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SOCIETY FOR SCIENCE & THE PUBLIC
SEPTEMBER 30, 2017

Outbursts From a Waning Sun

Bats' Navigation Secrets

Nature Inspires Sticky Solutions

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DIRTY SKIES

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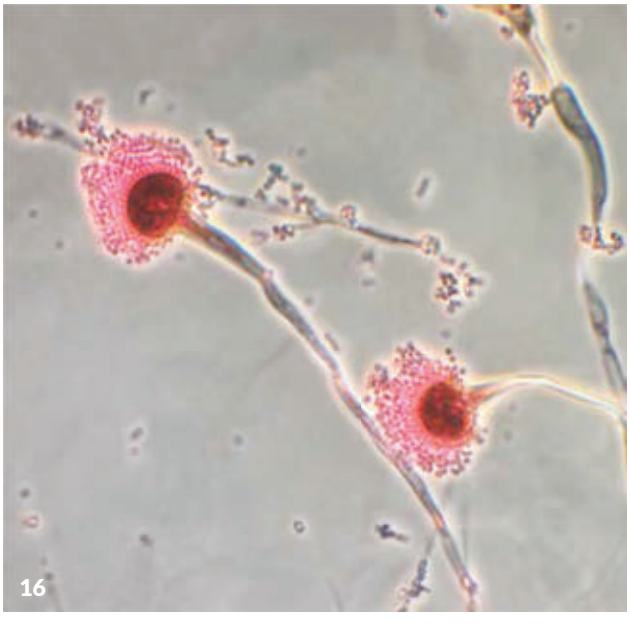
Features

News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Departments

COVER Scientists are linking pollution from vehicles and industry to a growing list of health problems, including diabetes and dementia. *plherrera/iStockphoto*

CLOCKWISE FROM TOP: PAPILIO/ALAMY STOCK PHOTO; RONSTIK/ISTOCKPHOTO; CDC

Nature offers inspiration, and occasionally courage

When Donald Griffin and Robert Galambos first reported that bats use the ricocheting echoes of sound waves to pilot through the environment, some scientists doubted it was possible. The team's experiments, conducted in the late 1930s at Harvard University and reported in the early 1940s, coincided with World War II and the proliferation of active sonar systems for use on ships and submarines. "The notion that bats might do anything even remotely analogous to the latest triumphs of electronic engineering struck most people as not only implausible but emotionally repugnant," Griffin later said.

But Griffin disagreed. In 1944 in an issue of *Science*, he proposed the term "echolocation" to cover not only "locating obstacles by means of echoes" in bats, but also by people, including via radar, fathometers and submarines using "apparatus working on the same basic principles." The word "echolocation" didn't replace existing technical terms — in fact, it's sometimes called "biosonar" — but the scientific community quickly came around. Today, a lot of neuroscientists have a deep respect for bats' impressive abilities, and some are studying how bat brains process the signals necessary for navigating, as freelance writer Amber Dance reports on Page 22. These insights might lead to improvements to sonar, as well as new, bat-inspired technologies. It makes sense: Humans have been perfecting sonar for more than a century, but evolution has been honing echolocation for much, much longer.

The same is true for sticky goo. Slugs, mussels and other critters release slimy secretions as part of normal life. Researchers are turning to these critters to design adhesives that perform well in the human body, as covered by Laurel Hamers on Page 14. *Science News* often reports on how nature inspires science and technology. There are robots that grow like plants (*SN Online: 7/19/17*) and grippers modeled on gecko feet (*SN Online: 6/28/17*) — those stories include video at www.sciencenews.org. Materials scientists interested in building better bridges are taking cues from bone (*SN: 4/15/17, p. 5*). And the great variety of wild yeasts inspires brewers to experiment with new flavors of beer (Page 4). That's applying nature's know-how for practical (and pleasurable) purposes.

But not all of nature's lessons go down as smoothly as a cold pint. Over the last several decades, humankind has learned that we can't dump pollution into our skies (or seas, or soils) without some serious consequences. Though the air may be cleaner today than half a decade ago, exhaust from vehicles and industrial emissions still pose public health risks that might even extend beyond the lungs, as Laura Beil reports on Page 18. And though it's hard to say for sure how climate change has contributed to recent, destructive hurricanes, there's no doubt that increases in atmospheric carbon dioxide, thanks largely to human activities, are altering our planet and threatening our futures.

How, as a society, will we respond? Will we be inspired to take the kind of action that leads to long-term change? It's easy to hold off, to claim change is too hard and to become discouraged. When we lose heart, we need only look to the bats. As Helen Thompson reports on Page 17, even these exquisitely adapted fliers will face-plant now and then. — *Elizabeth Quill, Acting Editor in Chief*

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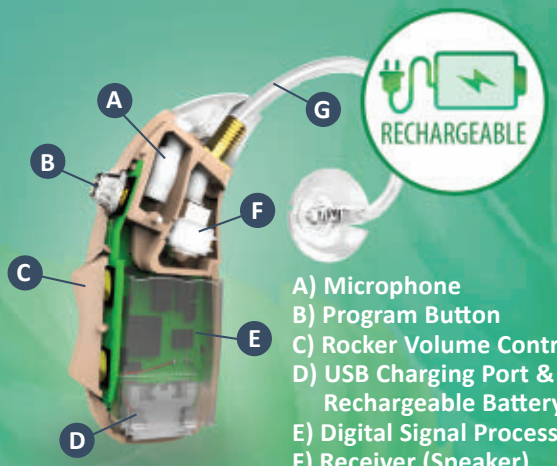

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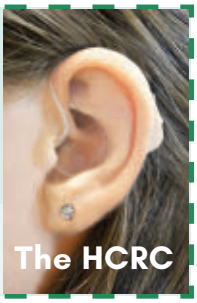

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Excerpt from the October 7, 1967 issue of *Science News*

50 YEARS AGO

Confusion over effects

No one knows whether chronic marijuana smoking causes emotional troubles or is a symptom of them.... This dearth of evidence has a number of explanations: serious lingering reactions, if they exist, occur after prolonged use, rarely after a single dose; marijuana has no known medical use, unlike LSD, so scientists have had little reason to study the drug.... Also, marijuana has been under strict legal sanctions ... for more than 30 years.

UPDATE: In 29 states and in Washington, D.C., marijuana is now commonly prescribed for post-traumatic stress disorder and chronic pain. But the drug's pros and cons remain hazy. Regular pot use has been linked to psychotic disorders and to alcohol and drug addiction (*SN Online: 1/12/17*). And two recent research reviews conclude that very little high-quality data exist on whether marijuana effectively treats PTSD or pain. Several large-scale trials are under way to assess how well cannabis treats these conditions.

Pichia kudriavzevii yeast forms a biofilm where liquid meets air in a lab flask. Biochemist Matthew Bochman is testing this and other wild yeasts, found here, there and everywhere, for their beer-brewing properties.

THE SCIENCE LIFE

Biochemist brews a wild beer

Craft brewers are going wild. Some of the trendiest beers on the market are intentionally brewed with yeast scavenged from nature, rather than the carefully cultivated ale or lager yeast used in most commercial beers.

Matthew Bochman is in on the action. By day, he's a biochemist at Indiana University Bloomington who studies how cells keep their DNA intact. On the side, he can be found bagging new kinds of wild yeast. When Bochman, a self-professed yeast whisperer, moved to Indiana, he made friends with many local craft brewers, including Robert Caputo.

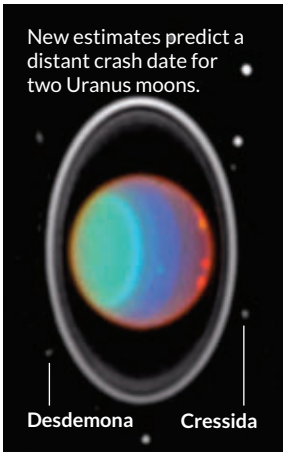
Caputo wanted to make a beer that is 100 percent Indiana. He had state-grown hops and malt grains, and Indiana water is plentiful. "The missing ingredient was the Indiana yeast," Bochman says. Caputo asked Bochman

TEASER

Moons of Uranus face future collision

If you could put Uranus' moon Cressida in a gigantic tub of water, it would float.

Cressida is one of at least 27 moons that circle Uranus. Robert Chancia of the University of Idaho in Moscow and colleagues calculated Cressida's density and mass using visible variations in an inner ring of Uranus as the planet passed in front of a distant star. The moon's density is 0.86 grams per cubic centimeter and its mass is 2.5×10^{17} kilograms. These results, reported online August 28 at arXiv.org, are the first to reveal any details about the moon. Knowing its density and mass helps researchers determine if and when Cressida might collide with another of Uranus' moons.



Voyager 2 discovered Cressida and several other moons when the spacecraft flew by Uranus in 1986. Those moons, plus two others found later, are the most tightly packed in the solar system and orbit within 20,000 kilometers of Uranus. Such close quarters puts the moons on collision courses. Based on the newly calculated mass and density of Cressida, simulations suggest that it will slam into the moon Desdemona in under a million years. Cressida's density indicates it is made of mostly water ice. If the other moons have similar compositions, they may have lower than expected masses, which means this and other collisions may happen in the more distant future. Determining what the moons are made of may also reveal their post-collision fate: Will they merge, bounce off of each other or shatter? —*Ashley Yeager*

FROM TOP: M. BOCHMAN; JPL-CALTECH/NASA, STSCI

to help find the missing microbes. "So we went yeast hunting," Bochman says.

He collected about 100 strains of yeast. "Whenever I was out and about I would grab something — a piece of bark, a berry — bring it back to the lab and get yeast from it." The microbes are everywhere, he says. "It's hard not to find yeast."

But not just any yeast will do. For beer brewing, Bochman needed yeast that eats the sugar maltose in wort — the liquid extracted from grain mash that gets fermented into beer. Brewing yeast also has to be tolerant of hops, which make weak acids that might slow yeast growth. The yeast must be able to live in 4 to 5 percent alcohol. And, of course, the microbes have "to smell and taste at least neutral, if not good," Bochman says. Not all yeasts pass the sniff test. Eight strains of *Saccharomyces paradoxus* made beer that "smelled and tasted ... of adhesive bandages," Bochman and colleagues report online August 7 at bioRxiv.org.

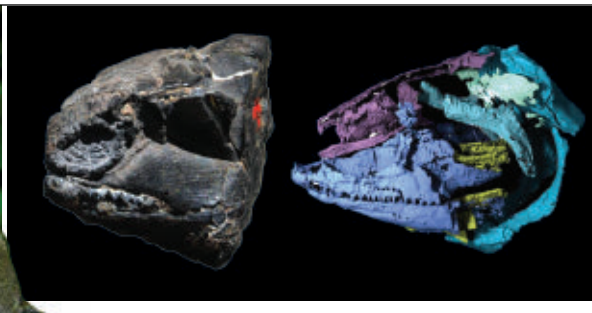
But in 2015, a batch of wild beer brewed in an open vat in a vacant lot in Indianapolis by Bochman's friends at Black Acre Brewing Co. yielded a winner. Among the four species and six strains of yeast in the beer was a *Saccharomyces cerevisiae* strain called YH166. *S. cerevisiae* is a species of yeast used to brew ales and to make bread. YH166 lends beer an aroma that is "an amazing pineapple, guava something. Like an umbrella drink," Bochman says.

He doesn't yet know what chemicals the yeast makes to produce the tropical fruit scent. He puts his money on one of the sweet-smelling esters yeast use to attract fruit flies (*SN: 11/15/14, p. 13*).

Sour beer brewers may also benefit from Bochman's bioprospecting. Sour beers generally contain lactic acid bacteria in addition to yeast. Brewers need separate equipment for brewing sour beer because it's difficult to get rid of all the bacteria when switching back to brewing other beers. Among 54 species of yeast Bochman and colleagues studied, five strains can make both alcohol and lactic acid to brew sour beers without bacteria. The researchers described the five sourpusses online July 28 at bioRxiv.org.

Some beers brewed with wild yeast taste fruity; others have notes from the barnyard.

Bochman and Caputo formed the company Wild Pitch Yeast to sell these strains. The company supplied yeast isolated from cobwebs, trees and other spots to brewers making all-Indiana beers, dubbed "Bicentenni-ales," for the state's 200th anniversary last year. Bochman and Caputo are relying on brewers to tell them how the newfound yeasts perform in the real world. "The proof is in the brewing," Bochman says. "You can do as many lab tests as you want, but you're never going to know how something will act until you throw it into some wort and let it bubble away for a couple of weeks." — *Tina Hesman Saey*



CT scans of an ancient ray-finned fish fossil helped scientists conclude that ray-finned fishes (modern example at left) evolved more recently than thought.

CLOCKWISE FROM TOP: RONSTIK/ISTOCKPHOTO; FOSSIL AND CT SCAN: ANDREY ATUCHIN; M. FRIEDMAN/UNIV. OF MICHIGAN

RETHINK

Fossils shake up fish family tree

When it comes to some oddball fish, looks can be deceiving.

Polypterus, today found only in Africa, and its close kin have generally been considered some of the most primitive ray-finned fishes alive, thanks in part to skeletal features that resemble those on some ancient fish. Now a new analysis of fish fossils of an early polypterid relative called *Fukangichthys* unearthed in China suggests that those features aren't so old. The finding shakes up the evolutionary tree of ray-finned fishes, making the group as a whole about 20 million to 40 million years younger than thought, researchers propose online August 30 in *Nature*.

Ray-finned fishes — named for the spines, or rays, that support their fins — are the largest group of vertebrates, making up about half of all backboned animals. They include 30,000 living species, such as gars, bowfins and salmon. The group was thought to originate about 385 million years ago, in the Devonian Period. But the new research, using 3-D CT scans of the previously discovered fossils, shifts the fishes' apparent origin to the start of the Carboniferous Period some 360 million years ago, says study coauthor Matt Friedman, a paleontologist at the University of Michigan in Ann Arbor.

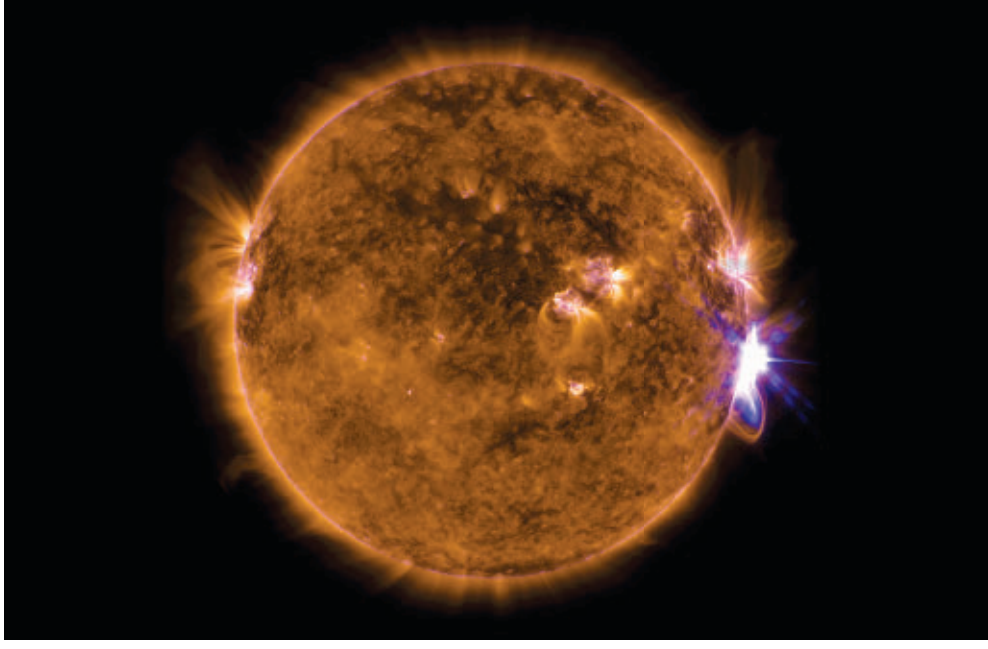
One of the largest extinction events in Earth's history marks the boundary between the Devonian and Carboniferous. "We know that many groups of backboned animals were hard hit by the event," Friedman says. But after the massive die-off, ray-finned fishes popped up and, according to previous fossil evidence, their diversity exploded. The new finding "brings the origin of the modern ray-finned fish group in line with this conspicuous pattern that we see in the fossil record," Friedman says. It suggests these vertebrates didn't survive the event. They came after, then flourished. — *Viviane Callier*

ATOM & COSMOS

Flares hold clues to solar mystery

Physicists seek to explain big bursts near end of sun cycles

BY LISA GROSSMAN



A sunspot spat out seven large flares from September 4 to 10. The Sept. 10 event (bright flash at right) is shown in this ultraviolet image. These flares will help test a theory of why big flares tend to occur as a solar cycle ebbs.

SDO/GSFC/NASA

A series of rapid-fire solar flares may offer the first chance to test a new theory of why the sun releases its biggest outbursts when its activity is ramping down. Migrating bands of magnetism that meet at the sun's equator may cause the biggest flares, even as the sun is going to sleep.

A single complex sunspot called Active Region 2673 emitted seven bright flares — powerful bursts of radiation triggered by magnetic activity — from September 4 to 10. Four were X-class solar flares, the most intense kind. The strongest, released on September 6, was an X9.3-class flare. The most powerful since 2006, it disrupted shortwave radio communication over the sunlit side of the Earth for up to an hour. It also flung a blob of energetic plasma, called a coronal mass ejection, toward Earth, sparking auroras over North America on September 7 that were visible as far south as Arkansas.

All that activity is counterintuitive, as the sun is near the end of an unusually weak solar cycle, which began in 2008 (*SN: 11/2/13, p. 22*). Solar magnetic activity waxes and wanes about every 11 years, generating more dark sunspots at the peak of the cycle and fewer at the trough.

Solar physicists realized in the 1960s that the peak flare rate comes a few years after the sunspot maximum. Even stranger, the strongest flares tend to occur on the cycle's downswing. The quietest cycles may even produce the biggest flares.

"When you're descending to a quiescent phase of the cycle and things are getting more organized and simplified, how is it we are getting things this complex?" asks Madhulika Guhathakurta, an astrophysicist with NASA's Heliophysics Division. "It still remains an interesting question."

Scott McIntosh, a solar physicist at the National Center for Atmospheric Research in Boulder, Colo., has a potential answer. In a series of papers, including a 2015 paper in *Nature Communications*, he and colleagues argue that complex sunspots like AR 2673 and their forceful flares are the result of opposing bands of magnetism vying for supremacy.

These bands are like magnetic jet streams, McIntosh says. But unlike jet streams on Earth, which generally stay anchored at certain latitudes, the sun's bands migrate over the course of the solar cycle. They begin closer to the poles and over time move toward the equator, possibly by pulling on each other with tremendous magnetic force.

The northern band and the southern band twist in opposite directions, so when they finally meet at the equator, it's chaos. Their magnetic lines tangle and twist. McIntosh thinks those warring bands may create more complicated sunspots, called deltas, which appear as a mottled mess of light and dark representing different magnetic poles. McIntosh could tell that AR 2673 was a delta as soon as he saw it. These deltas make up "about 5 percent of the total number of sunspots, but contribute almost 100 percent of the trouble," he says.

Over the next year and a half or so, the bands will cancel each other out completely, marking the end of the solar cycle. "This is their last hurrah," McIntosh says.

During weak solar cycles, McIntosh and colleagues suggest, this process takes longer. That lets the bands spend more time wrestling with each other and merging, creating complex spots that build up massive amounts of energy to release in flares.

Monitoring the sun for more deltas and large flares will help test if the theory is right, or if something else, like the sun's internal churning, back-loads strong flares. "If this delta is joined by further deltas before the end of the cycle, that's more empirical proof that our idea of band interaction really is steering the game," McIntosh says.

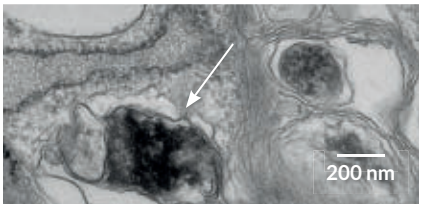
Proving his idea will require a better understanding of what's going on deep in the sun, which computer simulations are not up to yet, Guhathakurta says. But she likes McIntosh's approach of merging observations and theory. Predicting the most powerful flares is important for protecting communications satellites and power grids from the surge in energetic particles that flares can cause.

"If we can actually figure this out, really associate it to something in the solar cycle, then it certainly helps us with long-term forecasting," she says. ■

BODY & BRAIN

Rogue dopamine linked to Parkinson's

Treatment with antioxidants might lessen nerve cell destruction



Dark spots of neuromelanin (arrow) appear in 90-day-old nerve cells derived from a person with a Parkinson's-related mutation. The deposits contain a damaging form of dopamine.

BY LAURA SANDERS

The brain chemical missing in Parkinson's disease may have a hand in its own death. Dopamine, the neurotransmitter that helps keep body movements fluid, can kick off a toxic chain reaction that ultimately kills the nerve cells that make it, a new finding suggests.

By studying lab dishes of human nerve cells, or neurons, derived from Parkinson's patients, researchers found that a harmful form of dopamine can inflict damage on cells in several ways. The result, published online September 7 in *Science*, "brings multiple pieces of the puzzle together," says neuroscientist Teresa Hastings of the University of Pittsburgh School of Medicine.

The finding also hints at a way to combat Parkinson's disease: Less cellular damage occurred when some of the neurons were treated early on with antioxidants, molecules that can scoop up harmful chemicals inside cells.

Dimitri Krainc, a neurologist at the Northwestern University Feinberg School of Medicine in Chicago, and colleagues took skin biopsies from healthy people and people with one of two types of Parkinson's disease, inherited or spontaneously arising. The researchers coaxed these skin cells into becoming dopamine-producing neurons. These cells were similar to those found in the substantia nigra, the movement-related region of the brain that degenerates in Parkinson's.

After neurons carrying a mutation that causes the inherited form of Parkinson's had grown in a dish for 70 days, the researchers noticed some worrisome changes in the cells' mitochondria. Levels of a harmful form of dopamine known as oxidized dopamine began rising in these energy-producing organelles, reaching high levels by day 150. Neurons derived from people with the more common, sporadic form of Parkinson's showed a similar increase but later, beginning at day 150. Cells derived from healthy people didn't accumulate oxidized dopamine.

Oxidized dopamine seemed to kick off other cellular trouble. Defects in the cells' lysosomes, cellular cleanup machines, soon followed. So did accumulation of a protein called alpha-synuclein, which plays a role in Parkinson's.

Those findings are "direct experimental evidence from human cells that the very chemical lost in Parkinson's disease contributes to its own demise," says analytical neurochemist Dominic Hare, of the Florey Institute of Neuroscience and Mental Health in Melbourne, Australia. Because these cells churn out dopamine, they are more susceptible to dopamine's potential destructive forces, he says.

When neurons carrying a mutation that causes inherited Parkinson's were treated with antioxidants, the damage was lessened. To work in people, antioxidants would need to cross the blood-brain barrier, a difficult task, and reach the mitochondria. And this would need to happen early, probably even before symptoms appear, Krainc says. ■

GENES & CELLS

Genes foretell flu shot response

For now, predictive powers are limited to young people

BY AIMEE CUNNINGHAM

A genetic "crystal ball" can predict whether certain people will respond effectively to the flu vaccine.

Nine genes are associated with a strong immune response to the flu vaccine in those age 35 and under, a study finds. If these genes were highly active before vaccination, an individual would generate a high level of antibodies after vaccination, no matter the flu strain in the vaccine, researchers report online August 25 in *Science Immunology*. This response can help a person avoid getting the flu.

The researchers tried to find predictive genes in people age 60 and above — a group that includes those more likely to develop flu-related complications — but failed. Even so, the study is "a step in the right direction," says immunologist Elias Haddad of Drexel University College of Medicine in Philadelphia. "It could have implications in terms of identifying responders versus nonresponders by doing a simple test before a vaccination."

Computational immunologist Purvesh Khatri of Stanford University School of Medicine and colleagues wondered if a person needs to be in a certain immune state to respond effectively to a flu shot. So the team looked for a common genetic signal in blood samples from 175 people with different genetic backgrounds, from different locations in the United States, and who received the flu vaccine in different seasons. After identifying the predictive genes, the team used another 82 samples to confirm that the crystal ball could predict a strong response.

The nine genes make proteins that have various jobs, including directing other proteins' movements. Khatri expects the study will spur investigations into how the genes promote a successful vaccine response.

Older people's responses are more diverse than younger people's, says coauthor and computational biologist Raphael Gottardo of the Fred Hutchinson Cancer Research Center in Seattle. So it may take a larger set of samples to find a common genetic thread. ■

L. F. BURBULLA *ET AL*/*SCIENCE* 2017

MATTER & ENERGY

Quantum storage device fits on a chip

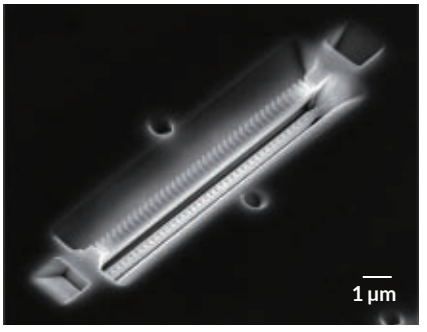
Miniature crystal could help qubit-encoded messages travel far

BY MARIA TEMMING

A new data storage device, which takes up less than a millionth the amount of space of its predecessors, could be a key component of future communication systems.

Scientists fashioned a tiny crystal that stores snippets of quantum information — which unlike computer data "bits" that come only in 0s and 1s, can also exist as both 0 and 1 simultaneously. This crystal is the first quantum memory device of its kind that could fit on a chip alongside nano-sized instruments for detecting and sending signals written in quantum bits. This work, reported online August 31 in *Science*, improves prospects for establishing a widespread, ultrasecure network of quantum communications.

Crystal quantum memory devices hoard data by absorbing photons, each of which carry a quantum bit, or qubit, of data. Generally, the bigger the crystal, the greater the chance that one of its atoms will absorb a photon. For a cube-shaped crystal to snare photons as well as the new device, it would have to be a millimeter across, says molecular engineer Tian Zhong of the University of Chicago.



Serrations help this minuscule memory device (imaged by a scanning electron microscope) catch photons carrying quantum bits of data.

Zhong and colleagues' crystal is about 10 micrometers long and 0.7 micrometers wide — about as wide as a bacterial cell.

The secret to the device's tiny size is its shape: a triangular prism with notches etched on top. "The grooves towards the ends of the [crystal] collectively behave as two mirrors, one on each side," Zhong says. Photons entering the crystal at one end bounce back and forth between the "mirrors" many times before they can escape, upping the chances of absorption.

Zhong's team tested the crystal's storage capabilities by using an optical fiber to inject it with one bunch of photons, then another. The qubit carried on each photon was 0 if it belonged to the earlier pulse, 1 if it belonged to the later pulse or 0 and 1 if (thanks to the rules of quantum mechanics) it belonged to both pulses.

Some of the photons got absorbed by neodymium atoms in the crystal, each of which could hold on to a photon for about 75 nanoseconds. Once photons escaped, they zipped out through the optical fiber. So the team saw one blip of light come out of the crystal, followed by another.

For the most part, each photon that emerged from the device preserved its original identity as a 0, 1 or both. "This is what demonstrates that the device can perform quantum memory," says co-author Andrei Faraon, a Caltech physicist. "It doesn't destroy that information."

This kind of device could expand the reach of future quantum computer networks, says physicist Jevon Longdell of the University of Otago in New Zealand.

Photons carrying quantum data through fiber-optic cables tend to get lost along the way, so qubit-encoded messages can't make nonstop trips longer than about 100 kilometers, Longdell says. But chips packing photon detectors, generators and these memory devices could serve as a pit stop between optical fibers, to help messages go the distance. ■

BODY & BRAIN

Zika could thwart lethal brain cancer

Virus kills the stem cells that turn into glioblastoma tumors

BY LAUREL HAMERS

Zika's damaging neurological effects might someday be enlisted for good — to treat brain cancer.

In human cells and in mice, the virus killed the stem cells that become a glioblastoma, an aggressive brain tumor, but left healthy brain cells alone, researchers report online September 5 in the *Journal of Experimental Medicine*.

Previous studies had shown that Zika kills stem cells that generate nerve cells in developing brains (*SN: 4/2/16, p. 26*). Neural precursor cells and stem cells that turn into glioblastomas share some similarities. So Jeremy Rich, a regenerative medicine scientist at the University of California, San Diego, and colleagues suspected Zika might also target the cells that cause the notoriously deadly cancer.

In human cell cultures, Zika infected glioblastoma stem cells and halted their growth, Rich's team reports. The virus also infected full-blown glioblastoma cells but at a lower rate, and didn't infect normal brain tissues. Zika-infected mice with glioblastoma either had tumors that shrank or had tumor growth slow compared with uninfected mice. The infected mice also lived two to three times longer.

Using a virus to knock out cancer isn't a new idea. Treatments that rely on modified polioviruses to target tumors are in clinical trials, and a modified herpesvirus is approved by the U.S. Food and Drug Administration for treating melanoma.

"Right now we don't know what kind of viruses are best" for fighting cancer, says Andrew Zloza, head of surgical oncology research at the Rutgers Cancer Institute of New Jersey in New Brunswick. Zika is yet another candidate.

Rich and colleagues are now testing in mice whether combining Zika with traditional cancer treatments such as chemotherapy is more effective than either treatment by itself. Because Zika targets the cells that generate tumor cells, it might prevent tumors from recurring. ■

T. ZHONG

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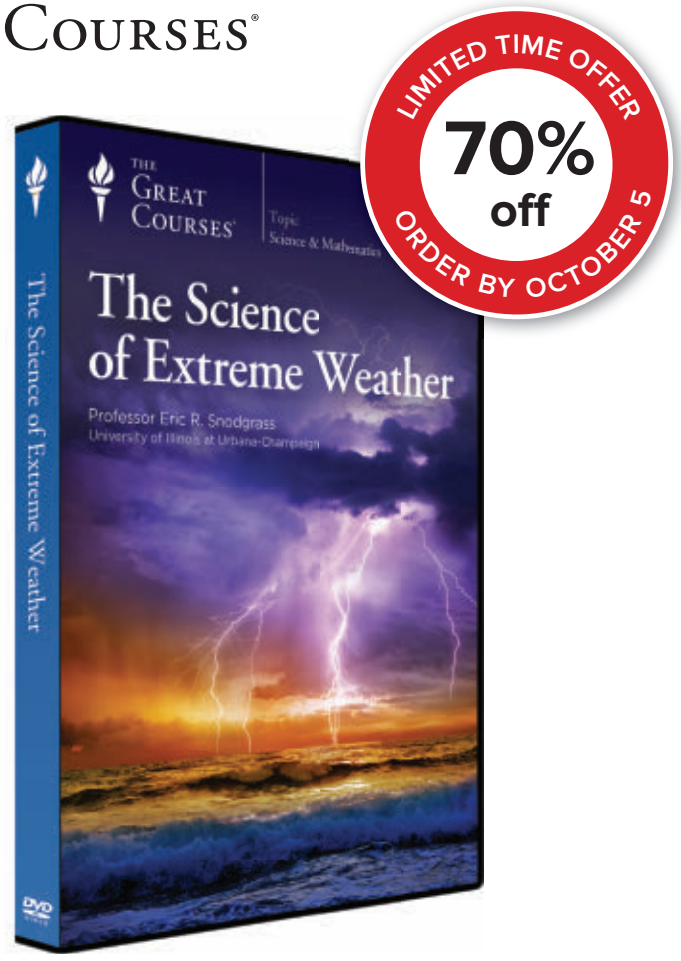

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LIFE & EVOLUTION

Some woolly rhinos grew odd neck ribs

Defect may have signaled genetic trouble in shrinking population

BY SUSAN MILIUS

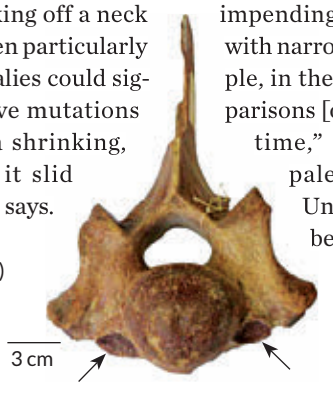
As time ran out for the woolly rhino, strange things happened. Before going extinct, some of the beasts faced an unusually high risk of growing bizarre ribs in their neck, a new study suggests. Those misplaced ribs might have signaled the animals' impending demise.

Scientists studied the lowermost neck bone from 32 woolly rhinos and found indented spots on five where ribs had once attached. That amounts to strange neck ribs in about 16 percent of the creatures.

For comparison, 56 specimens of the same vertebra from modern rhino skeletons had no such spots, says evolutionary biologist Frietson Galis of the Naturalis Biodiversity Center in Leiden, the Netherlands. Galis and Alexandra van der Geer, a paleontologist also at Naturalis, report the work August 29 in *PeerJ*.

Found in what is now the North Sea and in adjacent Dutch deltas and coastal areas, the bones date from about 35,000 to 115,000 years ago, a time of changing climate. The woolly rhino probably disappeared from Western Europe not long after about 35,000 years ago, though populations to the east survived longer.

Extra bits of rib sticking off a neck bone might not have been particularly harmful. But the anomalies could signal that more disruptive mutations were cropping up in a shrinking, inbred population as it slid toward extinction, Galis says.



Two indented spots (arrows) on this hefty neck vertebra of a woolly rhino may be an indicator of neck ribs, a physical abnormality.

F. GALIS

The basics of neck vertebrae are set early in a mammal embryo's development, and mutations that affect neck bones may be too disruptive for many embryos to survive to birth. Neck ribs have been associated with childhood cancer in people and congenital abnormalities in animals that do survive beyond birth.

The researchers didn't match ribs with the odd vertebrae, but the attachment points look like those on vertebrae supporting ribs.

A stronger test of the proposed link between neck ribs and woolly rhinos' impending doom needs more fossils with narrower date ranges. For example, in the study, "there are no comparisons [of neck vertebrae] through time," says Johannes Müller, a paleozoologist at Humboldt University of Berlin. It would be helpful to know how often the ribs show up in woolly rhinos from a time when their populations were flourishing, he says. ■

MATTER & ENERGY

Potential signs of quantum collapse

'Jitter' matches predictions of wave function theory

BY EMILY CONOVER

A tiny, shimmying cantilever wiggles a bit more than expected in a new experiment. The excess jiggling of the miniature, diving board–like structure might hint at why the strange rules of quantum mechanics don't apply in the familiar, "classical" world. But that potential hint is still a long shot: Other sources of vibration are yet to be fully ruled out.

Quantum particles can occupy more than one place at the same time, a condition known as superposition. Only once a particle's position is measured does its location become definite. In quantum terminology, the particle's wave function, which characterizes the spreading of the particle, collapses to a single location.

In contrast, larger objects are always found in one place. "We never see a table or chair in a quantum superposition," says theoretical physicist Angelo Bassi of the University of Trieste in Italy, a coauthor of the study, to appear in *Physical Review Letters*. But standard quantum mechanics doesn't fully explain why large objects don't exist in superpositions, or how and why wave functions collapse.

Extensions to standard quantum theory can alleviate these conundrums by assuming that wave functions collapse spontaneously, at random intervals. For larger objects, that collapse happens more quickly, so on human scales objects don't show up in two places at once.

Now, scientists have tested one such extension to the theory by looking for one of its predictions: a small jitter, or "noise," imparted by the random nature of wave function collapse. The scientists looked for this jitter in a half-millimeter-long cantilever. After cooling the cantilever and isolating it to reduce external sources of vibration, an unexplained trembling still remained.

In 2007, physicist Stephen Adler of the Institute for Advanced Study in Princeton, N.J., predicted that the level of jitter from wave function collapse would be large enough to spot in experiments like this one. The new measurement is consistent with Adler's prediction.

"That's the interesting fact, that the noise matches these predictions," says study coauthor Andrea Vinante, formerly of the Institute for Photonics and Nanotechnologies in Trento, Italy. But, he says, he wouldn't bet on the source being wave function collapse. "It is much more likely that it's some not very well understood effect in the experiment."

To conclude that wave function collapse is the cause of the excess vibration, Adler says, every other possible source will have to be ruled out. "It's going to take a lot of confirmation to check that this is a real effect," he says.

Bassi and colleagues plan to change the design of the cantilever to attempt to isolate the source of the vibration. ■

ATOM & COSMOS

Don't blame aliens for star's flickering

Dust or odd stellar cycle could explain Tabby's erratic behavior

BY LISA GROSSMAN

Alien megastructures are out. The unusual fading of an oddball star is more likely caused by either clouds of dust or an abnormal cycle of brightening and dimming, two new papers suggest.

Huan Meng of the University of Arizona in Tucson and colleagues suggest that KIC 8462852, known as Tabby's star, is dimming thanks to an orbiting cloud of fine dust particles. The team observed the star with the infrared Spitzer and ultraviolet Swift space telescopes from October 2015 to December 2016 — the first observations of Tabby's star in multiple wavelengths of light. The star is dimming faster in short blue wavelengths than longer infrared ones, suggesting small particles are blocking its light.

"That almost absolutely ruled out the alien megastructure scenario, unless it's an alien microstructure," Meng says.

Tabby's star, located about 1,280 light-years away in the constellation Cygnus, is most famous for suddenly dropping in brightness by up to 22 percent over the course of a few days. Later observations suggested the star is also fading by a few percent per year (*SN: 9/17/16, p. 12*), which Meng's team confirms in a paper posted online August 24 at arXiv.org.

Joshua Simon of the Observatories of the Carnegie Institution for Science in Pasadena, Calif., and colleagues found a similar dimming in data on Tabby's star from a sky survey going back to 2006. The researchers also found for the first time that the star grew brighter in 2014, and possibly in 2006, the team reports in a paper August 25 at arXiv.org.

"That's fascinating," says astrophysicist Tabetha Boyajian of Louisiana State University in Baton Rouge. She first reported the star's flickers in 2015 (the star is nicknamed for her) and is a coauthor on Meng's paper. "We always speculated that it would brighten sometime. It can't just get fainter all the time — otherwise it would disappear."

The brightening and dimming could be due to a magnetic cycle like the sun's, Simon suggests. But no known cycle makes a star's light vary by quite so much, so the star would still be odd.

Brian Metzger, an astrophysicist at Columbia University, previously suggested that pieces of a ripped-up planet falling into the star could explain both the long- and short-term dimming. He thinks that model still works, though it needs some tweaks.

"This adds some intrigue," Metzger says, "but I don't think it really changes the landscape." Newer observations could complicate things further: The star began another series of dimmings in May. Metzger says he's waiting to see papers analyzing those dips. ■

LIFE & EVOLUTION

Horses traded toes for speed, strength

As body size grew over evolutionary time, equines lost digits

BY EMILY UNDERWOOD

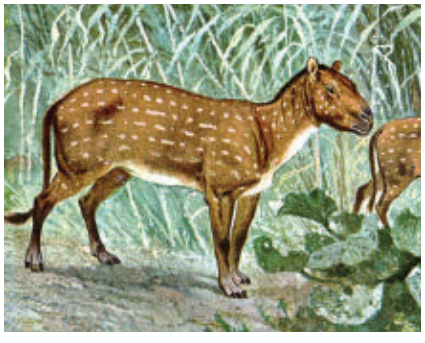
Horses can leap over high hurdles, gallop at up to 70 kilometers per hour and haul around up to nearly 1,000 kilograms of body weight — and all with just one toe on each foot. A new study in the Aug. 30 *Proceedings of the Royal Society B* helps explain why: Streamlined digits improved horses' strength and speed.

Along with zebras and donkeys, horses are among the few single-toed creatures in the animal kingdom. Scientists have long suspected that horses' single, hoofed toes helped them run farther and faster over grasslands, letting them flee predators and find fresh forage. But the hypothesis that having one, big toe is better than having several, biomechanically speaking, has never been directly tested.

"This study takes an important step" toward resolving why horses shed digits during their early evolution, says Karen Sears, an evolutionary biologist at UCLA.

Ancient horses had a lot of toes to lose. The dog-sized *Hyracotherium*, which lived about 55 million years ago, had four toes on its front feet and three on its back feet. *Merychippus*, which lived about 10 million years ago, resembled a modern horse but had three toes on all feet, including one long middle digit with a toenail-like hoof at the end. The only surviving horse genus, the single-toed *Equus*, emerged about 5 million years ago.

The ancient horse *Hyracotherium* (illustrated) had four toes on its front feet and three on its back feet. New simulations examine why modern horses evolved to have just one, big toe.



To retrace the evolution of horse toes, Brianna McHorse, a paleontologist at Harvard University, and colleagues used CT scans to capture the internal structure of fossilized foot bones from 12 kinds of extinct horses. The team also studied the feet of the closely related Central American tapir, which has toes like *Hyracotherium*. A computer simulation let the researchers estimate how the bones would respond to the stresses of locomotion for each species, such as jumping or accelerating into a gallop. Then the scientists compared what happened when they applied the animal's full body weight to just the central toe, or spread it among multiple toes.

Side toes significantly increased early horses' ability to bear their own weight, the team found — the central toe of early horses would have fractured without help from other toes. As the era of modern horses approached and side toes dropped away, however, the middle toe bone grew thicker and hollower. These changes made the single-toed foot nearly as sturdy — resistant to bending and compression — as multiple toes.

As horses' legs grew longer, the extra toes at the end of the limb would have been "like wearing weights around your ankles," McHorse says. Shedding those toes could have helped early horses save energy, allowing them to travel farther and faster, she says. The study couldn't determine what changes came first — whether bulking up the middle toe drove the loss of side toes, or the loss of side toes caused changes in the middle toe.

Horses aren't the only animals to have lost toes or fingers to the evolutionary chopping block. "Digits have been lost many times in animals that walk, run, hop and fly," says biologist Kim Cooper of the University of California, San Diego. Modeling how forces of locomotion act on an animal's bones — living or extinct — could help scientists understand why. ■

BODY & BRAIN

How gut bacteria may affect anxiety

MicroRNAs could be key to microbes' effect on brain

BY MARIA TEMMING

Tiny molecules in the brain may help gut bacteria hijack people's emotions.

Bacteria living in the human gut have strange influence over mood, depression and more, but it has been unclear exactly how belly-dwelling bacteria exercise remote control of the brain (*SN: 4/2/16, p. 23*). Now research in rodents suggests that gut microbes may alter the inventory of microRNAs — molecules that help keep cells in working order by managing protein production — in brain regions involved in controlling anxiety.

The findings, reported online August 25 in *Microbiome*, could help scientists develop new treatments for some mental health problems.

Mounting evidence indicates "that the way we think and feel might be able to be controlled by our gut microbiota," says study coauthor Gerard Clarke, a psychiatrist at University College Cork in Ireland. For instance, the presence or absence of gut bacteria can influence whether a mouse exhibits anxiety-like behaviors, such as avoiding bright lights or open spaces.

Clarke and colleagues compared normal mice, whose gastrointestinal tracts were teeming with bacteria, with mice bred in sterile environments, whose guts didn't contain microbes. In brain regions involved in regulating anxiety — the amygdala and prefrontal cortex — microbe-free mice had an overabundance of some types of microRNA and a shortage of others compared with normal mice. After scientists exposed some sterilized mice to microbes, the rodents' microRNA levels more closely matched those of normal mice.

The team also examined microRNAs in the amygdala and prefrontal cortex of rats whose gut bacteria had been killed by antibiotics. These rats overproduced

HEINRICH HARDER, TOMCATX/WIKIMEDIA COMMONS

and underproduced some of the same microRNAs that were off-kilter in sterile mice. The researchers suspect that gut bacteria affect their host's anxiety levels by tampering with microRNAs in specific parts of the brain.

"I was a little surprised by the findings — in a positive way — because I think not many people so far have thought about microRNAs in this context," says Peter Holzer, a neurogastroenterologist at the Medical University of Graz in Austria. "It's heading into a new area in gut-brain research that hasn't been pursued."

How gut bacteria dial microRNA production up and down in the brain remains unknown. Maybe the microbes send signals along the vagus nerve, a kind of information highway that runs from gut to brain (*SN: 11/28/15, p. 18*). Or perhaps bacteria churn out molecular by-products that provoke the immune system to make chemicals that cause the brain to generate more or less of particular microRNAs. Outlining microbes' mental manipulation scheme from start to finish "is still a work in progress," Clarke says.

Next the team wants to see if probiotics can cultivate certain gut bacteria, and therefore fine-tune microRNA levels in specific parts of the brain. Adjusting microRNA abundances in a way that assuages anxiety could help lead to the development of new medications for psychiatric and neurological disorders.

MicroRNA-based medications may be unrealistic in the short term, though, says UCLA gastroenterologist Kirsten Tillisch. "People tend to like to extrapolate these types of results to humans and start moving quickly towards clinical applications. It is just so tempting," she says. "But we know historically the translation from lab animal to human is hit-and-miss." ■

HUMANS & SOCIETY

Neandertal tar-making reconstructed

Bark-burning methods may not have required mastery of fire

BY BRUCE BOWER

Neandertals took stick-to-itiveness to a new level. Using just scraps of wood and hot embers, our evolutionary cousins figured out how to make tar, a revolutionary adhesive that they used to attach stones to handles for making spears, chopping tools and other implements, a new study suggests.

Tar derived from birch bark dates to at least 200,000 years ago at Neandertal sites, well before the earliest known evidence of tar production by *Homo sapiens* around 70,000 years ago. Now, archaeologist Paul Kozowyk of Leiden University in the Netherlands and colleagues have re-created the tar-making methods that Neandertals could have used.

Three straightforward techniques could have yielded enough adhesive for Neandertals' purposes, Kozowyk's team reports August 31 in *Scientific Reports*. None of the methods require the use of ceramic containers such as kilns or heating bark to precise temperatures.

"This new paper demystifies the prehistoric development of birch-bark tar production, showing that it was not predicated on advanced cognitive or technical skills but on knowledge of familiar, readily available materials," says archaeologist Daniel Adler of the University of Connecticut in Storrs.

The findings do, however, fuel another burning question: whether Neandertals had mastered the art of controlling fire. Some researchers suspect that Neandertals relied on specialized fire knowledge to make adhesives; others contend that Neandertals only exploited the remnants of wildfires. Although the study suggests Neandertals invented low-tech ways to make tar with fire, it's not clear whether those fires were intentionally lit.

Kozowyk's group tested each of three tar-making techniques five to 11 times. The lowest-tech approach consisted of rolling up a piece of birch bark, tying it with wood fiber and covering it in a mound of ashes and embers from a fire. The experimenters collected up to about one gram of tar this way.

A second strategy involved igniting a roll of birch bark at one end and placing it in a small pit. The researchers either scraped tar off bark layers or collected tar drippings. The most tar gathered with this method, about 1.8 grams, was in a trial using a birch-bark cup placed beneath a bark roll with its lit side up and covered in embers.

Repeating either the ash-mound or pit-roll techniques once or twice would yield the small quantity of tar found at one particular Neandertal site. Six to 11 repetitions would produce a tar haul equal to that unearthed at another site.

To make tar, Neandertals might have placed embers from a fire over a roll of burning birch bark in a pit and collected the tar in a birch-bark vessel (like the one shown).

In the third technique, the scientists put a birch-bark vessel for collecting tar into a small pit. They placed a layer of twigs and then pebbles across the top of the pit, and next added a large, loose bark roll covered in a dome-shaped coat of wet soil. Finally, a fire was lit on the earthen structure. After some practice, one trial resulted in 15.7 grams of tar — enough to make a lump comparable in size to the largest chunks found at Neandertal sites.

An important key to making tar was reaching roughly the right heat level. At some point each procedure heated bark to between about 200° and 400° Celsius.

If they exploited naturally occurring fires, Neandertals had limited time and probably relied on a simple technique such as ash mounds, Kozowyk proposes. If Neandertals knew how to start and maintain fires, they could have pursued more complex approaches. ■

P. KOZOWYK

When startled, the dusky slug (*Arion subfuscus*) produces a goopy defense slime that slows down predators. Scientists are studying the chemical structure of this goo to make better surgical adhesives.

A. SMITH

MATH & TECHNOLOGY

Designing a better glue from slug goo

Bio-inspired adhesives could make surgery smoother and safer

BY LAUREL HAMERS

Finding a great glue is a sticky task — especially if you want it to attach to something as slick as the inside of the human body. Even the strongest human-made adhesives don't work well on wet surfaces like tissues and organs. For surgeons closing internal incisions, that's more than an annoyance. The right glue could hold wounds together as effectively as stitches and staples with less damage to the surrounding soft tissue, enabling safer surgical procedures.

A solution might be found under wet leaves on a forest floor, recent research suggests. Jianyu Li of McGill University in Montreal and colleagues have created a surgical glue that mimics the chemical recipe of goopy slime that slugs exude when they're startled. The adhesive stuck to a pig heart even when the surface was coated in blood, the team reported in the July 28 *Science*. Using the glue to plug a hole in the pig heart worked so well that the heart still held in liquid after being inflated and deflated tens of thousands of times. Li, who did the research while at Harvard University, and colleagues also tested the glue in live rats with liver lacerations. It stopped the rats' bleeding, and the animals didn't appear to suffer any bad reaction from the adhesive.

The glue has "excellent, excellent properties," says Andrew Smith, a biologist at Ithaca College in New York.

And slugs aren't the only biological inspiration for new adhesives. Clues to better glues have long been hiding out in damp, soggy and downright wet places. For slugs, mussels, marine worms and a cadre of other critters, secreting sticky substances that attach strongly to soaked surfaces is just a fact of life. That's why scientists are studying the structures of those substances to design new and better surgical adhesives.

"There's really a big need to develop new ways of sealing tissues, of affixing devices to tissues — in particular, for minimally invasive procedures," says Jeff Karp, a biomedical engineer at Brigham and Women's Hospital in Boston. While existing medical-grade superglue is great at sealing up fingertip cuts, it is too toxic to use inside the body. Other alternatives just aren't sticky enough to fully replace stitches. With a better glue, surgeons could also make snips that are too tiny to be stitched or stapled closed. Smaller incisions speed healing time and decrease risk of complications, Karp says.

Smith says he isn't surprised that slug slime could lead to a big advance. For several years, he's been trying to understand how the slug *Arion subfuscus* builds its ooze. For his research, Smith prods slugs gently with the tip of a metal spatula to startle them, and scoops up the slime as it's released. "If you get it on your hands, it'll set within seconds into an extremely sticky material," he says.

The goo, Smith and others have found, overcomes a major challenge that adhesive designers face. It seems obvious that glue should be sticky. Yet the molecules in glue need to adhere not just to the things you're trying to stick together, but also to each other. And that stickiness can't come at the expense of flexibility, especially for medical applications. Soft, squishy organs are going to jiggle; skin is going to stretch. Without some bendiness, the glue might attach securely to each of the surfaces being stuck together, but the glob of glue itself might snap or shear under stress.

Slug defense slime solves that problem with two interwoven networks of molecules, tangled together like strings of holiday lights. One network is rigid, with chemical bonds that break easily, Smith says. The other is deformable, stretching substantially without breaking. This combo makes the goo simultaneously tough, flexible and sticky.

Li's slug-inspired adhesive takes a similar approach. One layer of the material is a polymer, a type of material made from long molecules built from many repeated subunits, like a string of beads. Positively charged appendages dangling off the polymers are drawn to wet tissue surfaces by the same forces underlying static electricity. This first layer weaves into another layer, a water-based gel. The gel layer acts like a shock absorber in a car, Li says. It soaks up energy that might otherwise dislodge or snap the adhesive.

Despite being 90 percent water, the material is both sticky and tough, Li says. The fact that it's mostly water makes it more likely to be nontoxic to humans.

Though Li's adhesive has been tested only in human cell cultures and in lab animals, another bio-inspired glue has made its way into human trials. It's based on work published by Karp and colleagues in 2014 in *Science Translational*

Medicine. Karp's team developed a viscous liquid that solidifies into a tough but stretchy glue when illuminated by light, and demonstrated that the liquid can seal holes in hearts.

"Nothing we create is really that similar to anything you see in nature, but some of the ideas gave us critical insights," Karp says. The researchers realized, for example, that a lot of natural glues that work in water have hydrophobic elements that help clear away the water for a better stick. The research sparked Karp and colleagues to found a company, Gecko Biomedical, which Karp now advises. On September 11, the company announced the completion of a small clinical trial of its adhesive: The sealant immediately stopped blood flow after an artery-clearing operation in about 85 percent of 22 participants. Because of that success, Gecko Biomedical now has approval to market the glue in Europe.

Bio-inspired adhesives can do more than patch up incisions, though. Russell Stewart, a bioengineer at the University of Utah in Salt Lake City, is tapping into marine-dwelling sandcastle worms for a different glue goal: He wants to create a better embolic agent — a way to deliberately block blood flow to certain tissues. Embolic agents can cut blood flow to a tumor, say, or stem internal bleeding. Often, these materials are liquids that reach their target through a catheter and then solidify into a sticky mass to block tiny vessels. But such glues can be difficult to control — they need to harden at just the right time — and current options often rely on harsh materials that require special equipment and can cause pain for patients.

A slug-inspired glue (blue patch) stuck to the slimy surface of a pig heart and stretched without snapping or detaching.

Inspired by the sandcastle worm (*Phragmatopoma californica*), Stewart has designed a new — and he thinks better — embolic agent. A sandcastle worm uses fingerlike appendages coming out of its face to arrange grains of sand into expansive tubular reefs. It squirts small dabs of a liquid adhesive out of these appendages to make the grains stick together. That glue's structure is quite different from slug slime, Stewart has found. It's a solution of oppositely charged proteins strongly attracted to each other. The proteins make up a dense liquid that doesn't mix with water. A worm packages each ingredient in the glue separately, so the proteins combine only once secreted. After mixing, the glue solidifies in about 30 seconds.

Stewart's mimic also starts out as a liquid that transforms into a hard foam-like material within a few seconds of hitting blood, his team reported in 2016 in *Advanced Healthcare Materials*. That means the material can be injected as a liquid and doesn't harden until it's in the right place. Early tests have been promising: The foam completely blocked the arteries of rabbits' kidneys without moving into tissue where it didn't belong.

The range of biological adhesives is impressive, says Jonathan Wilker, a chemist at Purdue University in West LaFayette, Ind. "They're so wildly different," both in terms of chemical makeup and functional properties. That diversity provides a wide palette for scientists seeking glues for specialized applications. And Wilker's own work adds mussels to the list.

Mussels secrete a strong adhesive that helps them stick tenaciously to rocks and ship hulls. Their secret is a molecule called DOPA, Wilker says. DOPA, or 3,4-dihydroxyphenylalanine, sticks well to other DOPA molecules and to other substances. That gives it the same balance of toughness and stickiness that's also found in slug slime. Certain amino acids found in mussel proteins might also aid the underwater adhesion. For example, an amino acid called lysine that hangs off of mussel adhesion proteins appears to help clear water molecules out of the way, leaving a drier surface for proteins glomming on.

Mussels grab on to slippery rocks and boat hulls with astonishing strength. The proteins in their sticky secretions (shown) might hold clues to building a better glue.

Wilker's copycat adhesive is made up of long chains of polystyrene molecules (essentially, Styrofoam) with units of DOPA mixed in. Those long chains of tricked-out polystyrene molecules tangle together and cross-link to create a strong adhesive. He's made different varieties of the mimic, tailored for different applications. After being immersed in water, one version held on tighter underwater than the glue made by mussels themselves, Wilker's team reported in February in *Applied Materials Interfaces*. Another version is biodegradable.

If he can make the glues nontoxic to cells, they could possibly be used inside the body. In one recent study, Wilker created an artificial adhesive protein that mimics the natural protein elastin. The artificial version excelled in both dry and damp test environments, his team reported in April in *Biomaterials*.

Bringing animal-inspired adhesives into the human body won't necessarily be a simple task, though. It requires tackling some problems that other animals don't need to solve, Karp says. A slug, for instance, produces its slime as it needs it. It doesn't stockpile gallons of glue in its tiny body, or instantly churn out a year's supply. A successful real-world glue, however, will need to be easy to produce in large quantities and safe to store for months at a time, Karp points out. Those are problems humans will have to solve on their own. That's the next challenge. ■

FROM TOP: J. WILKER; J. LI, ADAM D. CELIZ, DAVID J. MOONEY

GENES & CELLS

In the lungs, mold cells self-destruct

Mouse study shows why some spores aren't a health problem

BY LAUREL HAMERS

Immune cells can turn certain invaders on themselves, forcing the unwanted visitors to prematurely self-destruct, researchers have discovered.

In mice, when white blood cells in the lungs engulf spores of a common airborne fungus, these immune cells release an enzyme that sends the fungal cells into programmed cell death. That prevents the spores from setting up shop in the lungs and sparking a potentially deadly lung infection, the researchers report in the Sept. 8 *Science*.

Found naturally in soil and decaying organic matter, the fungus, *Aspergillus fumigatus*, releases airborne spores that are found in small doses in the air people breathe every day. The finding may help explain why most people can regularly inhale the spores and not get sick. In people with weakened immune systems, though, this natural defense system doesn't work. This research could eventually lead to better treatments for these patients.

Programmed cell death is a natural part of a cell's life cycle — a way for organisms to break down old cells and make way for new ones. "Research in the last couple of decades has shown that microbes can exploit [cell death] pathways to cause disease," says study coauthor Tobias Hohl, an infectious disease researcher at Memorial Sloan Kettering Cancer Center in New York City. But this study shows that the tables can be turned. "Not only can microbes exploit this in hosts, but host cells can exploit these pathways to instruct certain microbes to kill themselves."

Pulmonologist Borna Mehrad of the University of Florida College of Medicine in Gainesville, who wasn't part of the study, says, "The idea that the host triggers the mechanism of [programmed cell death] as a way of defending against infection is very cool."

Hohl and colleagues identified a gene in *A. fumigatus* that puts the brakes on programmed cell death. The gene, *AfBIR1*, shares an ancestor with the human gene *survivin*, which also regulates cell death.

When the researchers amped up the activity of *AfBIR1* in a strain of the fungus, half the mice infected with the spores died during the eight-day study period. (Mice infected with unmodified spores were fine.) Cues that would normally send fungal cells to their death didn't register, so the fungus was able to grow in the mice's lungs.

In another experiment, the scientists gave mice a drug called S12, which took away *AfBIR1*'s brake effect. As a result, the mice fought off the infection. "Those two findings suggested to us that this fungal [cell death] pathway really is critical," Hohl says.

> When white blood cells engulf spores of a common fungus, the immune cells release an enzyme that sends the fungal cells into programmed cell death.

Hohl did this research with an engineered variety of *A. fumigatus* that changes color when its suicide instructions kick in. That advance allowed the researchers to make observations that weren't possible before, Mehrad says.

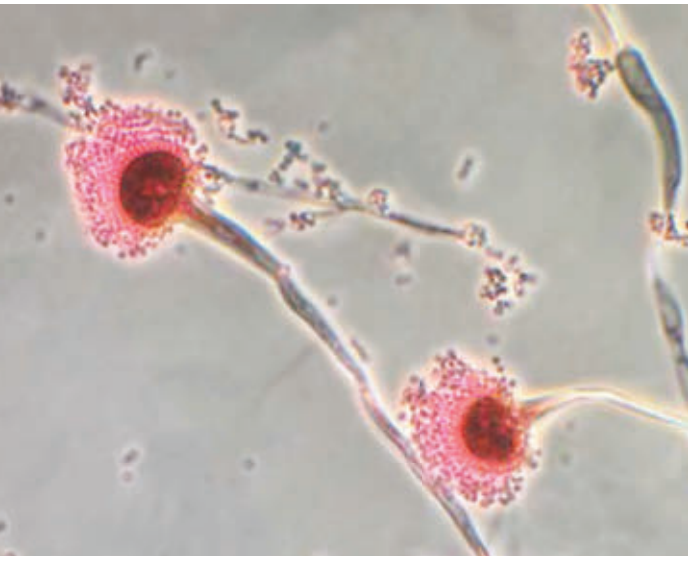
For instance, Hohl and colleagues noticed that fungal cells being engulfed by neutrophils, a type of white blood cell, appeared to be undergoing programmed cell death. That suggested that neutrophil activity might set off fungal programmed cell death.

Neutrophils release an enzyme called NADPH oxidase, and mice deficient in the enzyme weren't as good at fending off the fungus, Hohl found. That makes sense with clinical data in humans too. People with a genetic mutation that causes a deficiency in NADPH oxidase are particularly vulnerable to *Aspergillus* infection, Hohl says. People who have fewer neutrophils, due to chemotherapy or late-stage AIDS, for instance, also make less of the enzyme and are less able to resist a fungal infection.

Though survival rates vary, the U.S. Centers for Disease Control and Prevention estimates that 41 percent of organ transplant recipients who contract an *Aspergillus* infection die within a year. Seventy-five percent of stem cell transplant recipients with the infection die in that same time frame. Someday, a version of S12 that's modified to work in humans might be able to boost these patients' defenses against *A. fumigatus* infections, Hohl suggests.

In the future, he wants to see whether the same mechanisms extend to other fungal species too. ■

Aspergillus fumigatus (shown) is a common fungus found in soil. New immunology research is helping to explain how the organism can make people with weakened immune systems so sick, while going undetected in healthy people.



CDC

HUMANS & SOCIETY

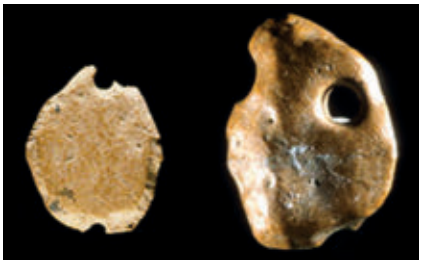
People may have lived in Brazil more than 20,000 years ago

People hunted giant sloths in the center of South America around 23,120 years ago, researchers say — a find that adds to evidence that humans reached South America well before Clovis hunters roamed North America 13,000 years ago.

Evidence of people's presence at Santa Elina rock-shelter, in central-west Brazil, so long ago raises questions about how people first entered South America. Early settlers may have floated down the Pacific Coast in canoes before heading 2,000 kilometers east to the remote rock-shelter, or they might have taken an inland route from North America, Denis Vialou of the National Museum of Natural History in Paris and colleagues report in the August *Antiquity*. Other proposed Stone Age South American sites lie much closer to the coast than Santa Elina does.

Excavations revealed remains of hearths, stone artifacts and bones of giant sloths. Sloth remains included small, bony plates from the skin that humans apparently made into ornaments of some kind by adding notches and holes.

Three different dating methods indicate that people reached Santa Elina over 20,000 years ago. — *Bruce Bower*



These notched sloth bones, perhaps personal ornaments, are evidence of an early human arrival to South America, scientists propose.

D. VIALOU *ET AL*/*ANTIQUITY* 2017

ATOM & COSMOS

Star that exploded in 1437 tracked to its current position

Some stars erupt like clockwork. Scientists have tracked down a star that Korean astronomers saw explode nearly 600 years ago and confirmed that it's had more outbursts since. The finding suggests that what were thought to be three different stellar objects actually came from the same object at different times, offering new clues to stars' life cycles.

On March 11, 1437, Korean astronomers saw a new "guest star" in the tail of the constellation Scorpius. The star glowed for 14 days, then faded. The event was what's known as a classical nova explosion, which occurs when a dense stellar corpse called a white dwarf steals enough material from an ordinary companion star for the white dwarf's gas to spontaneously ignite. The resulting explosion can be up to a million times as bright as the sun but doesn't destroy the star.

Michael Shara of the American Museum of Natural History in New York City and colleagues used digitized photographic plates dating from as early as 1923 to trace a modern star back to the nova. The team tracked the star as it moved away from the center of a shell of hot gas, the remnants of an old explosion, thus showing that the star was responsible for the burst. The researchers also saw the star, which they named Nova Scorpii AD 1437, give smaller outbursts called dwarf novas in the 1930s and 1940s. The findings were reported in the Aug. 31 *Nature*.

The discovery fits with a proposal Shara and colleagues made in the 1980s. They suggested that three different stellar observations — bright classical nova explosions, dwarf nova outbursts and an intermediate stage in which a white dwarf is not stealing enough material to erupt — are all different views of the same system. — *Lisa Grossman*

LIFE & EVOLUTION

Why bats crash into windows

Walls can get the best of clumsy TV sitcom characters and bats alike.

New lab tests suggest that smooth, vertical surfaces fool some bats into thinking their flight path is clear, leading to collisions and near misses.

The furry fliers famously use sound to navigate — emitting calls and tracking the echoes to hunt for prey and locate obstacles (see Page 22). But some surfaces can mess with echolocation.

Stefan Greif of the Max Planck Institute for Ornithology in Seewiesen, Germany, and colleagues put bats to the test in a flight tunnel. Nineteen of 21 greater mouse-eared bats (*Myotis myotis*) crashed into a vertical metal plate at least once, the scientists report in the Sept. 8 *Science*. In some crashes, bats face-planted without even trying to avoid the plate.

Smooth surfaces act as acoustic mirrors, the team says: Up close, they reflect sound at an angle away from the bat, producing fuzzier, harder-to-read echoes than rough surfaces do. From farther away, smooth surfaces don't produce any echoes at all.

Infrared camera footage of wild bat colonies showed that vertical plastic plates trick bats in more natural settings, too. — *Helen Thompson*

ATOM & COSMOS

Dark matter still remains elusive

Patience is a virtue in the hunt for dark matter. Experiment after experiment has come up empty in the search — and the newest crop is no exception.

Observations hint at the presence of an unknown kind of matter sprinkled throughout the cosmos. Several experiments are focused on the search for one likely dark matter candidate: weakly interacting massive particles, or WIMPs (*SN: 11/12/16, p. 14*). But those particles have yet to be spotted.

Recent results, posted at arXiv.org, continue the trend. The PandaX-II experiment, based in China, found no hint of the particles, scientists reported August 23. The XENON1T experiment in Italy also came up WIMPless according to a May 18 paper. Scientists with the DEAP-3600 experiment in Sudbury, Canada, reported their first results on July 25. Signs of dark matter? Nada. And the SuperCDMS experiment in the Soudan mine in Minnesota likewise found no hints of WIMPs, scientists reported August 29.

Another experiment, PICO-60, also located in Sudbury, reported its contribution to the smorgasbord of negative results June 23 in *Physical Review Letters*.

Scientists haven't given up hope. Researchers are building ever-larger detectors, retooling their experiments and continuing to expand the search beyond WIMPs. — *Emily Conover*

Watch bat echolocation fail at **bit.ly/SN_bats**

BAD AIR

Breathing pollution may harm a lot more than our lungs

By Laura Beil

To the residents of Donora, Pa., a mill town in a crook of the Monongahela River, the daily haze from nearby zinc and steel plants was the price of keeping their families fed. But on October 27, 1948, the city awoke to an unusually sooty sky, even for Donora. The next day, the high school quarterbacks couldn't see their teammates well enough to complete a single pass.

The town was engulfed in smog for five days, until a storm finally swept the pollution out of the valley. By then, more than one-third of the population had fallen ill and 20 people were dead. Another 50 perished in the following months.

After the Donora tragedy, the federal government began to clamp down on industries that release pollutants into the air. Environmental advocates in the coming decades fought for, and won, tighter regulations. As a result, combined emissions of six common air pollutants have dropped by about 70 percent nationwide since the 1970 passage of the Clean Air Act, which regulates U.S. emissions of hazardous air pollutants. In 35 major U.S. cities, the total number of days with unhealthy air has fallen by almost two-thirds just since 2000. "It's one of the great success stories of public health," says Joel Kaufman, a physician and epidemiologist at the University of Washington School of Public Health in Seattle.

Our bodies feel the difference. One study, reported in *JAMA* last year, followed 4,602 children in Southern California between 1993 and 2012 to see how lung health correlated with three common air pollutants. As levels of ozone, nitrogen dioxide and particulate matter fell over time, so did the number of children who reported a daily cough, persistent congestion and other symptoms of irritated lungs. At the start of the study, 48 percent of children with asthma had reported bronchitis symptoms in the previous year. In communities with the greatest drop in pollutants during the study period, bronchitis prevalence fell by as much as 30 percent in children with asthma.

But the air pollution story isn't over. Researchers from the Harvard T.H. Chan School of Public Health in Boston recently reported on links between air quality and mortality throughout the entire U.S. Medicare population (more than 60 million people who are age 65 and older or disabled). The analysis looked at levels of two common air pollutants and death rates from 2000 to 2012, while accounting for factors that might confound the results, such as race and socioeconomic status. The analysis, published in June in the *New England Journal of Medicine*, found that when pollutant levels rose (but remained at levels below national standards), so did death rates.

Even with vast improvements in air quality since the '70s, people haven't stopped dying from the air they breathe. An analysis published in 2013 from researchers at MIT estimated that about 200,000 premature deaths occur each year in the United States because of fine particulate air pollution. A study published in January in *Environmental Health Perspectives* reported that daily deaths over a decade in metropolitan Boston peaked on days when concentrations of three common air pollutants were at their highest, even though those levels would currently satisfy the U.S. Environmental Protection Agency.

"We've made these improvements in exposure," Kaufman says, "but what more do we need to clean up?"

So despite a half-century of progress, airborne grime is still a menace — probably in ways the people of Donora never imagined. Researchers are now finding that more than the lungs are at risk, as dirty air may in fact be an accomplice to some of the greatest threats to public health, including diabetes, obesity and even dementia. Those studies are likely to inform the ongoing debate over antismog rules. The U.S. House of Representatives voted this summer to delay implementation of updated standards for the Clean Air Act.

Slow burn

As it has for more than a century, air pollution in America largely arises from power plants, industries, vehicles and

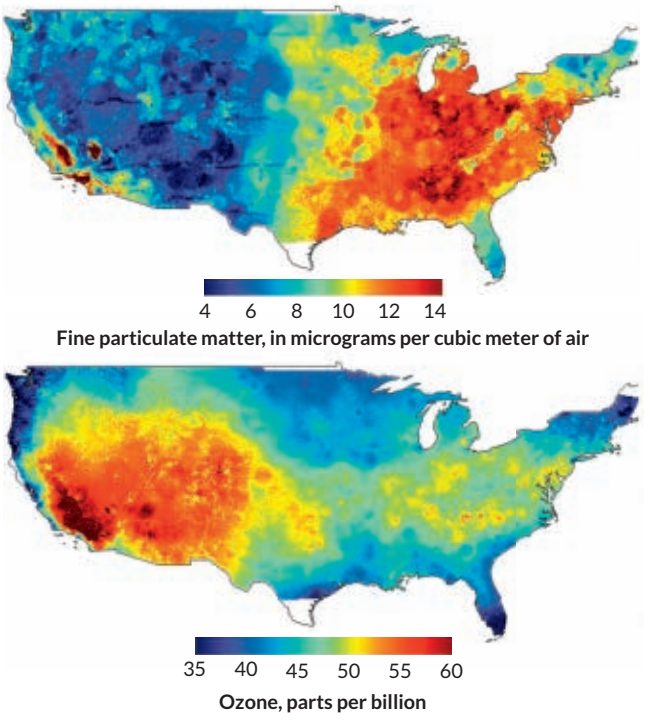
VAGENGEIM/SHUTTERSTOCK

other sources of fuel burning. The pollution is generally a mixture of gases — such as carbon monoxide, sulfur dioxide and nitrogen oxides — and particulate matter, microscopic solids or droplets that can be inhaled into the lungs. The pollutant that has declined the least is ozone, a hard-to-control noxious gas formed when nitrogen oxides and volatile organic compounds react with sunlight. Ozone pollution tends to soar on hot, windless summer days as the sun blazes.

Particulates come from tail pipes and smokestacks, but also consist of tiny fragments shed from tires, roads and brake pads. Fine particulates (less than 2.5 micrometers wide, or about a quarter of the width of the smallest grain of pollen) are of greatest concern because they can penetrate deeply into the lungs to reach the body's innermost nooks and crannies. A study in April in the journal *ACS Nano* demonstrated that fact. Fourteen healthy volunteers intermittently riding exercise bikes inhaled gold nanoparticles — stand-ins for particulates — and 15 minutes later, the nanoparticles were detected in the bloodstream and remained present in the body for as long as three months.

While events in Donora showed that air pollution can have immediate consequences, it took decades for researchers to realize that deaths from smog could be going undetected, lost in the background noise of mortality statistics. In 1993, Harvard University scientists published a study in the *New England Journal of Medicine* looking at mortality rates among adults in six U.S. cities. The researchers studied more than 8,000 people for 14 to 16 years. In areas with higher levels of sulfate particles in the air, a measure of pollution, mortality rates were higher. Dozens of similar studies have followed, including one published in 2003 that looked at death rates across 20 of the largest U.S. cities. That research found that the highest death rates occurred the day after particulate concentrations reached their highest levels, though the levels were subtle enough to go unnoticed at the time.

Scientists now know that inhaling pollutants triggers a flurry of physiological coping mechanisms throughout the body. "Until 20 years ago, we thought that air pollution affected only the respiratory system," says Petros Koutrakis, an environmental chemist who heads the EPA Harvard Center for Ambient Particle Health Effects. By 2004, the American Heart Association published a consensus statement in *Circulation* laying out "a strong case that air pollution increases the risk of cardiovascular disease," the leading cause of U.S. deaths.

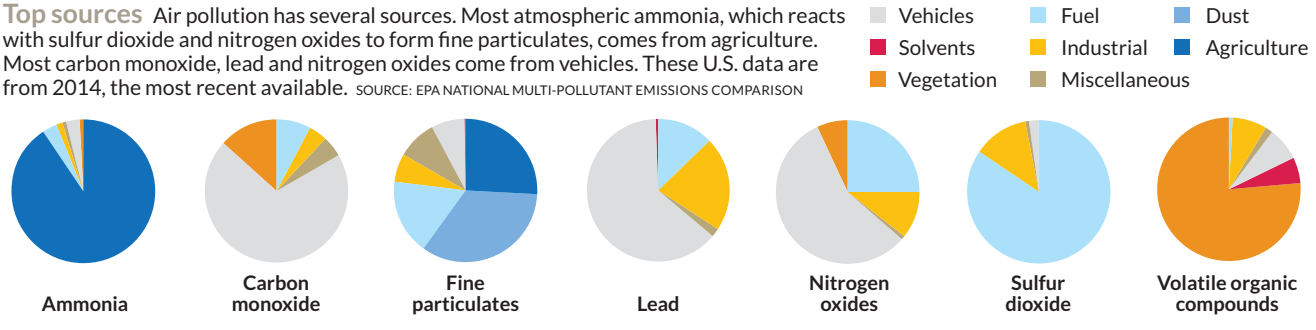


Location matters Average concentrations of two major air pollutants from 2000 to 2012 varied by U.S. region. Fine particulates disproportionately affect the eastern half of the country, whereas ozone, shown here in warm months, is a bigger problem in the west.

More studies followed that statement, including one from Kaufman and colleagues in the *New England Journal of Medicine* in 2007. The researchers studied 65,893 women, looking for a link between exposure to fine particulates and death from heart attack or stroke, or even nonfatal heart attacks or the need for artery-clearing procedures. In the end, each increase of 10 micrograms of fine particulates per cubic meter of air increased the risk of any cardiovascular health event by 24 percent and the risk of dying from heart attack or stroke by 76 percent. In 2010, the American Heart Association updated its position: "The overall evidence is consistent with a causal relationship between [fine particulate] exposure and cardiovascular morbidity and mortality." While the mechanism is still under study, research points to inflammation, heart rate variability and blood vessel damage.

Evidence keeps accumulating. A study by Koutrakis and colleagues, published in 2012 in *Archives of Internal Medicine*,

Top sources Air pollution has several sources. Most atmospheric ammonia, which reacts with sulfur dioxide and nitrogen oxides to form fine particulates, comes from agriculture. Most carbon monoxide, lead and nitrogen oxides come from vehicles. These U.S. data are from 2014, the most recent available. SOURCE: EPA NATIONAL MULTI-POLLUTANT EMISSIONS COMPARISON



FROM TOP: Q. DI *ET AL*/*NEJM* 2017; T. TIBBITTS

found similar results. When particulate concentrations rose even to mild levels — those classified as a "moderate health concern for a very small number of people" by EPA standards — the risk of stroke rose by 34 percent within a day of exposure.

Pounds and pollution

Lately, studies have moved from cardiovascular disease into more unexpected territory. And they've turned up compelling evidence that air quality may contribute to excess body weight. Frank Gilliland, an environmental epidemiologist at the University of Southern California in Los Angeles, became intrigued when laboratory studies suggested that certain pollutants in the environment might function as "obesogens," contributing to weight gain by mimicking or disrupting the action of hormones, or having other effects. Still, he says, "I was very skeptical."

Out of curiosity, he began to look for a link between childhood obesity and living close to a major roadway. His first study, published in 2010, examined over 3,000 children across California. Although the researchers found an association, they couldn't rule out other explanations that would also lead back to cars. "Maybe the kids aren't getting exercise because there's a lot of traffic out," he says.

Newer findings are more convincing, including a 2014 study by Gilliland and colleagues. They studied body mass index among children exposed to traffic-related air pollution. Of course, as the children grew over the five-year study period, their BMIs increased from an average of 16.8 to 19.4 kilograms per square meter. But children exposed to the most air pollution, compared with those least exposed, had a 14 percent larger BMI increase, which meant an additional 0.4 kg/m² increase in BMI by age 10. Adults, too, appear to be affected. Researchers from Harvard Medical School and elsewhere published a study in 2016 in the journal *Obesity* looking at whether adults living with constant exposure to traffic are more likely to be overweight. In particular, people who lived within 60 meters of a major road had a higher BMI, by 0.37 kg/m², and more fat tissue than those who lived 440 meters from a busy road. The healthy range for an adult's BMI is 18.5 to 25 kg/m².

Studies in animals have started to offer hints why this might be the case. Last year in the *FASEB Journal*, Chinese researchers described an experiment in which one group of pregnant rats was raised in filtered air scrubbed of pollutants, while another breathed the usual Beijing haze. Though they were fed the same diet, the animals living in Beijing air were heavier at the end of their pregnancies, as were their offspring that continued to breathe the dirty air eight weeks after birth. Among later autopsy findings: Rats exposed to pollution experienced higher levels of inflammation, which is thought to be a contributor to weight gain and metabolic disruption.

The relationship is probably subtle, and interwoven with genetics and lifestyle. UCLA researchers who followed a large group of African-American women over 16 years found no association between weight and exposure to particulates. For now, the connection between obesity and pollution is still a subject of investigation. But given that 11 million Americans live along major roadways, even a small effect could have widespread consequences.

Not so safe As U.S. air pollution levels drop, studies accumulate linking even those levels considered safe to a broad range of ailments.

1970
Clean Air Act requires 90 percent cut in emissions from new autos by 1975

1993
First study to show a higher mortality rate among people living in cities with high levels of inhalable particles and sulfates

2009
Mouse study links air pollution with glucose intolerance and diabetes

2010
Kids living near busy California roads more likely to gain weight than others in study

2012
First study to note cognitive decline among people exposed to higher air particulate levels

2016
Study links Parkinson's disease with exposure to nitrogen dioxide

2017
Studies in children and adults link ozone concentrations in the air with diabetes

When smog rolled in to the mill town of Donora, Pa., almost 70 years ago, the pollution hovered long enough to cause dozens of deaths. Today the town claims responsibility for launching the clean air movement.

ALFRED EISENSTAEDT/GETTY IMAGES

Links to diabetes

For many people, diabetes goes hand in hand with obesity. One of the earliest compelling studies to suggest a relationship between diabetes and air pollution was an animal experiment published in 2009 in *Circulation* from researchers at Ohio State University and other institutions. The test was relatively simple: Two groups of mice were fed a high-fat diet for 24 weeks. One lived in clean, filtered air; the other group was housed in enclosures polluted with air containing fine particulates, at concentrations still within EPA standards. The mice breathed the polluted air for six hours per day, five days a week for 128 days. Even though they ate the same food, the mice living in dirty air developed metabolic changes characteristic of insulin resistance while the other mice did not. Similarly, a 2013 study from EPA scientists found that mice exposed to ozone can develop glucose intolerance, a precursor for diabetes.

In July in *Diabetes*, Gilliland and colleagues published data not only finding links between air pollution and diabetes in children, but also insight into the body's physiological

response. In the study, 314 overweight or obese children in Los Angeles were followed for an average of three years. At the end of the study, children who lived in neighborhoods with the highest concentrations of nitrogen dioxide and particulates had experienced greater declines in insulin sensitivity and had signs of impaired pancreatic beta cells, which produce insulin.

As for adults, a study this year in *Environment International*, conducted by researchers from eight institutions, tracked more than 45,000 African-American women across the United States. Those who were exposed to the highest concentrations of ozone were about 20 percent more likely to develop diabetes, even after adjusting for other possible explanations such as diet and exercise levels.

Brain drain

One of the latest lines of research suggests that poisons in the air might accelerate aging in the brain. Studies have long documented the connection between the nose and brain function. For reasons not yet known, for instance, one of the early signs of Parkinson's disease is a loss of the ability to distinguish smells.

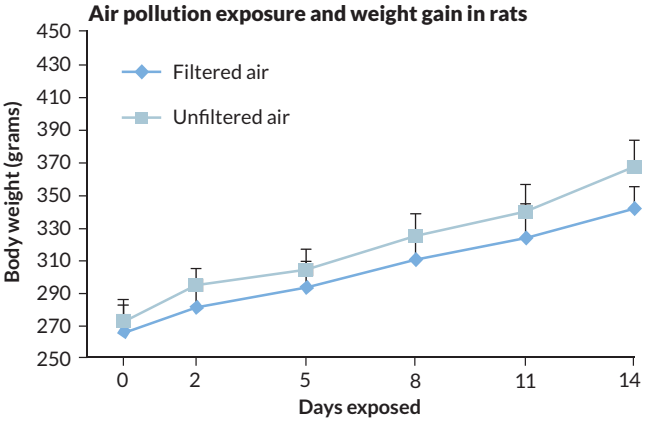
During her graduate studies at Harvard, Jennifer Weuve, now an epidemiologist at the Boston University School of Public Health, wondered if airborne pollutants might be bad for the brain. "There was really intriguing data from animal studies," she says, which showed that inhaled pollutants had toxic effects on nerve cells. In 2012, she published the first study to note a faster-than-normal cognitive decline among people exposed to higher levels of particulates, both those smaller than 2.5 micrometers and even larger ones that are thought to be less harmful. Her study, published in *Archives of Internal Medicine*, analyzed data from the Nurses' Health Study Cognitive Cohort, which included almost 20,000 women ages 70 to 81, and used geographic information and air-monitoring data to estimate pollution exposure.

> "What is it going to take for more people to take this seriously?"
>
> JENNIFER WEUVE

More recently, researchers from Sweden examined the relationship between pollution exposure and dementia, studying the records of people in northern Sweden participating in a long-term study of memory and aging. In 2016 in *Environmental Health Perspectives*, the researchers reported that people with the most exposure to air pollution were also the most likely to be diagnosed with Alzheimer's or other forms of dementia. In all, more than a dozen human studies have examined pollution's link to dementia. Last year in *NeuroToxicology*, Weuve and colleagues reviewed 18 human studies published as of late 2015, and concluded that as a whole, the evidence was "highly suggestive" and in need of more exploration. "What is it going to take for more people to take this seriously?" Weuve asks.

While the relationship is far from established, animal data may help clarify the results. One study published this year in *Neurobiology of Aging*, from researchers at the University of Southern California, examined brain changes in mice exposed to particulate air pollution at levels commonly found near freeways. After exposure to the pollution for five hours per day, three days a week for 10 weeks, the animals showed accelerated aging in the hippocampus, a region of the brain associated with memory. And a 2015 study of older women exposed to high levels of particulate matter, at levels common in the eastern half of the United States and in parts of California, showed a small decrease in the volume of white matter, the myelin-coated nerve cell projections called axons.

Dirty calories To test whether breathing in air pollution could affect body weight, Chinese scientists exposed one group of pregnant rats to Beijing's highly polluted air and another group to filtered air. After two weeks, the rats in the dirty air were heavier.



Parkinson's disease may also be linked to pollution. Danish researchers, with colleagues in the United States and Taiwan, published a study last year in *Environmental Health Perspectives* looking at people with and without Parkinson's and their exposure to nitrogen dioxide, a marker for traffic-polluted air. The scientists identified 1,828 people in Denmark with Parkinson's diagnosed between 1996 and 2009, and compared them with about the same number of randomly selected healthy people. Those exposed to the highest levels of air pollution had the greatest risk of developing the disease. The data, the researchers wrote, "raise concern given the increase in vulnerable aging populations."

If science bears out the connection between pollution and brain health, or pollution and metabolism, environmental advocates and businesses may have even more reason to push for cleaner air. Researchers hope in the future to have more data on which pollutants cause the greatest harm, and why. In Donora, the site of one of the country's biggest air pollution disasters, a sign at the Smog Museum now reads "Clean Air Started Here." No one can yet say how clean is clean enough. ■

Explore more

- Robin M. Babadjouni *et al*. "Clinical effects of air pollution on the central nervous system; a review." *Journal of Clinical Neuroscience*. September 2017.

Y. WEI ET AL/THE FASEB JOURNAL 2016

Bat Brains

Studies of free-flying bats reveal nerve cells that enable complex navigation

By Amber Dance

Ninad Kothari's workplace looks like something out of a sci-fi film. The graduate student at Johns Hopkins University works in a darkened, red-lit room, where he trains bats to fly through obstacle courses. Shielding within the walls keeps radio and other human-made signals from interfering with transmissions from the tiny electrical signals he's recording from the bats' brains as the animals bob and weave. Layers of foam further insulate the cavelike lab against sound waves. An array of cameras and microphones complete the futuristic scene.

The high-tech setup has its homemade touches, too: In one obstacle course, bats dodge dangling Quaker oatmeal cylinders.

Kothari is part of a small cadre of neuroscientists who are getting the best sense yet of how bat brains work at a cellular level, thanks to modern technologies. Eavesdropping tools, which rely on tiny probes that track the activities of individual nerve cells, or neurons, are now miniaturized enough to outfit bats with head-mounted, wireless sensors. As the animals fly freely around the lab, the researchers can listen in on neurons.

By allowing the bats to behave naturally, unencumbered by bulky equipment, scientists will discover exciting new facets of how bat brains work, says neuroscientist Nachum Ulanovsky of the Weizmann Institute of Science in Rehovot, Israel, who invented the new wireless sensors with colleagues. He and others, studying several different species of bats, are investigating how the flying mammals perceive their environment and navigate through it.

A big brown bat (*Eptesicus fuscus*) participates in experiments at Johns Hopkins University's high-tech bat laboratory.

The go-to lab animals for studying how the mammalian brain maps and navigates its surroundings are mice and rats. But bat researchers say their animal of choice offers distinct advantages. For one, rodent navigation studies are mostly limited to fairly basic environments in the lab, such as mazes. Those setups are "too simple to tell much about how the system operates in complex environments in the real world," says Edvard Moser of the Norwegian University of Science and Technology in Trondheim. Moser shared a 2014 Nobel Prize for discovering place cells in the rodent brain (*SN Online: 10/6/14*). Place cells help the animal identify its location in a mental map of the environment.

Since bats fly, scientists can more easily investigate how bat brains deal with space in three dimensions. Researchers are already reporting on new types of neurons not yet observed in rodents or other animals. Moser expects that rodent and human brains may map and navigate spaces in a manner similar to bats; scientists have already seen "striking" parallels between rat and bat brains, he says.

BEN FALK AND BROCK FENTON

Bats are also interesting to scientists because bat brains must switch between several kinds of input to make sense of the world. Like people, they use their ears and eyes (contrary to popular myth, no bat species is entirely blind, though some rely on vision more than others). On top of that, most bats also use echolocation to sense their surroundings. While flying, an echolocating bat produces calls that bounce off objects — such as trees to avoid or insects to chase — then return to the bat as echoes. With their supersensitive ears, and their finely tuned brains, bats use this information to determine where things are. The echolocation calls are typically beyond the range of human hearing, which is good because the calls are quite loud, about 100 decibels or so, says Khaleel A. Razak, a neuroscientist at the University of California, Riverside. He likens the volume to what a person would experience standing next to a pounding jackhammer.

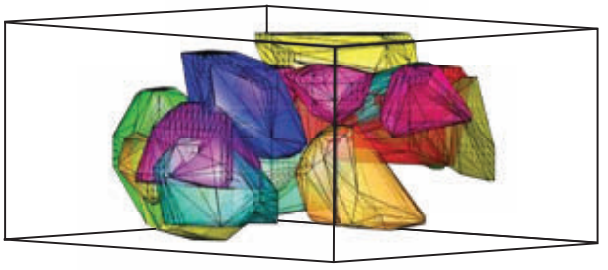
By tracking the routes bats fly, as well as their calls and the echoes they pick up, bat-brain aficionados are starting to match behavior with brain activity. In some of the most recent studies, scientists have begun to figure out how bats pinpoint the locations of the sounds of prey and map and navigate the greater world. The researchers may have a thing or two to teach sonar engineers (see "Borrowing from bats," Page 25).

Going natural

To understand bats' brain activity at the level of individual neurons, researchers implant tiny wires. The aim is to read when individual neurons "fire," that is, when one brain cell generates an electrical signal to send along to other cells in the brain or body. Exactly what these neurons are communicating remains hazy, but they might, for example, tell another part of the brain that there's a sound coming in from the right or left.

The hippocampus is where Ulanovsky focuses. This deep-brain structure, involved in learning and memory, is a place where bats make and store maps of their surroundings. Usually neuroscientists have to tether an animal to a bulky data recorder with wires, but Ulanovsky wants his bats to fly. He and colleagues designed a lightweight, miniature data logger small enough to mount atop a bat's head. The recorder, which connects to the tiny implanted wires, wirelessly transmits its readings to Ulanovsky's computer. "This allows us to get closer to the natural behavior," he says.

Ulanovsky asks how the firing patterns of neurons match up with the free-flying bats' actions. In a handful of papers published since 2007, he and colleagues have identified key types of navigational neurons that scientists had also seen in rats, like place cells that fire when a bat is in a particular spot. Another type of cell, called grid cells, seems to work via an imaginary mental grid the brain lays over the real environment (*SN Online: 8/5/13*). These cells activate when a bat crosses the grid lines. Other neurons turn on when a bat's head is at a particular angle. "We found them all in bats, just like in rodents," Ulanovsky says. Those findings, though satisfying, told only half the story, he says: how a bat understands where it is at any given time. But what if the bat has a goal destination in mind, too? "We had an understanding of how point A is represented, but not point B," he says. "It has been a big missing link."



As an Egyptian fruit bat flew around a lab (represented by the box), place cells in its brain fired. Each colored shape represents a different location within the room where specific place cells fired.

In experiments reported in January in *Science*, Ulanovsky's team identified hippocampal neurons responsible for keeping track of target destinations in Egyptian fruit bats (*Rousettus aegyptiacus*), pointy-eared critters with doglike faces that use echolocation to find tasty fruits and nectar.

The researchers trained the bats to fly around a room to a banana reward, which was sometimes hidden behind a curtain. In one experiment, the team placed wire probes in the hippocampus of three bats, eavesdropping on a total of 309 neurons in the vicinity of the electrodes. Of those, 58 fired when a bat was at certain angles to its goal and 49 fired when it was certain distances from its goal. Twenty-four of the neurons responded to both angle and distance. With input from those three types of neurons, the bat's brain kept track of the location of the treat.

"It's an exciting and important study," says Hugo Spiers, a neuroscientist at University College London who studies navigation in people and rats. "How cells in the hippocampus might provide guidance signals has been very underinvestigated." Spiers is now looking for similar goal-directed neurons in rats. People probably have neurons similar to those reported by Ulanovsky, Spiers adds.

Actions and reactions

Before starting his group at the Weizmann Institute, Ulanovsky learned about bats in the lab of Cynthia Moss, now Kothari's adviser at Johns Hopkins. Moss focuses on an area on the surface of the brain, the midbrain superior colliculus. Like the hippocampus, the superior colliculus also maps a bat's environment, but there's a difference. The hippocampus makes a map of environmental features with respect to each other; no matter where the bat is, it keeps the same basic mental map. The superior colliculus generates a map of the world with the bat at the center, so the map changes as the animal moves.

The superior colliculus links what an animal perceives with how it moves in response. In an eyesight-favoring animal like a human, that might mean turning the head or shifting gaze to get a better look at the sudden movement of an oncoming car or a zooming baseball. For bats, one role of the superior

M.M. YARTSEV AND N. ULANOVSKY/*SCIENCE* 2013

colliculus is to help the bat orient itself to sounds, such as the echoes of its own calls.

Most studies of animal sensory processing, including Moss' past work, involve restrained animals. Studies might also use speakers emitting calls and echoes to create a sort of "virtual reality" for bats instead of using their natural calls and echoes, Moss notes. For more than a decade, she's been working toward the experiments Kothari and postdoctoral researcher Melville Wohlgemuth recently performed in her high-tech bat room. Moss' group is among the first to look at how neurons in the superior colliculus respond to the auditory world, in three dimensions, while an animal is freely moving.

Moss and her team study big brown bats (*Eptesicus fuscus*), which, in fact, are "not very big," Moss says. They're a bit smaller than the average hamster, though their wingspan is a foot long. In the wild, these bats nosh on beetles and other small insects. Measuring the precise distance to an insect meal, with both predator and prey aloft, is a crucial life skill.

As the bats flew their oatmeal-container obstacle course, and another that required them to find a hole in a net, Kothari and Wohlgemuth recorded neuron activity, with sensors similar to Ulanovsky's. But to match specific neurons with what the bats were doing and perceiving, the scientists needed to know what calls the animals produced, and what echoes the animals heard. That's where the microphones around the room come in.

The researchers took advantage of the fact that echolocation is a back and forth between a bat and its world. The bat can tune the direction and rate of its calls, depending on what it's investigating. So the scientists, eavesdropping with ultrasonic microphones, can infer what the bats are homing in on, as if the animals are broadcasting, for example, "I'm focusing in on this yummy mealworm on my right." Then, the researchers used computer software to predict what echoes would come back to the bat. (Putting mikes on the bats' heads would be too heavy for the lightweight fliers, and probably not sensitive enough to pick up those echoes, anyway.)

Pallid bats, named for the pale fur on their bellies, are gleaners. They use their large ears to listen for rustling prey — beetles, crickets or other crawlers — and zoom down to pick them off the ground.

PAPILIO/ALAMY STOCK PHOTO

Moss and colleagues predicted that certain neurons would respond to the angle an echo returned from, as well as to the time delay, which indicates the distance of the sound-reflecting object. Indeed, of 119 neurons the researchers managed to monitor from two big brown bats, 41 fired in response to an echo returning at particular angles and distances from the animal. Those neurons were helping the bats localize objects in three-dimensional space.

During their flights, the bats sometimes sent out sonar sound groups, rapid clusters of echolocation calls. Moss had hypothesized that these clusters help bats get better spatial resolution to really focus on the objects of greatest interest. That's important, for instance, when navigating a dense forest or cluttered room. The new study, not yet published, supports the idea.

The bats seem to use the clusters to narrow interest to objects a certain distance away, which the bats can measure by the time delay between their call and the returning echo. The farther away something is, the longer the delay. When the bats were just doing normal, nonclustered echolocation, a given neuron that fires for an eight-millisecond echo delay would also respond to a range of echo times — say, any time between four and 12 milliseconds, Moss explains. But when the bats emitted clustered calls, the same neuron would respond only to echoes coming in at a delay close to eight milliseconds. The bats were fine-tuning their brains so they could get a better, sharper impression of the most interesting objects, she says.

The value of the study lies in the observations in untethered animals, says Shihab Shamma, a neuroscientist and engineer at the University of Maryland in College Park who studies sound processing in ferrets. "This one is more natural," he says. "That's really cool, to actually see what the processing is in the brain," Shamma says.

Because the circuitry of the superior colliculus is common across mammals, Kothari predicts that similar 3-D processing of space occurs in humans and other primates, too.

From all directions

These latest findings with untethered bats broaden understanding of how animals navigate. But the researchers are well aware that each study focuses on only a small part of a larger process. For example, what happens after a navigation-related neuron in the superior colliculus or hippocampus fires? How does the brain turn neuron firing into a map of its world or a decision to move from here to there? "Very little is known," Ulanovsky says.

Razak, at UC Riverside, has an idea about how the firing of certain neurons gets interpreted, though it's only a hypothesis. He studies echolocation as well as direct listening for environmental sounds in a group of bat species called gleaning bats. They're also called whispering bats

Borrowing from bats

Bats, with their superb ability to echolocate, are inspiring advanced technologies — from better Navy sonar to gadgets that might deliver packages or help farmers manage crops. And engineers aren't waiting for neuroscientists to work out every detail of how the bats' brains manage the task.

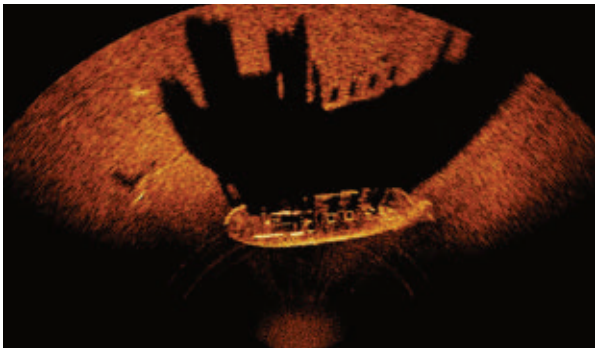
"We think we have enough information to be useful to us, to develop a bio-inspired sensor," says research engineer Jason Gaudette of the Naval Undersea Warfare Center Newport Division in Rhode Island. Like bats, the Navy uses sonar to find and visualize objects in the deep. But current versions are far less elegant than the flying mammals' system.

The Navy's sonar arrays can be huge, encompassing hundreds of "ears" that listen for sonar pings from atop a submarine's dome or trailing behind it in a long tail. Bats, Gaudette notes, dodge obstacles and find mosquito-sized meals with just two ears. He and colleagues have developed a bat-inspired prototype device that they hope can perform more like bats do. Mounted on the nose of a half-meter-long, torpedo-shaped autonomous undersea robot, the sonar system has one sound transmitter and three receivers (Gaudette hopes to eventually get that number down to two or even one).

The system uses algorithms inspired by research in bats to interpret returning sonar echoes for navigation. If it works, the system could help the Navy perform sonar imaging using less space and less money while offering sharper images, Gaudette says.

Researchers in Israel are hoping to help farmers with a bat-inspired kind of sonar. Neuroecologist Yossi Yovel of Tel Aviv University is creating computer algorithms describing how bats might interpret returning echoes to distinguish different plants.

Yovel collaborates with Avital Bechar, a researcher at the Institute of Agricultural Engineering near Rishon LeZion, Israel, who wants to help farmers predict their crops' yield, which can vary widely from year to year. The same acre of tomato plants, for example, could yield 30 or 120 tons of fruit, Bechar estimates. Such a wide range puts farmers at a disadvantage in negotiating a price for crops and forces the farmers to guess how much equipment and how many pickers they'll need at harvest time.



The U.S. Navy uses sonar to image underwater objects and obstacles, such as this shipwreck in Narragansett Bay in Rhode Island. Taking inspiration from bats, naval researchers hope to get sharper images with smaller, cheaper sonar equipment.

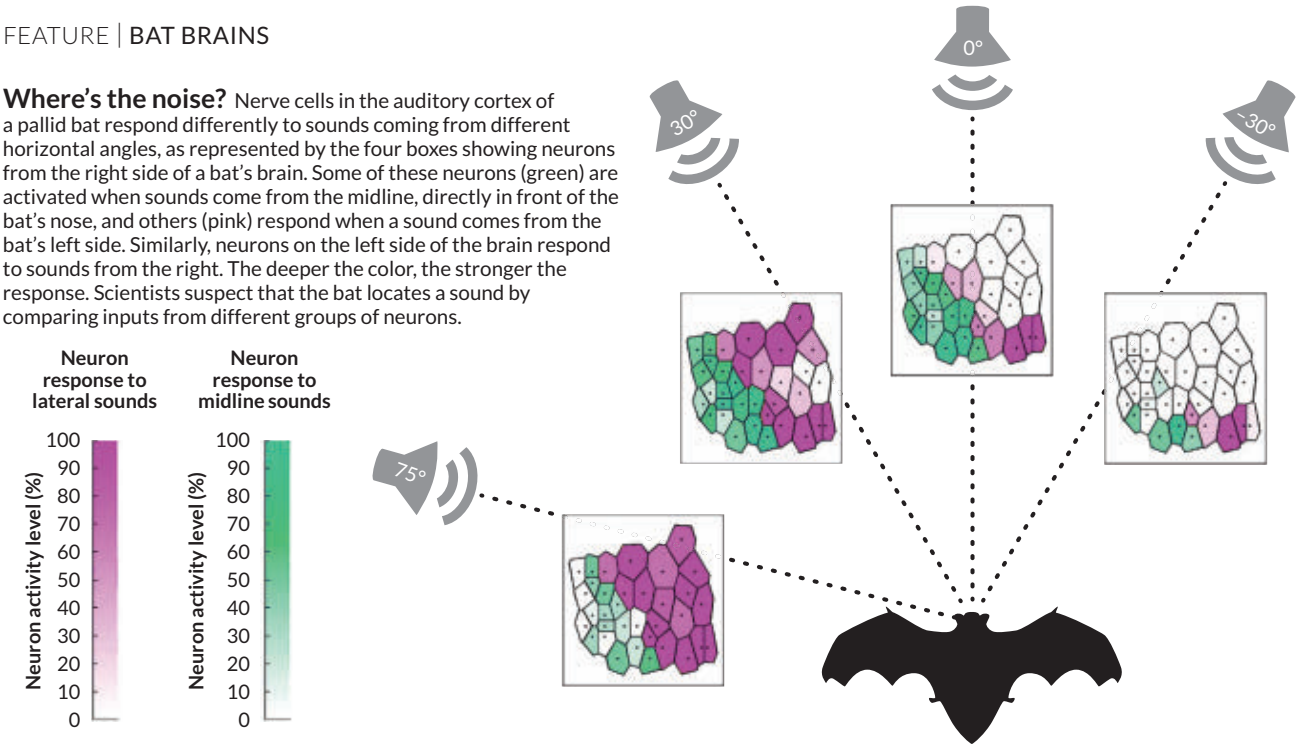
The Institute of Agricultural Engineering in Israel is testing algorithms inspired by bat echolocation to count leaves and fruit. Ultimately, the system might help farmers better plan for harvest.

Bechar's sonar system, which emits batlike sounds and records via microphones that mimic bat ears, can penetrate three rows of plants deep — farther than cameras could. Then it calculates the number of leaves and pounds of fruit per plant, based on Yovel's algorithms. Bechar has mounted the scanner on a prototype robot and plans to affix it to a drone to count fruit in 15-meter-high date palms. The researchers also hope to add weed-detection capability. Bechar expects it to be "a game changer in agriculture, because it will reduce the unknowns."

At Virginia Tech in Blacksburg, engineer Rolf Mueller is learning tricks from the physical structures of bats' noses and ears. Certain bat groups, such as horseshoe bats (one species Mueller works with is *Rhinolophus ferrumequinum*), send out their echolocation calls through their noses, like a snort. Complex, fleshy formations called nose-leaves change the outgoing sound as it comes out of the nose. And the bats' ears have more than 20 muscles, which rapidly change shape as the bat listens for echoes, Mueller says. That flexibility gives the animals more information, he suspects: "It's like seeing the world with a different perspective, at the same time, [from] one echo."

His group developed a prototype robot with mechanical "nose-leaves" and shape-shifting "ears," and sent it zooming through forested areas on a zip line to record how the bot perceives trees and branches. Eventually, Mueller envisions an autonomous underwater bot or an airborne drone with a similar sonar setup. The drone could be useful for delivering packages in forested or otherwise complicated areas without crashing. — *Amber Dance*

FROM TOP: ITAMAR ELYAKIM; J. GAUDETTE, NAVAL UNDERSEA WARFARE CENTER



Where's the noise? Nerve cells in the auditory cortex of a pallid bat respond differently to sounds coming from different horizontal angles, as represented by the four boxes showing neurons from the right side of a bat's brain. Some of these neurons (green) are activated when sounds come from the midline, directly in front of the bat's nose, and others (pink) respond when a sound comes from the bat's left side. Similarly, neurons on the left side of the brain respond to sounds from the right. The deeper the color, the stronger the response. Scientists suspect that the bat locates a sound by comparing inputs from different groups of neurons.

because they emit quiet echolocation calls as they fly along, ears cocked for the rustles of insect prey on the ground.

Specifically, Razak works with gleaners known as pallid bats (*Antrozous pallidus*), because of their white bellies, which Razak suspects might offer camouflage from the gaze of insects looking upward. Pallid bats are remarkably good at pinpointing the location of a sound, with an accuracy of 3 to 4 degrees, Razak says. Humans appear to be better at this task, able to tell the difference between sounds separated by just 1 to 2 degrees. But we have the advantage of several inches between our two ears, making it easier to triangulate the source of sound. "If you normalize to head size, the bat is a champion," Razak says.

He studies the auditory cortex, an outer part of the brain involved in hearing and interpreting sounds. In his previous research, Razak reported how certain cortex neurons, in anesthetized bats, respond to sounds coming in from different angles in a horizontal semicircle in front of the animal. In a 2015 report in the *Journal of Neuroscience*, he started to explain how bats determine the vertical angle to dinner.

There are two overlapping maps in the cortex, one for horizontal and one for vertical angles. For the horizontal angle, one group of neurons fires when a sound comes in from directly in front of the bat's nose. Other groups respond to sounds to the left or the right of the animal. The auditory cortex on the right side of the brain responds to sounds in what Razak refers to as the left "hemifield" — anywhere to the left side of the head. The more right-brain neurons are firing, the more directly to the left the sound is. The same thing happens on the left side of the bat's brain, for sounds on the right.

A second map indicates the vertical angle. A few neurons fire for sounds that are coming in low, and more fire for sounds coming in from a higher elevation. To decode those signals, Razak hypothesizes, there could be some as-yet-undefined "comparer" that integrates the information from the two maps. If the comparer is getting mostly straight-ahead signals, it knows the sound is coming from dead in front of the bat's nose. If it's getting mostly right hemifield signals from the left side of the brain, it can deduce that the sound is coming from somewhere to the right side of the head, at a range of horizontal or vertical angles to the ear. If it's hearing a lot of that input from the right side of the brain, then the sound is on the left.

This theory is the first idea proposed for how the auditory cortex of any animal understands the location of an object at both horizontal and vertical angles, Razak says. He's now designing experiments to test this idea and search for the comparer.

Taken together, these studies are beginning to paint a picture of what goes on in the brain as a bat perceives and moves through its environment. But there's still plenty of uncertainty about the bat brain and how well it matches to what the human brain does. "These are still big questions: How do we make sounds and how does our brain control what we make? How do we develop the sense of localization?" says Razak. "The bats continue to offer some interesting insight."

What's already certain is that the flying creatures have earned the respect of the scientists working with them. After all, Moss notes, the big brown bat's brain is the size of a lima bean, but still manages to process sounds in a way human sonar engineers envy. ■

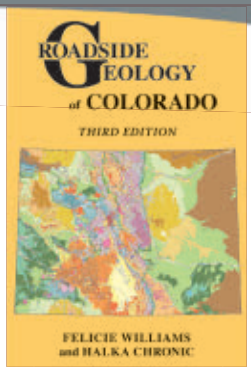
Explore more

■ Ayalet Sarel *et al.* "Vectorial representation of spatial goals in the hippocampus of bats." *Science.* January 13, 2017.

Amber Dance is a freelance writer based in Los Angeles.

K.A. RAZAK/*J. NEUROSCI.* 2011. ADAPTED BY E. OTWELL

GEOLOGIC ROAD TRIP OF THE MONTH



MESA VERDE NATIONAL PARK

Mesa Verde National Park was established to preserve and display unusual archeological remains—clustered dwellings on the mesa surface and cave-sheltered apartment houses of people who inhabited this area from A.D. 900 to 1250. But the dramatic mesa with its high shale slopes and nearly impregnable sandstone cliffs is as distinctive geologically as the archeological sites it preserves.

Forming the lower slopes of Mesa Verde, the Mancos Shale is well exposed along the entrance road. This brownish gray shale accumulated as mud in the shallow sea that spread across the center of the continent in Cretaceous time. Many small faults offset its thin sandstone layers. It slides extremely easily, necessitating never-ending road repairs. In addition to removing landslide debris from the highway, repairs involve stabilizing slides by unloading their tops, buttressing their lower ends, and adding drainage pipes to lessen wetting of the shale. The ditch on the inner edge of the road catches small slides and rockfalls and helps drain rainwater and snowmelt from slide areas.

Above the Mancos Shale are shoreline sandstones of the Mesaverde Group, deposited as the Cretaceous sea retreated eastward. Originally defined as a single formation, the Mesaverde is now given group status and subdivided into three formations. The lowest of these, the Point Lookout Sandstone, forms the cliffs that top the northern end of Mesa Verde. Farther south it is overlain by the shale-coal sequence of the Menefee Formation, deposited in marshes and swamps close to the sea's edge. Above the Menefee Formation is the Cliffhouse Sandstone. The strata dip southward here; the Cliffhouse Sandstone and Menefee Formation have eroded off the high northern prow of Mesa Verde.

Slope-forming Mancos Shale and cliff-forming sandstones of the Mesaverde Group characterize Mesa Verde National Park. Erosion of the soft shale undermines resistant, blocky sandstone layers that form the upper cliffs. —Lucy Chronic photo

The cliff dwellings of Mesa Verde were built in sheltering recesses in the Cliffhouse Sandstone. Springs emerging at the bottom of the porous sandstone supplied water to the villages. The springs also promoted cave formation, weakening and undermining the rock. —Felicie Williams photo

The Menefee Formation erodes easily, undermining the massive, light-colored Cliffhouse Sandstone. Rainwater percolating through the porous sandstone reaches the less permeable shales of the Menefee Formation and flows sideways along the layers. Weakened by seepage from small springs where this flow emerges from the cliffs, the sandstone falls away or spalls off in great arcs to create the arched caves that sheltered early inhabitants. What could be more convenient than a weatherproof shelter furnished by nature, complete with a supply of running—or at least seeping—water? The cliffs of the Point Lookout Sandstone below sufficed to keep out enemies and provided a ready disposal system: refuse was just tossed over the edge. Archeologists searching for clues to the daily life of early inhabitants often look along the base of the cliffs.

Streams that drain Mesa Verde are typical of plateau areas. Upstream, each major stream branches again and again to form a treelike or dendritic pattern. Stream erosion is not severe here now, but during times of more intense rainfall, as in the rainy cycles that accompanied Ice Age glaciation, each small stream worked its way headward into the plateau, branching and rebranching, following joints in the rock to carve the narrow, steep ravines. As a result, the mesa is shaped something like a human hand, with deep canyons draining southward between its long fingers.

The first inhabitants of Mesa Verde lived on the surface of the plateau, where they built pit houses, farmed, and hunted. Farming was facilitated by a thin coating of fine, even-grained soil, wind-deposited silt dating back to Pleistocene times. Later, cave dwellings gave protection from both weather and enemies; farming still continued on the top of the mesa. Cave dwellings were occupied for less than one hundred years before their abandonment, which may have been caused by a twenty-four-year drought dated by tree-ring studies. Many other ruins in the Southwest were abandoned at about the same time.

Attendees selected for 2017 Research Teachers Conference

Society for Science & the Public has selected 200 science research teachers to attend the 2017 Research Teachers Conference in Washington, D.C., from October 13 to 15, 2017. The conference, sponsored by Regeneron, will bring together teachers representing 45 states, the District of Columbia and Puerto Rico.

The teachers were selected via lottery and will receive an all-expense-paid weekend. Conference attendees will share best practices, troubleshoot challenges that may arise in supporting students in independent science research and learn more about the Society and the Regeneron Science Talent Search.

JESSICA YURINKO

CONGRATULATIONS TO THE SELECTED TEACHERS:

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Larry Caffee
Yolonda Walters

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Cheryl Williams

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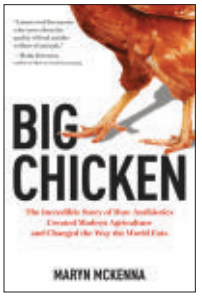

Big Chicken
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BOOKSHELF

Farm tale warns against antibiotics

Journalist Maryn McKenna opens *Big Chicken* by teasing our taste buds with a description of the succulent roasted chickens she bought at an open-air market in Paris. The birds tasted nothing like the bland, uniform chicken offered at U.S. grocery stores. This meat had an earthy, lush, animal flavor. From this tantalizing oh-so-European tableau, McKenna hits us with a sickening contrast — scientists chasing outbreaks of drug-resistant *Salmonella* infections in humans, and ailing chickens living in crowded conditions and never seeing the light of day.

Antibiotics are at the root of both nightmares, McKenna argues. She draws clear connections between several dramatic foodborne outbreaks and the industrialization of chicken production, made possible, in large part, by the heavy use of the drugs. That reliance on antibiotics has also spurred the rise of drug-resistant bacteria. In fact, the overuse of antibiotics in livestock is a bigger driver of resistance than the overuse of antibiotics in people.

Farmers began using the drugs after studies in the 1940s showed that antibiotics boosted muscle mass. For chickens, that meant the birds got bigger and grew faster with less feed. Today, a meat chicken weighs twice what it did 70 years ago at slaughter and reaches that weight in half the time. Once farmers saw opportunity for growth and packed more birds into barns, the drugs took on a new role: to protect crowded animals from illness.

McKenna weaves in real people's stories with clearly explained scientific details and regulatory history. If this story has a villain, it's Thomas Jukes, whose noble goal was to feed the world with cheap protein. In the '50s, Jukes was a researcher at Lederle Laboratories, one of the first manufacturers of antibiotics. He did some of the early studies testing the drugs as growth promoters. He saw signs that bacteria were developing resistance, but he saw no risk to the chickens, McKenna writes. Jukes railed against efforts in the '70s to regulate antibiotic use in livestock and, up until he died in 1999, refused to acknowledge any downsides.

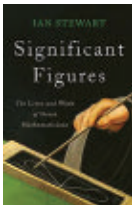
In addition to profiling farmers who embraced industrialization, McKenna introduces those who have turned their backs on antibiotics. These farmers, including many in the United States, have learned to raise drug-free chickens, mainly by going back to the old ways — letting chickens roam free, day and night, pecking at grubs in the ground. Some farms in the Netherlands even manage to raise industrial numbers of chickens without propping them up with antibiotics.

McKenna's story almost has a happy ending. In 2014, the fast-food restaurant Chick-fil-A announced it would, within five years, stop serving chicken raised with antibiotics. Chicken producers, as well as McDonald's, Subway, Costco and Walmart, followed suit.

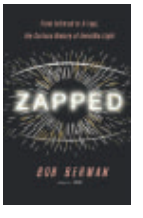
But we're not out of the woods yet, McKenna warns. She likens antibiotic resistance to climate change, calling it "an overwhelming threat, created over decades by millions of individual decisions and reinforced by the actions of industries." The book might not make you give up chicken, but you may be more likely to look for sustainably raised birds to put on the dinner table.
— Cori Vanchieri

BOOKSHELF

What It's Like to Be a Dog
Gregory Berns
A neuroscientist shares what he's learned about the inner lives of dogs and other animals through studies of their brains. *Basic Books, $28*



Significant Figures
Ian Stewart
The history and development of mathematics is recounted through short biographies of 25 key thinkers, from Archimedes to Ada Lovelace to William Thurston. *Basic Books, $28*



Zapped
Bob Berman
By blending history with modern applications, a science writer illuminates X-rays, microwaves and the rest of the electromagnetic spectrum's "invisible light." *Little, Brown and Co., $26*

Firestorm
Edward Struzik
A journalist investigates the growing threat of wildfires throughout North America. *Island Press, $30*

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Spritely voyage

Engineers recently launched prototypes of miniature spacecraft. The prototypes, each a single circuit board, include solar panels, radios, thermometers and gyroscopes, ***Maria Temming*** *reported in "Sprites blast into space" (SN: 9/2/17, p. 5).*

"Does the gyroscope actually stabilize the chip, or just provide information that can be signaled back to ground stations?" reader **Mark S.** asked online. He also wondered how a Sprite keeps its solar cells aimed at the sun. "Doesn't it need a small battery for those moments it's briefly shadowed by the Earth?"

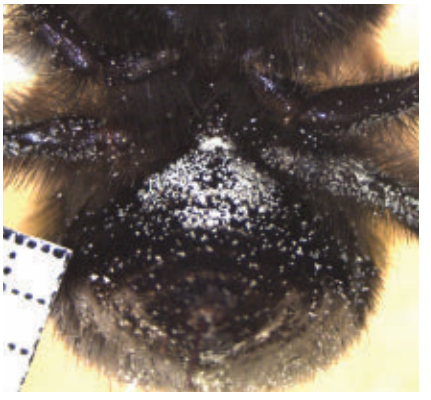
The gyroscope is just a sensor and does not stabilize the spacecraft, says Sprite designer and Harvard engineer **Zac Manchester**. The current Sprite model can't steer itself and works only when basking in sunlight — there's no backup battery on board. "We don't worry about keeping them continuously powered on," he says. But self-steering is something **Manchester** and colleagues hope to develop for future versions.

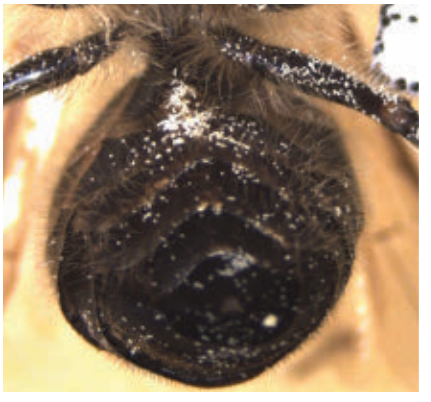
No relation

The genomes of five Canaanites whose remains were unearthed in Sidon, Lebanon, shed light on the ancient civilization's forebearers and descendants, ***Maria Temming*** *reported in "DNA reveals Canaanites' fate" (SN: 9/2/17, p. 8).*

"The five Canaanites are all from a single location (Sidon), so their genealogy may not be representative of the entire Canaanite territory," online reader **Tony Cooley** wrote. "If they were buried closely together, they may have been relatives.... The source does not discuss how the five individuals were obtained."

The individuals were not relatives, says **Claude Doumet-Serhal**, director of the British Museum excavations in Sidon and study coauthor. The five ancient people analyzed in this study were discovered in different types of graves — including pits, constructed graves and in various jars — that were dated to different time periods during the Canaanite age in Sidon, between about 1900 B.C. and 1550 B.C.





You missed a spot, bee

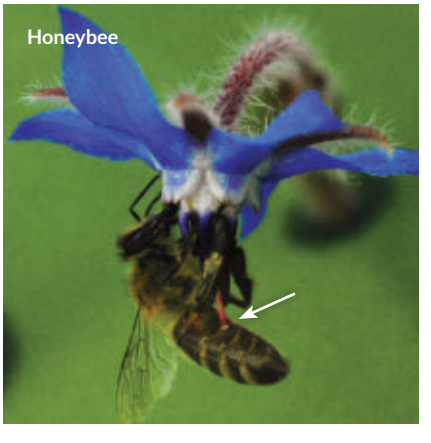
Bee bodies may be built just right to help pollen hitch a ride between flowers.

For the first time, scientists have identified where and how much pollen is left behind on the bodies of bumblebees and honeybees after the insects groom themselves. These residual patches of pollen align with spots on bees' bodies that come into contact with flowers' pollen-collecting reproductive parts (images at right, arrows), researchers report September 6 in *PLOS ONE*.

Typically, as these bees visit flowers for nectar, the insects brush much of the pollen that powders their bodies into pocketlike structures on their legs to carry home for bee larvae to eat. In fact, bees are so good at such grooming that over a flower's lifetime, less than 4 percent of its pollen may reach the pollen-receiving parts of another flower of the same species. Given this pollen-hoarding prowess, researchers wondered how bees have such an important role in plant reproduction.

So biologist Petra Wester and colleagues put buff-tailed bumblebees (*Bombus terrestris*) and European honeybees (*Apis mellifera*) into jars with pollen. As the bees whizzed around, they stirred up the grains, evenly coating themselves in just a few minutes. When placed in clean jars, the insects groomed away. Even after a half hour of cleaning up, the bees still had pollen caked on some areas of their bodies, including the tops of thoraxes (above rows, left) and heads (above, middle) and the underside of their abdomens (above, right). "They cannot reach these spots so easily," says Wester, of Heinrich Heine University Düsseldorf in Germany, "similar to the fact that people cannot reach their back so easily."

Wester and colleagues placed other bees in cages with flowers whose pollen-producing anthers and pollen-collecting stigmas had been stained with fluorescent dyes. Examining these bees later, the researchers found dye smeared on the same ungroomed areas. The finding suggests that these "safe sites" for pollen on bees' bodies play a key role in moving pollen from flower to flower. —*Maria Temming*



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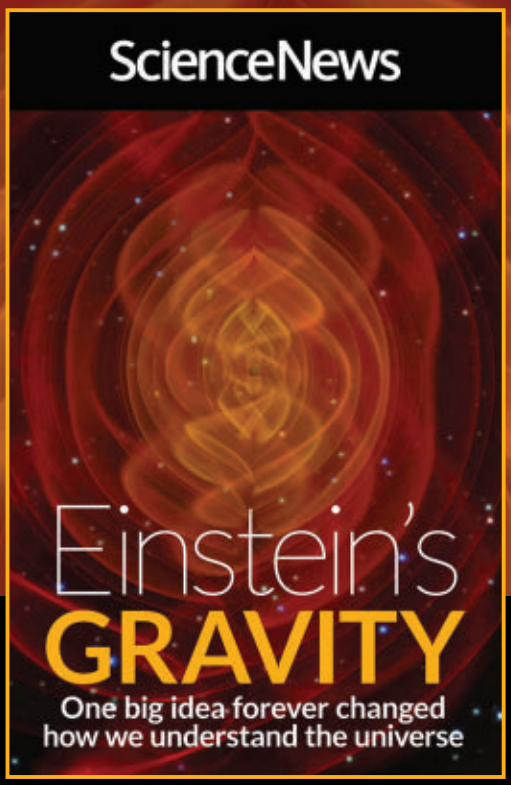
Einstein's BIG IDEA



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