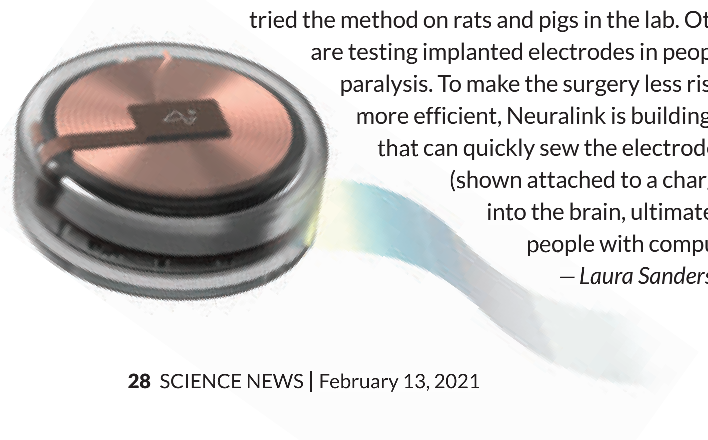
Electrode bracelet

A bracelet studded with electrodes can detect tiny nerve impulses on the wrist. The bracelet (shown) uses electromyography, which picks up the behavior of nerve cells that control muscles, to eavesdrop on signals that move from the brain to hand muscles. Developed by New York City–based CTRL-Labs, a neural interface company acquired by Facebook Reality Labs in 2019, the bracelet allows users to play chess in a virtual room, control a hand avatar and type with tiny movements from inside a pocket, for instance, without a keyboard, mouse or touch screen. The technology is still in development.

Under-skull implants

Thin tendrils laced with hundreds or thousands of electrodes will spread out in the brain to listen in on — and perhaps even stimulate — nerve cells. So far, Elon Musk's company Neuralink, based in Fremont, Calif., has tried the method on rats and pigs in the lab. Other labs are testing implanted electrodes in people with paralysis. To make the surgery less risky and more efficient, Neuralink is building a robot that can quickly sew the electrode threads (shown attached to a charging disk) into the brain, ultimately linking people with computers.

— Laura Sanders



Other experts fall somewhere in the middle. Ienca, for example, doesn't want to see restrictions on personal freedom. People ought to have the choice to sell or give away their brain data for a product they like, or even for straight up cash. "The human brain is becoming a new asset," Ienca says, something that can generate profit for companies eager to mine the data. He calls it "neurocapitalism."

And Ienca is fine with that. If a person is adequately informed — granted, a questionable if — then they are within their rights to sell their data, or exchange it for a service or product, he says. People ought to have the freedom to do what they like with their information.

General rules, checklists and regulations are not likely to be a good path forward, Rommelfanger says. "Right now, there are over 20 frameworks, guidelines, principles that have been developed since 2014 on how to handle neuroscience," she says. Those often cover "mental privacy" and "cognitive liberty," the freedom to control your own mental life.

Those guidelines are thoughtful, she says, but the technologies differ in what they're capable of, and in their possible ethical repurcussions. One-size-fits-all solutions don't exist, Rommelfanger says.

Instead, each company or research group may need to work through ethical issues throughout the development process. She and colleagues have recently proposed five questions that researchers can ask themselves to begin thinking about these ethical issues, including privacy and autonomy. The questions ask people to consider how new technology might be used outside of a lab, for instance.

Moving forward on the technology to help people with mental illness and paralysis is an ethical imperative, Rommelfanger says. "More than my fear of a privacy violation, my fear is about diminished public trust that could undermine all of the good this technology could do."

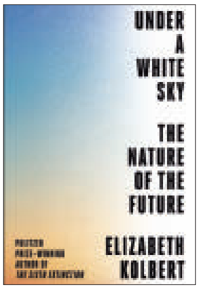
A lack of ethical clarity is unlikely to slow the pace of the coming neurotech rush. But thoughtful consideration of the ethics could help shape the trajectory of what's to come, and help protect what makes us most human. ■

Explore more

■ Rafael Yuste *et al.* "Four ethical priorities for neurotechnologies and AI." *Nature.* November 9, 2017.

This project on ethics and science was supported by the Kavli Foundation.

FROM TOP: KERNEL; CTRL-LABS; NEURALINK



Under a White Sky
Elizabeth Kolbert
CROWN, $28

BOOKSHELF

Human ingenuity can ruin and repair nature

In 1900, the city of Chicago completed a 45-kilometer-long canal that altered the hydrology of two-thirds of the United States.

That wasn't the intention, of course. The plan was to reverse the flow of the Chicago River to divert waste away from the city's source of drinking water: Lake Michigan. The engineering feat worked, but it also connected the Great Lakes and Mississippi River basins, two of the world's largest — and until then, isolated — freshwater ecosystems, allowing invasive species to pour through the opening and wreak ecological havoc.

Elizabeth Kolbert opens *Under a White Sky: The Nature of the Future* with this parable of humans' hubristic attempts to control nature. We've put our minds toward damming or diverting most of the planet's rivers, replacing vast tracts of natural ecosystems with crops, and burning so much fossil fuel that 1 in 3 molecules of atmospheric carbon dioxide came from human action, she writes. We've warmed the atmosphere, raised sea levels, erased countless species and forged an uncertain future for humankind and the planet.

Our collective ingenuity got us into this mess, and Kolbert explores whether that same ingenuity can get us out. This is "a book about people trying to solve problems created by people trying to solve problems," she writes. A fitting follow-up to her Pulitzer Prize–winning *The Sixth Extinction* (*SN: 2/22/14, p. 28*), the book will satisfy readers keen on a skeptical survey of how innovation could save coral reefs or turn climate-warming carbon into stone.

Kolbert takes a firsthand look at many of these interventions. She begins on a boat, traveling up the Chicago canal to inspect electric barriers meant to keep invasive Asian carp from forever altering the Great Lakes. Asian carp were introduced to the Mississippi River basin in the 1960s as a biological Weedwacker to control invasive plants. But the carp have swum amok throughout the basin and are now knocking at the door of Lake Michigan. Simply closing the canal would protect the lakes, but that's largely dismissed as being too disruptive to the city. Instead, humans innovate. "First you reverse a river," Kolbert writes. "Then you electrify it."

Each chapter builds on this theme of increasingly elaborate (or desperate?) interventions intended to limit the fallout of previous problem solving. The scale of the problems widens too, which could leave a reader's head spinning, but Kolbert keeps her globe-trotting grounded in immersive reporting and recurring nods to the tragic, and often comic, absurdity of it all.

To save the endangered Devils Hole pupfish (*Cyprinodon diabolis*), a couple-centimeters-long streak of sapphire found in a single desert pool in Nevada, researchers built a $4.5 million replica of the pool to house a backup population. The simulacrum — which mimics the smallest details of the actual pool, including a shallow shelf reconstructed from laser images of the real thing — requires round-the-clock caretaking. As Kolbert watches staff use tweezers to remove beetles that have developed a taste for young pupfish, she notes how much easier it is to ruin an ecosystem than to run one.

Devils Hole pupfish (left) live in a single water-filled cavern in Nevada (right). To ensure the species' survival, scientists maintain a captive population in a replica of the pool.

Saving larger ecosystems may require more powerful tools. In Australia, we meet researchers trying to genetically engineer less toxic cane toads, an invasive species that's poisoning untold numbers of native animals. Gene drive technology, which loads the dice of inheritance to propel certain mutations through a population (*SN: 12/12/15, p. 16*), could make all cane toads safer to eat within generations. Other scientists are considering the possibility of using gene drives to eliminate invasive rodents from islands like New Zealand.

Such power could prove difficult to wield, and many worry it would backfire. Mouse-eliminating gene drives might escape an island and spread across the globe.

Kolbert does not explicitly argue for or against these measures, but frankly acknowledges the stakes. "What's the alternative?" she writes. "Rejecting such technologies as unnatural isn't going to bring nature back. The choice is not between what was and what is, but between what is and what will be, which, often enough, is nothing."

Humankind's most audacious idea to rein in the collateral damage of modernization is geoengineering. By stuffing the stratosphere with reflective particles, Kolbert explains, we could almost immediately start to reverse global warming. But it would also turn the sky white, scramble weather patterns and who knows what else. The fundamental resource of all life — sunlight — would be dimmed, intentionally, by us.

Had we acted decades ago to curb greenhouse gas emissions or limit habitat destruction, such schemes would remain science fiction. But we've kicked the can down the road for too long. Gene editing species or geoengineering may be entirely crazy and disconcerting, Kolbert writes, but if they can pull us from the hole we've dug for ourselves, don't we have to at least consider them? Whether such technologies can save us and the planet, or only further muck it up, Kolbert cannot say. — *Jonathan Lambert*

Sustaining research outside classrooms

During the unprecedented COVID-19 pandemic, the Society for Science has found ways to continue supporting STEM education.

In a year of educational disruption, the Society for Science pivoted its programming in 2020 to provide STEM research kits to educators that would encourage scientific inquiry in all settings, regardless of whether the teachers were guiding their students remotely, in person or through a hybrid model. Participants in the Society's Advocate Program, STEM Research Grants program and research teachers conferences chose from a selection of 13 high-quality kits, which included Foldscope instruments, PocketLab weather sensors and Neuron SpikerBox Bundles. By providing teachers with this equipment, the Society wanted to ensure hands-on research and project-based learning could carry on, despite the circumstances.

In 2020, the Society gave

- **7,844** kits valued at more than **$415,000**
- To **373** teachers from over **270** schools
- In all **50** states and Puerto Rico, Washington, D.C., and American Samoa
- Impacting over **15,500** students

The kits were funded by

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Educator Sharon Taylor (pictured at bottom left) prepared foldable microscopes (bottom right) this past December to be shared with her students.

DECEMBER 19, 2020 & JANUARY 2, 2021

Toad talk

Guttural toads on islands in the Indian Ocean have shrunken limbs and bodies that may be evidence that "island dwarfism" can evolve quickly, ***Jake Buehler*** *reported in "Toads on two islands are shrinking fast" (SN: 12/19/20 & 1/2/21, p. 13).*

"I thought that island dwarfism usually happens to quite large animals ... and that small animals ... tend to evolve to larger sizes on islands," reader **Tim Cliffe** wrote. "If small animals do tend to grow larger, do the authors talk about why these small toads would instead be taking the dwarfism route?"

Generally speaking, yes, large animals become smaller when they colonize islands, and small animals get bigger, **Buehler** says. "This 'island rule' isn't absolute, and whether or not an animal moves toward dwarfism or gigantism may depend on the benefits normally afforded to them by their body size, and food constraints on the island," he says. The researchers noted that a relatively large body size may protect guttural toads against predators. On the islands, the toads may have become smaller since there are fewer hungry predators to dissuade, **Buehler** says.

Or perhaps the island toads have a spread-out mating schedule, which could explain why the amphibians are shrinking. "On the mainland, guttural toads mate once a year, and females that grow to large sizes very quickly produce a lot of eggs," **Buehler** says. But the island toads may be mating year-round, which would deflate the importance of getting large and producing a ton of eggs. "Figuring out exactly why island life is making these toads smaller is the next step in this project," he says.

Defining distance

A collision of two black holes 17 billion light-years from Earth snagged records for the farthest, most energetic and most massive black hole merger, ***Erika Engelhaupt*** *wrote in "Superlative science" (SN: 12/19/20 & 1/2/21, p. 34).*

Some readers wondered how the black hole merger could have occurred 17 billion light-years from Earth if the Big Bang occurred 13.8 billion years ago.

"Distance is actually quite complicated to define for a universe that is expanding and in which spacetime is not static," says *Science News* physics writer **Emily Conover**. "The gravitational waves produced by the merger took 7 billion years to reach us. That's what's called 'lookback time,'" she says. "But that's not the same thing as the distance of the source from us. Because the universe has expanded in the time it took those waves to reach us, the source is indeed 17 billion light-years away, according to one standard method of defining distance. That's also why that distance doesn't conflict with the age of the universe," she says.

Room to improve

A compound in hallucinogenic mushrooms eased depression symptoms in 13 people in a small study, but larger studies are needed, ***Laura Sanders*** *reported in "Psilocybin may help treat depression" (SN: 12/19/20 & 1/2/21, p. 6).*

"The article spoke of concern that most participants were white and that a broader diversity would be more helpful" to determine how effective the compound is, reader **Robert Walty** wrote. "This is quite true and as a 75-year-old man, I am also concerned about depression in the elderly," he wrote, noting that depression is common among older adults. "I look forward to larger studies with a truly broad diversity of participants."

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A painted pig takes cave art back in time

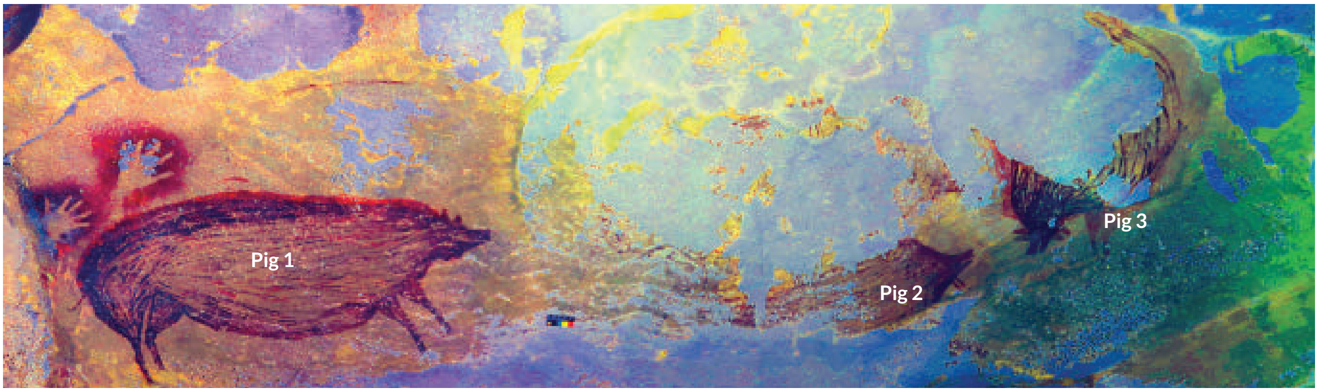
Inside a cave on the Indonesian island of Sulawesi, scientists have found one of the oldest known artistic depictions of a real-world object or life-form. It's a painting of a warty pig (shown above), an animal still found on Sulawesi, that was rendered on the cave's back wall at least 45,500 years ago, researchers report January 13 in *Science Advances*.

The discovery adds to evidence that "the first modern human cave art traditions did not emerge in Ice Age Europe, as long supposed, but perhaps earlier in Asia or even in Africa, where our species evolved," says study author Adam Brumm, an archaeologist at Griffith University in Brisbane, Australia.

At least two other partially preserved pig paintings appear on the cave wall near the newly dated figure, all executed in red or dark red and purple mineral pigments (an enhanced image shown below). The pigs appear to be confronting each other in a scene of some sort, says archaeologist Iain Davidson of the University of New England in Armidale, Australia. Similarly positioned, painted animals dating to roughly 30,000 years ago or more appear in scenes in France's Chauvet Cave, says Davidson, who did not participate in the new study.

Like a painted hunting scene from at least 43,900 years ago that was previously found in a separate Sulawesi cave (*SN: 1/18/20, p. 9*), minimum age estimates for the pig paintings are based on measures of radioactive uranium's decay in cauliflower-like mineral growths that formed in thin layers over and underneath parts of the depictions.

The team considers it likely that *Homo sapiens*, rather than a closely related species that lived in the region such as *Homo floresiensis* (*SN: 7/9/16, p. 6*), painted on the Sulawesi cave walls. *—Bruce Bower*



FROM TOP: MAXIME AUBERT; ADHI AGUS OKTAVIANA