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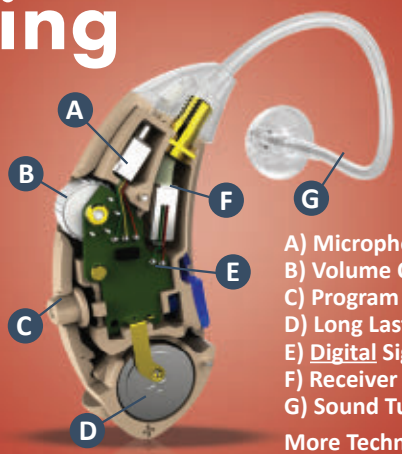

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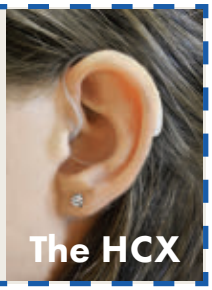

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VOL. 191 | NO. 1

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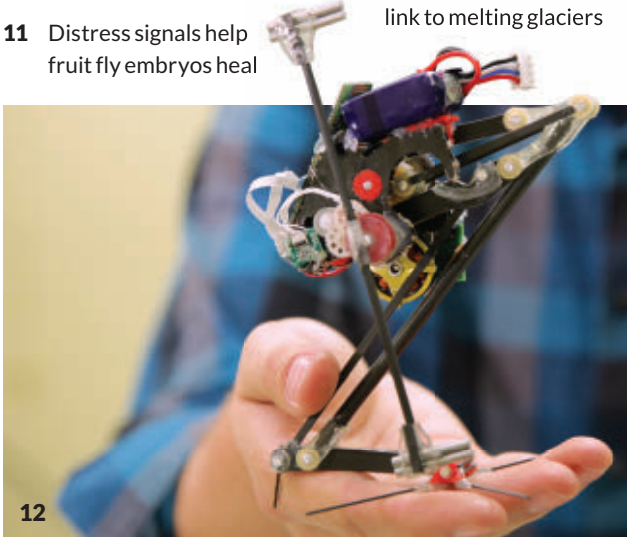
Features

News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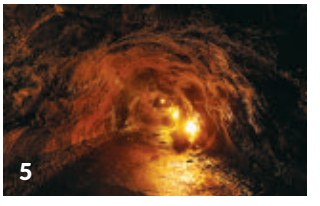
5

Departments

SOCIETY UPDATE
Intel ISEF finalists attend White House conference

COVER Supercontinents come and go over the ages. Amasia, illustrated here from the North Pole, might form in the distant future. *Nicolle Rager Fuller*

Mapping the future, of continents and batteries

The Earth is always moving beneath our feet. What seems permanent, still and solid is in fact constantly creeping. It's easy to forget that as we race through our busy days, measuring time with digital clocks rather than the achingly slow beat of rock.

On Page 18, contributing correspondent Alexandra Witze explores the long-term motions of the planet's portable continents. Within this blue dot, Witze reminds us, a swirling cauldron sits below the rocky crust and is now squeezing the Pacific Ocean and expanding the Atlantic. The current configuration of Earth's landmasses is not what it looked like 2 billion years ago, or even during the time of Pangaea roughly 250 million years ago. It's also not how the planet's visage will appear a few hundred million years from now (see this issue's cover illustration for a spectacular view of the future supercontinent, already named Amasia).

Taking a long view does not come easily to most people. But that's where science can help, enabling a new perspective on the past and the future — focusing our ability to see even gradual, geologically paced change and predict what will happen next. This is important for understanding Earth's crustal dynamics and forecasting the planet's future.

Out of concern for the planet's future on a much shorter timescale, scientists are fervently searching for next-generation battery technology that will be central to efforts to reduce dependence on fossil fuels (Page 22). Better batteries means more than a longer time between recharging your smartphone or laptop. Ideally, new high-capacity batteries will be able to efficiently store the energy captured by solar and wind power or enable a car to drive long distances without gasoline.

At first glance, the search for better batteries seems glacially slow. The arrival of the lithium-ion battery was a big deal a quarter century ago, and it's still the reigning champ in many smaller devices. Attempts at making improvements can easily go awry (consider Samsung's Galaxy Note 7, whose explosive battery has resulted in airlines banning it from every flight). Improving batteries, contributing correspondent Susan Gaidos reports, involves both chemistry and design. New options are on the horizon: not-quite-ready-for-prime-time prototypes using lithium-sulfur or even lithium and air. In the next few years, many of these may move from the lab to commercial applications, with some perhaps destined for widespread use.

It may be hard for humans to see the long-term view, but, as the many involved in battery research illustrate, it is possible to imagine what might make things better some day. Along with the discoveries themselves, sharing the progress and stalls of science, through a journalistic lens, remains crucial. That's what we do here at *Science News* — it's our mission and our passion. Recently, we got a boost for our work from the Knight Foundation, which selected us for a strategic planning grant and invited us to participate in a donation matching program to support excellent journalism (www.newschallenge.org). Some good news for 2017. — *Eva Emerson, Editor in Chief*

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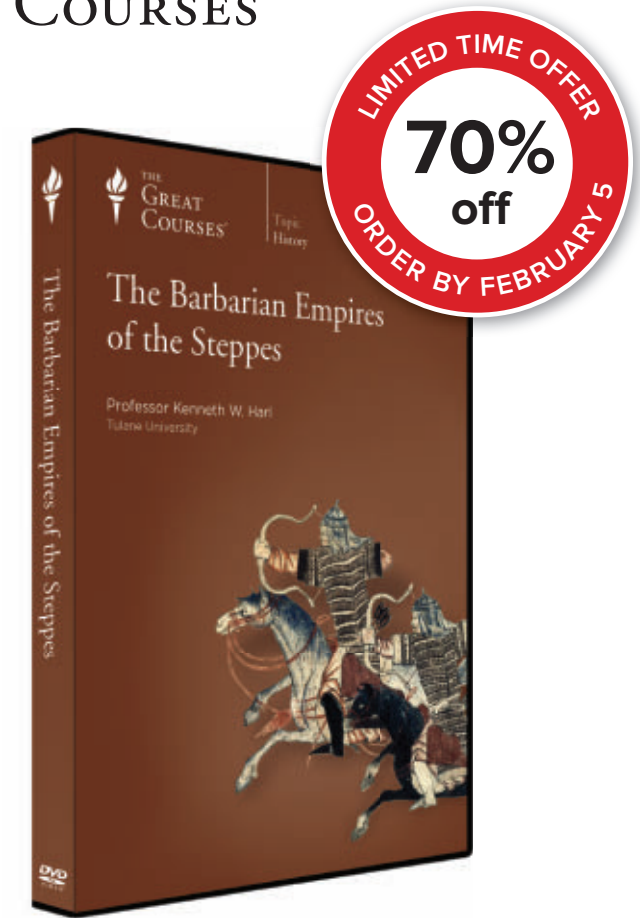

Meet History's Most Fearsome Leaders

Attila the Hun and Genghis Khan loom large in the popular consciousness as two of history's most fearsome warrior-leaders. Yet few people are aware of their place in a succession of nomadic warriors who emerged from the Eurasian steppes to seize control of civilizations.

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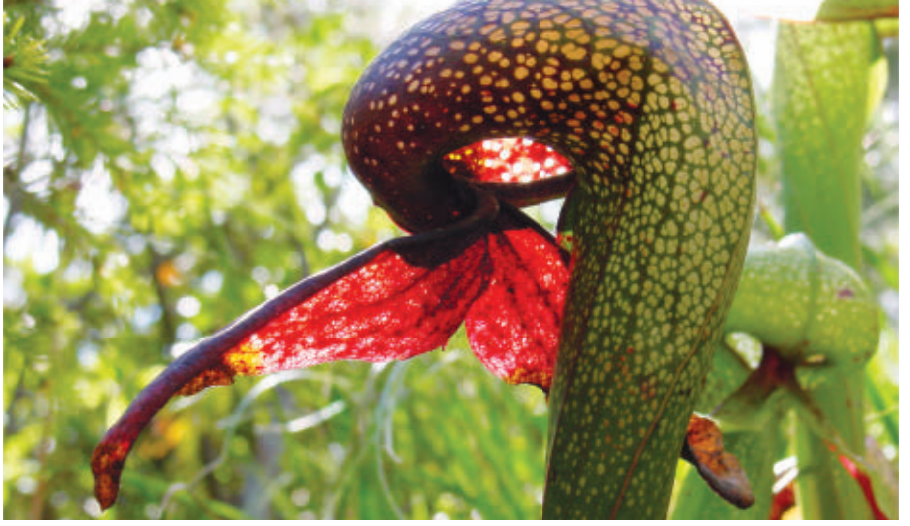
Excerpt from the January 14, 1967 issue of *Science News*

50 YEARS AGO

Tenth moon of Saturn

The first natural satellite in the solar system to be discovered since artificial satellites were launched has been found circling Saturn. Dr. Audouin Dollfus of the Observatory of Physical Astronomy at Meudon, France, spotted Saturn's tenth satellite on three photographs taken in mid-December when the planet's rings were seen edge-on from earth.

UPDATE: Saturn's 10th moon, officially named Janus in 1983, was the first satellite of the ringed planet discovered in the 20th century. It shares an orbit with the moon Epimetheus, seen days after Janus' discovery, although no one realized they were separate entities until 1978. Saturn actually hosts at least 62 moons, a diverse bunch, as revealed by the Cassini spacecraft. Water erupts from Enceladus, Hyperion is blanketed with bizarre terrain resembling a sponge from afar and methane lakes dot Titan's surface. Cassini, in orbit since 2004, will end its mission in September by plunging into Saturn's atmosphere (*SN: 11/12/16, p. 10*).



What in the world a meat-eating California pitcher plant is doing with a forked, red-veined frill of tissue near its mouth is much less clear than scientists had thought.

IT'S ALIVE

The green art of the deathtrap ambush

Tricking some bug into drowning takes finesse, especially for a hungry meat eater with no brain, eyes or moving parts. Yet California pitcher plants are very good at it.

Growing where deposits of the mineral serpentine would kill most other plants, *Darlingtonia californica* survives in low-nutrient soil by being "very meat dependent," says David Armitage of the University of Notre Dame in Indiana. Leaves he has tested get up to 95 percent of their nitrogen from wasps, beetles, ants or other insects that become trapped inside the snake-curved hollow leaves.

The leaves don't collect rainwater because a green dome covers the top. Instead, they suck moisture up through the roots and (somehow) release it into the hollow trap. "People have been doing weird experiments where they feed [a plant] meat and milk and other things to try to trigger it to release water," Armitage says. Experiments tempting the green carnivore with cheese, beef broth, egg whites and so on suggest there's some sort of chemical cue.

However the water enters the leaf pool, it starts out clear. As insects drown, the liquid darkens to a murky brown or red and "smells just horrible," he says. The soupiness comes from bacteria, which help doom prey by lowering the surface tension of the drowning pool, Armitage reports in the November *Biology Letters*. Ants or other small insects sink below the surface immediately instead of floating at the top.

In a leaf filled with insect carcasses, the bodies at bottom are more decomposed than newer arrivals.

But first, pitchers lure victims to the pool by repurposing an old plant ploy: free nectar. It's "highly nitrogen-rich and full of sugars, so it's delicious — I've tasted it," Armitage says. Pitcher plants sprout blooms, but the trap nectar doesn't come from the drooping flowers. A roll of tissue near the pitcher mouth oozes the treat.

That nectar-heavy roll curves onto what's called the fishtail appendage. Mature plants (2 years or older) grow this forked tissue like a moustache at the pitcher mouth. Biologists for more than a century have presumed that this big, red-veined, lickable prong worked as an insect lure. Armitage, however, tested the idea and says it may be wrong.

Clipping fishtails off individual leaves, or even off all the leaves in a small patch, did nothing to shrink the catch compared with fully mustachioed leaves, he reported in the *American Journal of Botany* in April 2016. The only thing fishtails lure, for the time being at least, are puzzled botanists. — *Susan Milius*

FROM TOP: NOAHELHARDT/WIKIMEDIA COMMONS (CC BY-SA 3.0); D. ARMITAGE

HOW BIZARRE

Moon's lava tubes might make nice digs

Lava tubes inside the moon could be structurally stable up to 5 kilometers across, new research suggests. Hawaii's are much smaller (one shown).

Future moon colonies could be totally tubular.

Slight variations in the moon's gravitational tug have hinted that kilometers-wide caverns lurk beneath the lunar surface. Like the lava tubes of Hawaii and Iceland, these structures probably formed when underground rivers of molten rock ran dry, leaving behind cylindrical channels. On Earth, such structures max out at around 30 meters across, but gravitational data suggest that the moon's tubes are vastly wider.

Assessing the sturdiness of lava tubes under lunar gravity, planetary geophysicist Dave Blair of Purdue University in West Lafayette, Ind., and colleagues estimate that the caves could remain structurally sound up to 5 kilometers across. That's wide enough to fit the Golden Gate Bridge, Brooklyn Bridge and London Bridge end to end.

Such colossal caves would be prime real estate for lunar pioneers, the researchers report in the Jan. 15 *Icarus*. Lava tubes could offer protection from extreme surface temperatures, harsh radiation and meteorite impacts. — *Thomas Sumner*

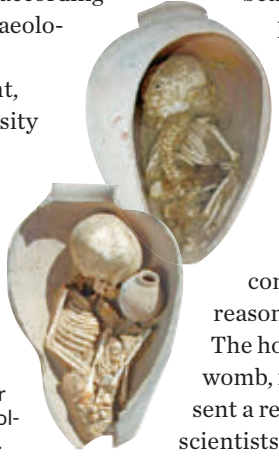
WHAT WERE THEY THINKING?

Pot burials were not just for the poor

New research is stirring the pot about an ancient Egyptian burial practice.

Many ancient peoples, including Egyptians, buried some of their dead in ceramic pots or urns. Researchers have long thought these pot burials, which often recycled containers used for domestic purposes, were a common, make-do burial for poor children.

But at least in ancient Egypt, the practice was not limited to children or to impoverished families, according to a new analysis. Bioarchaeologist Ronika Power and Egyptologist Yann Tristant, both of Macquarie University in Sydney, reviewed published accounts of pot burials at 46 sites, most near the Nile River and dating from about 3300 B.C. to 1650 B.C. Their results appear in the December *Antiquity*.



Ancient Egyptians buried children (shown) and adults in pots. The hollow vessels mirror the womb and may have symbolized a rebirth into the afterlife.

A little over half of the sites contained the remains of adults. For children, pot burials were less common than expected: Of 746 children, infants and fetuses interred in some type of burial container, 338 were buried in wooden coffins despite wood's relative scarcity and cost. Another 329 were buried in pots. Most of the rest were placed in baskets or, in a few cases, containers fashioned from reeds or limestone.

In the tomb of a wealthy governor, an infant was found in a pot containing beads covered in gold foil. Other pot burials held myriad goods: gold, ivory, ostrich eggshell beads, clothing or ceramics. Bodies were either placed directly into urns, or sometimes pots were broken or cut to fit the deceased.

People deliberately chose the containers, in part for symbolic reasons, the researchers propose. The hollow vessels, which echo the womb, may have been used to represent a rebirth into the afterlife, the scientists say. — *Emily DeMarco*

Names of eight stars (brightest dots) in the constellation Orion, plus one (Cursa, far right) in Eridanus, are among the 227 officially sanctioned by the International Astronomical Union.

THE NAME GAME

Name that star

For centuries, stargazers have known which star was Polaris and which was Sirius, but those designations were by unofficial tradition. The International Astronomical Union, arbiter of naming things in space, has now blessed the monikers of 227 stars in our galaxy. As of November 24, names such as Polaris (the North Star) and Betelgeuse (the bright yellow star at upper left) are official.

Until now, there has been no central star registry or guidelines for naming. There are many star catalogs, each one designating stars with different combinations of letters and numbers. That excess of options has left most stars with an abundance of labels (HD 8890 is one of more than 40 designations for Polaris).

The tangle of titles won't disappear, but the new IAU catalog is a stab at formalizing the more popular names. Before this, only 14 stars (included in the 227) had been formally named, as part of the IAU's contest to name notable exoplanets and the stars that they orbit (*SN: 2/6/16, p. 5*). One famous star is returning to its ancient roots. The brightest member of Alpha Centauri, the triplet of stars that are the closest to our solar system, is officially dubbed Rigil Kentaurus, an early Arabic name for "foot of the centaur." — *Christopher Crockett*

GENES & CELLS

Proteins turn back aging clock

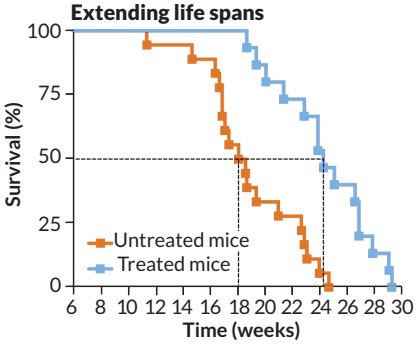
Reprogrammed cells lengthen life of prematurely aging mice

BY TINA HESMAN SAEY

Four proteins that can transform adult cells into embryonic-like ones can also turn back the aging clock, a new study in mice suggests.

Partial reprogramming of cells in prematurely aging mice extended average life span from 18 weeks to 24 weeks, researchers report in the Dec. 15 *Cell*. Normal mice saw benefits, too: Muscles and pancreas cells healed better in middle-aged mice that got rejuvenation treatments than in mice that did not. The experiment could be evidence that epigenetic marks — chemical tags on DNA and proteins that change with age, disease and environmental exposures — are a driving factor of aging. Some marks accumulate with age while others are lost.

"It's an inspiring paper," says Jan van Deursen, a biologist at the Mayo Clinic in Rochester, Minn., who studies diseases of aging. He gives the paper an "A" for sparking imagination, but lower marks for practical applications to human aging because it would involve gene therapy and could be risky. "It's all cool, but I don't see that it could ever be applied in medicine," he says. "We could be terribly wrong. Hopefully we are."



Living curve Prematurely aging mice with progeria have an average life span of about 18 weeks (orange), but giving the mice twice weekly cell reprogramming treatments increased their average life span to 24 weeks (blue).

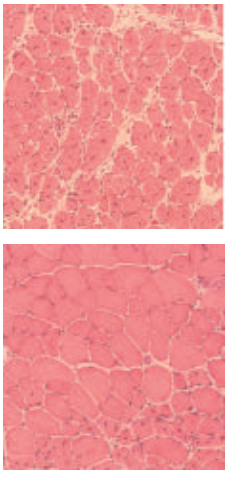
Researchers reset the aging clock by genetically engineering mice to make four proteins when treated with the antibiotic doxycycline. Those four proteins — Oct4, Sox2, Klf4 and c-Myc — are known as "Yamanaka factors" after the Nobel Prize–winning scientist Shinya Yamanaka. He demonstrated in 2006 that the proteins could turn an adult cell into an embryonic-like cell known as an induced pluripotent stem cell, or iPS cell (*SN: 11/3/12, p. 13*; *SN: 7/14/07, p. 29*).

The factors help strip away epigenetic marks that enable cells to know whether they are heart, brain, muscle or kidney cells. As a result, stripped cells revert to the ultraflexible pluripotent state, capable of becoming nearly any type of cell. Other researchers have used the Yamanaka factors to reprogram cells within living mice before, but those attempts resulted in tumors. (Many cancer cells resemble stem cells in that they don't have a specific identity and are "undifferentiated.")

Those tumors indicated to Alejandro Ocampo and colleagues that the proteins were rewriting epigenetic programming to take cells back to an undifferentiated state. But "you don't need to go all the way back to pluripotency" to erase the marks associated with aging, says Ocampo, a stem cell biologist at the Salk Institute for Biological Studies in La Jolla, Calif. A milder reprogramming treatment might reverse aging without stripping away cells' identity and leading to cancer, Ocampo and colleagues thought.

To turn on the Yamanaka factors, the researchers gave doxycycline to genetically engineered mice with progeria, a premature aging disease, two days per week. Mice that made the reprogramming proteins lived six weeks longer on average than mice not getting the treatment. The mice didn't get cancer but still died prematurely (lab mice usually live two to three years). "We are far away from perfection," Ocampo says.

Normally aging mice also benefited from the treatment. When the animals were 1 year old (roughly middle-aged), the researchers treated them with doxycycline two days per week for three weeks. Treated mice were better able to repair muscles and replace insulin-producing cells in the pancreas. Not all organs fared as well, Ocampo says, citing preliminary evidence. Ongoing experiments will determine whether the epigenetic reprogramming can make the mice live any longer or healthier.



Older mouse muscles (top) aren't as good at self-repair as muscles reprogrammed to a more youthful state (bottom).

FROM TOP: SALK INSTITUTE; A. OCAMPO *ET AL*/*CELL* 2016

People probably won't be genetically engineered the way mice are. But small molecules might also be able to wipe away epigenetic residue that builds up with aging and restore marks that were lost over time, returning to a pattern seen in youth, Ocampo suggests.

Researchers still don't know whether all cells are rejuvenated by the treatment. Yamanaka factors may breathe new life into aging stem cells, allowing them to replenish damaged tissues. Or the factors may wake up senescent cells — cells that have shut down normal functions and no longer divide, but may send signals to neighboring cells that cause them to age (*SN: 3/5/16, p. 8*). Reviving senescent cells could be dangerous, says van Deursen; the body shuts cells down to prevent them from becoming cancerous.

Plenty of evidence indicates that resetting epigenetic programming can extend life, Ocampo says. He points to a report that Dolly the Sheep's cloned sisters are aging normally (*SN: 8/20/16, p. 6*) as a hopeful sign that reprogramming isn't dangerous and might one day prevent many diseases associated with aging in people, if not lengthen life spans. ■

BODY & BRAIN

Virtual reality raises nausea risk

Women more likely than men to experience motion sickness

BY BETSY MASON

Playing a virtual reality game using a headset could give you motion sickness, particularly if you are a woman, a study using the Oculus Rift concluded.

Virtual reality headsets may have been a popular gift this holiday season, but new research suggests that some of their recipients may experience motion sickness — especially if they're women.

In a test of people playing one virtual reality game using an Oculus Rift headset, more than half felt sick within 15 minutes, a team of scientists at the University of Minnesota in Minneapolis reports online December 3 in *Experimental Brain Research*. Among women, nearly four out of five felt sick.

So-called VR sickness, also known as simulator sickness or cybersickness, has been recognized since the 1960s, and the U.S. military has long noticed that flight simulators made pilots nauseous. In recent years, anecdotal reports have begun trickling in about the new generation of head-mounted virtual reality displays making people sick. Now, with VR making its way into people's homes, there's a steady stream of claims of VR sickness.

"It's a high rate of people that you put in [VR headsets] that are going to experience some level of symptoms," says Eric Muth, an experimental psychologist at Clemson University in South Carolina with expertise in motion sickness. "It's going to mute the 'Wheee!' factor."

Oculus VR, which Facebook bought for $2 billion in 2014, released its Rift headset in March. The company declined to comment on the new research but says it has made progress in making the virtual reality experience comfortable for most people, and that developers are getting better at creating VR content. Most approved games and apps get a comfort rating based on things like the type of movements involved, and Oculus recommends starting slow and taking breaks. But some users still report getting sick.

The new study confirms these reports. A team led by Thomas Stoffregen, a kinesiologist who has been studying motion sickness for decades, tested the susceptibility of two sets of 18 male and 18 female undergraduates during two different VR games using an Oculus Rift DK2 headset. The first game, which involved using head motions to roll a virtual marble through a maze, made 22 percent of the players feel sick within the 15 minutes they were asked to play.

Another 36 students played the horror game *Affected*, using a handheld controller to navigate a creepy building. This time, 56 percent felt sick within 15 minutes. Fourteen of 18 women, nearly 78 percent, were affected, compared with just over 33 percent of men. Though the study tested only an Oculus Rift, other companies' VR headsets based on similar technology may have similar issues.

This gender difference shows up in almost any situation that can cause motion sickness, like a moving car or a rocking boat. But Stoffregen says that the disparity can't be explained by the most widely accepted theory of motion sickness, which suggests that it is caused by a mismatch between the motion your body is sensing and what your eyes are seeing — such as when you read in a moving car. With VR, the theory goes, your eyes think you're moving, but your body feels stationary, and this makes you feel sick.

Stoffregen thinks motion sickness is instead caused by things that disrupt your balance, like a boat pitching over a wave. And if you try to stabilize your body in the virtual world that you see — say, by leaning into a virtual turn — instead of in the physical world you're in, you can lose stability, leading to motion sickness.

Men and women are typically different shapes and sizes, so they differ in the subtle, subconscious movements that keep their bodies balanced, known as postural sway, Stoffregen says. This difference makes women more susceptible to motion sickness, he claims. For the new study, he measured participants' balancing motions before they played the games and found a measurable difference in sway between those who reported feeling sick and those who didn't.

Because motion sickness is characterized by a complicated set of symptoms, self-reporting by participants may not be a reliable way to measure it, Muth argues. And, he says, "I would say the science isn't there yet to draw that conclusion" about gender bias, adding he'd like to see the result replicated with a larger group.

Even so, with VR potentially poised to jump from the gaming world into more mainstream aspects of society, a gender disparity could become a real problem, especially if VR enters the workplace, Stoffregen says. "If it were only games, it wouldn't matter, and nobody would care." ■

HUMANS & SOCIETY

Lucy had taller kin, footprints suggest

Signs of tallest *Australopithecus afarensis* found in Tanzania

BY BRUCE BOWER

Famous footprints of nearly 3.7-million-year-old hominids, found in 1976 at the Laetoli site in Tanzania, now have sizable new neighbors.

While excavating small pits in 2015 to evaluate the impact of a proposed Laetoli museum, researchers found comparably ancient hominid footprints about 150 meters from the original discoveries. The prints reveal a vast range of body sizes for ancient members of the human family, reports a team led by archaeologists Fidelis Masao and Elgidius Ichumbaki of the University of Dar es Salaam in Tanzania. A description of the new footprints appears online December 14 in *eLife*.

Scientists exposed 14 hominid footprints, made by two individuals as they walked across wet volcanic ash. More than 500 footprints of ancient horses, rhinos, birds and other animals dotted the area around the hominid tracks. Like previously unearthed tracks of three individuals who apparently strode across the same layer of soft ash at the same time, the latest footprints were probably made by members of *Australopithecus afarensis*. That's the species best known for Lucy, discovered in Ethiopia in 1974. *A. afarensis* inhabited East Africa from around 4 million to 3 million years ago.

All but one of the 14 hominid impressions come from the same individual. Based on footprint dimensions, the researchers estimate that this presumed adult male — nicknamed Chewie in honor of the outsized *Star Wars* character Chewbacca — stood about 5 feet, 5 inches tall and weighed nearly 100 pounds. That makes him the tallest known *A. afarensis*. The team calculates that the remaining hominid footprint was probably made by a female who was 4 feet, 9 inches tall and about 87 pounds. Stature estimates for each of the other three Laetoli individuals fall below that of the ancient female.

Lucy lived about 500,000 years later and was about 3½ feet tall.

If Laetoli's five impression-makers were traveling together, "we can suppose that the Laetoli social group was similar to that of modern gorillas, with one large male and a harem of smaller females and perhaps juveniles," says paleontologist and study coauthor Marco Cherin of the University of Perugia in Italy.

Chewie's stature challenges a popular assumption that hominid body sizes abruptly increased with the emergence of the *Homo* genus, probably shortly after *A. afarensis* died out, Cherin adds.

The new paper's stature estimates are based on the Laetoli footprints, but "we don't have a firm idea of how foot size was related to overall body size in *Australopithecus*," says evolutionary biologist Kevin Hatala of Chatham University in Pittsburgh. Using size data from present-day humans to calculate heights and weights of *A. afarensis* footprint-makers "could lead to some error," Hatala says.

Paleoanthropologist Yohannes Haile-Selassie of the Cleveland Museum of Natural History notes that it's unclear whether the new footprints and those found in 1976 represent a single group that was walking together, or if some smaller footprints were also made by males. Cherin's proposal that large *A. afarensis* males controlled female harems "is a bit of a stretch," he says. ■

Footprints of the largest known *Australopithecus afarensis*, dating to nearly 3.7 million years ago, have been found in hardened volcanic ash at Tanzania's Laetoli site. These tracks run left to right.

RAFFAELLO PELLIZON

ATOM & COSMOS

Dawn spacecraft maps Ceres water

Evidence builds for abundant ice deposits on dwarf planet

BY CHRISTOPHER CROCKETT

Water ice lies just beneath the cratered surface of dwarf planet Ceres and in shadowy pockets within those craters, new studies report. Observations from NASA's Dawn spacecraft add to the growing body of evidence that Ceres, the largest object in the asteroid belt between the orbits of Mars and Jupiter, has held on to a considerable amount of water for billions of years.

"We've seen ice in different contexts throughout the solar system," says Thomas Prettyman, a planetary scientist at the Planetary Science Institute in Tucson and coauthor of one of the studies, published online December 15 in *Science*. "Now we see the same thing on Ceres." Ice accumulates in craters on Mercury and the moon, an icy layer sits below the surface of Mars and water ice slathers the landscape of several moons of the outer planets. Each new sighting of H_2O contributes to the story of how the solar system formed and how water was delivered to a young Earth.

On Ceres, a layer of ice mixed with rock sits within about one meter of the surface concentrated near the poles, Prettyman and colleagues report. And images of some craters around the polar regions, of spots that never see sunlight, show bright patches, at least one of which is made of water ice, a separate team reports December 15 in *Nature Astronomy*.

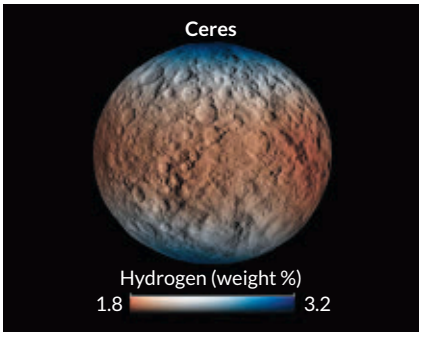
"Ceres was always believed to contain lots of water ice," says Michael Küppers, a planetary scientist at the European Space Astronomy Center in Madrid who was not involved with either study. Its overall density is lower than pure rock, implying that some low-density material such as ice is mixed in. The Herschel Space Observatory has seen water vapor escaping from the dwarf planet (*SN Online: 1/22/14*), and the Dawn probe, in orbit

around Ceres since 2015, spied a patch of water ice in the Oxo crater, though the amount of direct sunlight there implies the ice has survived for only dozens of years (*SN Online: 9/1/16*). The spacecraft has also found minerals on the surface that formed in the presence of water.

But researchers would like a map of Ceres' water. Knowing whether it is blended throughout the interior or segregated from the rock could help piece together the story of where Ceres formed and how the tiny world was put together. That, in turn, could provide insight into how diverse the worlds around other stars might be.

To map the subsurface ice, Prettyman and colleagues used a neutron and gamma-ray detector onboard Dawn. As Ceres is bombarded with cosmic rays — highly energetic particles that originate outside the solar system — atoms in the dwarf planet spray out neutrons. The amount and energy of the neutrons can provide a clue to the abundance of hydrogen, presumably locked up in water molecules and hydrated minerals.

Finding patches of ice was a bit more straightforward. Planetary scientist Thomas Platz and colleagues pinpointed permanently shadowed spots on Ceres, typically in crater floors near the north and south poles. The team then scoured images of those locations for bright patches. Out of the more than 600 darkened craters they identified, the researchers found 10 with bright deposits that could be surface ice. One had a chunk sticking out into just enough sunlight for Dawn to measure the spectrum of the reflected light and detect signs of water.



Dwarf planet Ceres has more hydrogen beneath its surface near the poles, indicating a subsurface layer of ice mixed with rock. Blue shows where hydrogen abundance is highest.

Water vapor escaping from inside the dwarf planet probably falls back to Ceres, where some of it gets trapped in these cold spots, says Platz, of the Max Planck Institute for Solar System Research in Göttingen, Germany.

Just because there is water doesn't mean Ceres is a good place for life. Temperatures in the shadows don't get above −216° Celsius. "It's pretty cold, there's no sunlight. We don't think that's a habitable environment," Platz says. Although, he adds, "one could mine for future missions to get fuel." Hydrogen and oxygen, the two elements that make up water, are common constituents of rocket fuel.

Ceres is now the third major heavily cratered body, along with Mercury and the moon, with permanently shadowed regions where ice builds up. "All the ones we've got info on to test this show you've accumulated something," says Peter Thomas, a planetary scientist at Cornell University who is not a part of either research team. Those details improve researchers' understanding of how water interacts with a variety of planetary environments. ■

GENES & CELLS

Cells gobble up strands of silicon

Phagocytosis draws in nanowires, opening way to bioelectronics

BY MEGHAN ROSEN

Human cells can snack on silicon.

Cells grown in the lab devour nanosized wires of silicon through an engulfing process known as phagocytosis, scientists report December 16 in *Science Advances*.

Silicon-infused cells could merge electronics with biology, says John Zimmerman, a biophysicist now at Harvard University. "It's still very early days," he adds, but "the idea is to get traditional electronic devices working inside of cells." Such hybrid devices could one day help control cellular behavior, or even replace electronics used for deep brain stimulation, he says.

Scientists have been trying to load electronic parts inside cells for years. One way is to zap holes in cells with electricity, which lets relatively big stuff, like silicon nanowires linked to bulky materials, slip in. Zimmerman, then at the University of Chicago, and colleagues were looking for a simpler technique that would let nanowires in easily and could potentially allow them to travel through a person's bloodstream like a drug.

Zimmerman's team had previously shown that cells could take in silicon nanowires, but no one knew how it worked. So he added the nanowires to different kinds of cells — including human umbilical vein cells, rat nerve cells and mouse immune cells — in laboratory dishes. Under a microscope, Zimmerman says, "you can see the cell grab the wire, wrap a membrane around it and pull it inside — kind of like a lasso." Then, the wire travels on molecular tracks through the cell's interior to settle around the nucleus.

Molecular tests suggested that nanowires entered via phagocytosis, a process by which some cells take in bacteria and cellular junk. During phagocytosis, a cell's membrane encapsulates the junk, forming a pouch that carries cargo to a recycling center inside the cell. The researchers predict nanowires will eventually be eliminated from cells.

Not all cell types swallowed the wires, though. Knowing which types do, and how the wires get inside, could help in predicting where the wires would end up in the body, Zimmerman says.

But how to go from nanowire-loaded cells to working electronic devices is still a "big question," says Mark Reed, a physicist at Yale University. The nanowires aren't actually hooked up to anything yet, he points out. ■

T.H. PRETTYMAN AND N. YAMASHITA/PLANETARY SCIENCE INSTITUTE

GENES & CELLS

Some cells survive attempted suicide

New studies probe mechanisms of death-defying anastasis

BY TINA HESMAN SAEY

Mostly dead is still partly alive, even for cells on the brink of suicide, new research suggests.

Near-death experiences may play a role in embryo development and help cancer cells that survive chemotherapy spread throughout the body, cell biologist Denise Montell of the University of California, Santa Barbara reported December 6.

Montell described a process called anastasis that saves cells in the midst of committing a type of cellular suicide known as apoptosis. She and others are just beginning to unravel how the process works. Preliminary results indicate that cells simultaneously start killing themselves and hold on to a lifeline in case conditions improve, she said.

Scientists had thought that once a cell going through apoptosis activated an executioner molecule known as a caspase, the cell would surely die, said Claire Walczak, a cell biologist at Indiana University in Bloomington. But cells sometimes call off their attempted suicides at the last moment, even after the executioner starts working, cell biologist Ho Lam Tang discovered in 2008 while a graduate student at the Chinese University of Hong Kong. Tang, now at Johns Hopkins University, and colleagues named the process anastasis, which in Greek means "rising to life."

The discovery that apoptosis is reversible "was really shocking," Walczak said. "It's a really nice illustration of how adaptable cells are."

Tang initially made the discovery by treating an immortal type of cancer cell, called HeLa cells, with a drug that stimulates apoptosis. Once the cells were dying, Tang washed away the drug and some of the cells recovered.

"That experiment is essentially what we do to patients" undergoing chemotherapy, said cell and molecular biologist J. Marie Hardwick of Johns Hopkins. She reported with Tang in 2015 in *Scientific Reports* that fruit fly egg cells can come back from apoptosis and even produce an adult fly.

Cancer patients are given a dose of chemotherapy drugs or radiation that causes cells to commit apoptosis. Then the treatments are stopped for a short time to allow the patient to recover. If cancer cells can come back through anastasis, they may cause a resurgence of the disease, Hardwick suggested. Many of the cells brought back by anastasis have genetic defects. "If you've already attempted to die, you've got problems," Hardwick said.

Some cells that survive apoptosis brought on by stresses such as heat or irradiation can go on to divide and "do basically anything a normal cell can do," Montell said. But unpublished work from her lab indicates that cells brought back from the brink of death by anastasis may never go back to their untreated state and may carry permanent memories of their near-death experiences, she reported.

Montell and colleagues compared gene activity in untreated cells and cells taken nearly to death and then allowed to recover for varying amounts of time. Cell survival proteins are already being made while the cell is preparing to kill itself, her team discovered.

> "Dying cells are actually hedging their bets. They're on the brink of death. They don't know if things are going to get better or get worse."
>
> DENISE MONTELL

"Dying cells are actually hedging their bets. They're on the brink of death. They don't know if things are going to get better or get worse," Montell said.

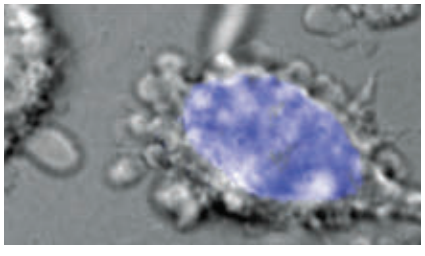
After recovery, the reanimated cells begin to move and to stimulate blood vessel production. Those are things cells do when healing a wound, but they are also actions that can help tumors grow or spread.

"This would be an extremely unbeneficial response if the cells in question happen to be cancer cells," Montell said. The findings suggest that stopping anastasis may lead to more effective cancer treatments.

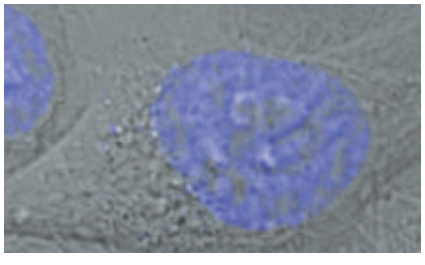
In other cases, stimulating anastasis may benefit patients, Montell said, such as by saving heart cells after a heart attack or the brain's nerve cells after a stroke. Those cells don't divide much so there's less risk of cancer, and recovered cells could restore heart and brain function.

Anastasis is important for organisms to develop properly, Montell and colleagues reported in *eLife* in April. Fruit flies grew slightly smaller wings when the researchers blocked caspase activity, stopping both apoptosis and anastasis. That result suggests that cells usually saved by anastasis ended up dying, making the wing smaller than usual. The cell savior process happens from embryo through adulthood, Montell and colleagues discovered. "We didn't expect to see it, but it was all over the place," she said. ■

Cell committing suicide



Same cell after recovery



Cells on the brink of dying from a type of programmed suicide known as apoptosis (top, a cancer cell known as a HeLa cell) can come back to life (bottom) through a process called anastasis if conditions improve. DNA is shown in blue.

H.L. TANG

MEETING NOTES

Cell distress chemicals help embryos quickly heal

Fruit fly embryos use molecular distress signals to call for wound healing. Those signals — chemicals known as reactive oxygen species — cause embryos to assemble structures called purse strings that rapidly cinch wounds shut, healing without leaving a scar.

Assembling purse strings is a new-found wound-healing role for reactive oxygen species, cell biologist Miranda Hunter of the University of Toronto reported December 4. Previous research has suggested that dead and dying cells spill reactive oxygen species and trigger immune cells to move into the wound.

In fruit fly embryos, cells blasted by a laser make a lot of reactive oxygen molecules and die, but cells neighboring the injury have just enough of the distress chemicals to initiate wound healing, Hunter and colleagues found. Those surrounding cells assemble the protein actin into a ring. A protein called myosin tugs on the actin to contract the ring and draw cells in to close the wound within about an hour.

Learning how fruit fly embryos quickly heal wounds without scarring and inflammation may eventually lead to better wound treatments for people. *— Tina Hesman Saey*

Extra chromosome has surprising effect on cancer

Having an extra chromosome may suppress cancer, as long as things don't get stressful, a new study suggests. The finding may help scientists unravel a paradox: Cells with extra chromosomes grow slower than cells with the usual two copies of each chromosome, but cancer cells, which grow quickly, often have additional chromosomes. Researchers have thought that perhaps extra chromosomes and cancer-causing mutations team up to produce tumors.

Cell biologist Jason Sheltzer of Cold Spring Harbor Laboratory in New York and colleagues examined mouse cells with an extra chromosome that also has cancer-promoting mutations. Cells with an extra chromosome — known as trisomic cells — grew slower in lab dishes and formed smaller tumors in mice than cells with cancer mutations but no extra chromosome. Even when the extra chromosome carries cancer-associated genes, the cells make less than usual of the cancer-driving proteins produced from those genes, Sheltzer reported December 5.

But after cells carrying extra chromosomes were grown with a low dose of chemotherapy drugs, they grew faster than cells with no extra chromosomes. That may be a consequence of chemotherapy: Cells that survive the stress of chemotherapy may have developed additional abnormalities that make the cancer more aggressive, Sheltzer said. *— Tina Hesman Saey*

MATH & TECHNOLOGY

New lightweight bot leaps with zip

For search-and-rescue, 'Salto' could parkour through rubble

BY MEGHAN ROSEN

Meet the robot that can do parkour.

Salto, a lightweight bot that stands on one skinny leg like a flamingo, can leap from floor to wall, then off again — like parkour athletes bouncing between buildings, researchers from the University of California, Berkeley report December 6 in *Science Robotics*.

Salto is not the highest jumping robot out there, but it's got something others lack: speed. The new bot can spring a meter off the ground in just 0.58 seconds — about what a bullfrog can do, study coauthor Duncan Haldane said in a news conference December 5.

The robot's mix of air and speed could one day aid search-and-rescue teams, he said. Ideally, a rescue robot would be able to move quickly and nimbly over rubble (*SN: 12/13/14, p. 16*). To do that, Haldane said, "it has to be able to jump."

For now, Salto is "great eye candy," says roboticist Jeff Duperret of the University of Pennsylvania. The study's authors "came up with a new idea and showed it really clearly," he says.

Haldane's bot was inspired by the lesser galago, a tiny, saucer-eyed primate (also known as a bushbaby). "Animals can outclass any robot when it comes to jumping," Haldane said. Galagos, in particular, stand out: They've got the highest known vertical jumping agility — the ratio of maximum jumping height to the time it takes to complete a jump.

Galagos hunker down in a kind of "supercrouch" that lets them access more energy for jumping, Haldane said. That gives them the ability "to jump high and do it quickly." His team built this capability into Salto's leg, a spindly series of eight carbon fiber bars connected with aluminum pins. In the

A little robot named Salto is an agile jumper that relies on a twisted latex spring to gain extra height. One day, robots like Salto could bound across rubble in search-and-rescue operations.

MATTER & ENERGY

Quantum effect passes space test

Distant stars squeeze loophole, confirm spooky entanglement

BY EMILY CONOVER

The spookiness of quantum mechanics has gone cosmic.

Physicists have used starlight to perform a "Bell test" to verify the strange nature of quantum mechanics. For decades, such tests have repeatedly confirmed quantum physics's quirks, but with loopholes. While most loopholes have been closed (*SN: 12/26/15, p. 24*), a lingering caveat remains: Measurement equipment's settings must be chosen randomly, which can be hard to indisputably achieve. To tackle that loophole, scientists used starlight as a source of randomness. Quantum mechanics emerged unscathed, an international team of physicists reports online November 22 at arXiv.org.

"It's a very elegant experiment and I think the results are quite beautiful," says physicist Krister Shalm of the National Institute of Standards and Technology in Boulder, Colo., who was not involved with the measurement. "I think it's an important loophole to consider."

But, says physicist Matthew Leifer of Chapman University in Orange, Calif., "I don't think it's going to radically change anyone's worldview." Scientists were already quite convinced of the counterintuitive nature of quantum physics.

Unlike everyday objects, quantum particles can be linked over long distances, behaving as one integrated whole, through a phenomenon called quantum entanglement. A pair of photons, for example, can be created such that their polarizations, or the orientation of their electromagnetic fields, line up. Before they are measured, the photons exist in a kind of limbo, with their polarizations pointing in multiple directions at once. But measure the polarization of one photon, and the result immediately tells the experimenter the state of its partner, even if they are light-years apart.

This strange distant interconnectedness, or "nonlocality," has made some scientists uneasy: Albert Einstein famously derided it as "spooky action at a distance." In the 1960s, physicist John Bell proposed a method to confirm whether quantum particles were really spooky.

In the new work, scientists performed a Bell test, but added a cosmic twist. The scientists produced entangled pairs of photons, separated the two photons by more than a kilometer, and measured both of their polarizations. The measured polarization could be one of two options — for example, it might be either horizontal or vertical. But in the test, the axis along which that polarization is measured is changed for different photons. The scientists might decide to measure at an angle of either 30 degrees or 120 degrees, for example.

If quantum mechanics holds true, the results of the two measurements will be more correlated than in a universe with nonspooky quantum mechanics. But this conclusion demands that the axis along which each photon's polarization is measured is chosen randomly and is unrelated to the produced photons.

To ensure that no outside influence

STEPHEN MCNALLY AND ROXANNE MAKASDJIAN/UC BERKELEY

Watch the robot jump at **bit.ly/SN_Salto**

robot's body, between the leg and the motor, the team attached a kind of latex spring that's like a twisted rubber band. When the team turns the motor on, the spring twists, storing energy.

As the bot settles into a deeper and deeper crouch, the motor has more time to twist the spring, Haldane said. And that gives Salto extra oomph when it finally jumps and the spring untwists. It's like the robot is getting a megaboost, Duperret says. The robot crouches again as it lands, and then can immediately take off for another jump.

That's an added bonus, said study coauthor Justin Yim. "The spring can store some of the energy of landing for use in the next jump," like a bouncing ball.

Salto, a palm-sized machine that weighs just 100 grams — about as much as two large eggs — joins a growing list of robots that hop off walls, spring off water or even launch themselves into the air with an explosion (*SN: 11/1/14, p. 11*). ■

could have an impact, the scientists used the color of photons produced by two stars, hundreds of light-years from Earth, to assign the measurement axis. Redder light triggered measurement on one axis, and bluer light, another. Any influence that could have affected both the photons and the starlight must have originated about 600 years ago or earlier — an unlikely scenario.

Previous Bell tests already provided strong evidence of quantum weirdness using other methods to generate randomness. Consequently, some scientists have questioned the importance of the new test. "I have to say that I'm not too impressed and surprised by the result," says physicist Nicolas Gisin of the University of Geneva. Authors of the study declined to comment while the paper is undergoing peer review.

With future tests, scientists could use more distant sources, such as quasars, to push the 600-year time limit back further. But the loophole is impossible to fully close, says Gisin. "You can always say that everything was determined at the Big Bang." ■

BODY & BRAIN

Brain waves fight Alzheimer's protein

Flashes of light induce nerve cells to trigger immune response

BY LAURA SANDERS

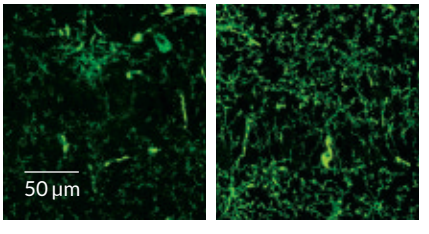
Flickering light kicks off brain waves that clean a protein related to Alzheimer's disease out of mice's brains, a study shows. The results, described in the Dec. 8 *Nature*, suggest a new approach to counteracting Alzheimer's.

Many potential therapies involve drugs that target amyloid-beta, the sticky protein that accumulates in the brains of Alzheimer's patients. The new method causes certain nerve cells to fire at a specific rhythm, generating brain waves called gamma waves that researchers believe may clear A-beta.

"This is a very creative and innovative new approach to targeting brain amyloid load in Alzheimer's," says geriatric psychiatrist Paul Rosenberg of Johns Hopkins Medicine. But he cautions that the mouse results are preliminary.

Neuroscientist Li-Huei Tsai of MIT and colleagues saw that mice engineered to produce lots of A-beta don't produce as many gamma waves in the hippocampus, a brain structure important for memory. Using optogenetics, the researchers genetically designed certain hippocampus nerve cells to fire signals in response to light. This induced gamma waves that fired rhythmically 40 times per second.

After just an hour of forced gamma waves, the mice had less A-beta in the hippocampus. Further experiments revealed that gamma waves packed a double whammy — they lowered A-beta by both reducing production and enhancing the brain's ability to clear it.



Compared with a mouse that received random brain stimulation (right), a mouse stimulated to produce more gamma waves (left) had less amyloid-beta (green) in its hippocampus.

Gamma waves kick off a series of brain changes that ultimately call microglia, a kind of immune cell, to action, the researchers suspect. After gamma waves were generated, microglia turned on genes associated with the cells' job as scavengers, roaming the brain and engulfing offending particles including A-beta. Tsai and colleagues saw more microglia with A-beta inside after gamma waves had been induced with optogenetics.

Optogenetics involves genetic tweaks to make cells respond to light, which limits its use in people. But the researchers found another way to make gamma waves, one that doesn't involve any genetic changes. Seeing fast flickers of light caused nerve cells in the mice's visual system to start firing rhythmically, creating gamma waves. And just as before, A-beta levels dropped in the brain area where gamma waves were created.

Scientists don't know whether gamma waves created in the mice's visual systems might spread to — and potentially benefit — other brain areas, Tsai said December 6 in a news conference. It's possible that visual stimulation might have a big effect in the brains of people, who rely on sight more than mice do, she said.

The visual flicker used on the mice isn't uncomfortable, Tsai said. "You can hardly see the flicker itself," she said, an attribute that may make the technology acceptable for people. Certain mental states, like those attained with meditation for instance, are also known to induce gamma waves. Other researchers are exploring other types of sensory input to boost the brain's gamma waves, including vibrating chairs.

Tsai and neuroscientist Ed Boyden, also of MIT, have founded a company that plans to test the technology on people. The similarity between the neural networks that make gamma waves in mice and people "gives us optimism to think about doing human trials," Boyden said in the news conference. ■

H.F. IACCARINO *ET AL*/*NATURE* 2016

EARTH & ENVIRONMENT

Earth's mantle is cooling fast

Mid-ocean ridges created thicker crust in the past

BY THOMAS SUMNER

Earth's innards are cooling off surprisingly fast.

The thickness of new volcanic crust forming on the seafloor has gotten thinner over the last 170 million years. The rate of that thinning suggests that the underlying mantle is cooling about twice as fast as previously thought, scientists reported December 13.

Such rapid mantle cooling offers fresh insight into how plate tectonics regulates Earth's internal temperature, said study coauthor Harm Van Avendonk, a geophysicist at the University of Texas at Austin. "We're seeing this kind of thin oceanic crust on the seafloor that may not have existed several hundred million years ago," he said. "We always consider that the present is the clue to the past, but that doesn't work here."

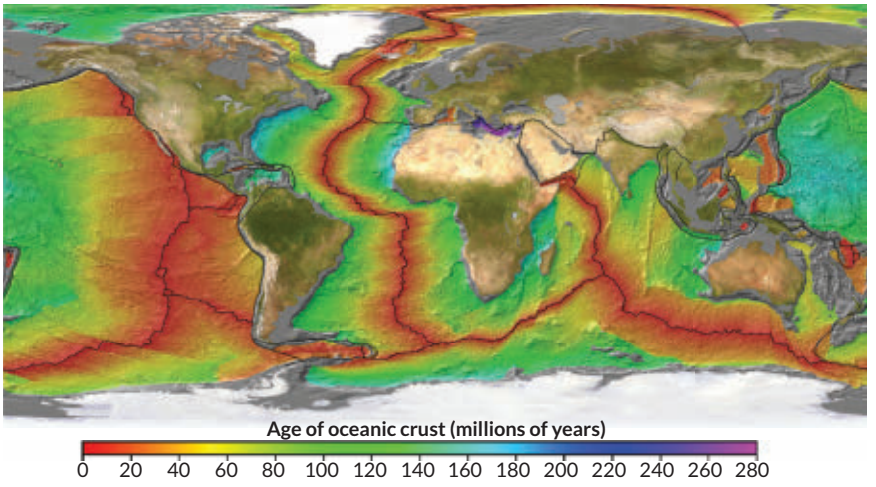
The finding is fascinating, though the underlying data are sparse, said Laurent Montési, a geodynamicist at the University of Maryland in College Park. Measuring the thickness of seafloor crust requires seismic studies, which haven't been done everywhere, like in the South Pacific, for example. Still, Montési said, "it's amazing that we can see the signature of the cooling of the Earth," and the finding could help explain why supercontinents such as Pangaea break apart.

Earth's mantle is made up of hot rock under high pressure. As material rises, pressure drops and the rock starts melting. This molten material can spew onto the surface at mid-ocean ridges and construct new crust. When the mantle is hotter, the melt zone is larger and the resulting crust is thicker. Near the boundary with the crust, mantle temperatures range from about 500° to 900° Celsius.

Van Avendonk and colleagues discovered that 170-million-year-old crust is 1.7 kilometers thicker on average than fresh crust. Chemical analyses of lava rocks had suggested that Earth's mantle cooled 6 to 11 degrees on average every 100 million years starting 2.5 billion years ago. But since the mid-Jurassic, about 170 million years ago, the researchers now estimate, the mantle has cooled 15 to 20 degrees on average per 100 million years. Scientists expect the mantle to cool over time, but this degree of cooling is surprising.

Plate tectonics causes this cooldown, the researchers proposed. The sinking, shifting and formation of plates drives convection that shifts heat in the planet's interior. This process also controls how fast different regions of the mantle cool. While mantle temperatures below the Pacific Ocean have fallen about 13 degrees per 100 million years, the mantle below the Atlantic and Indian oceans has cooled about 37 degrees per 100 million years.

The difference between the oceans is their relationship to continents. The Atlantic and Indian oceans opened when Pangaea ripped apart (see Page 18). Before then, the underlying mantle was covered by continental crust, which acted as an insulator to keep mantle temperatures toasty, Van Avendonk proposed. As Pangaea split and the continents shifted, mantle beneath the oceans cooled much faster. Over that time, the Pacific was largely isolated from the continents and cooled more gradually. ■



Cooling down Newly formed oceanic crust (redder areas) is thinner on average than older crust, scientists find. This thinning suggests that Earth's mantle is cooling faster than once thought.

NCEI/NOAA, R.D. MÜLLER *ET AL/GEOCHEM. GEOPHYS. GEOSYST.* 2008

MEETING NOTE

Glacier melting's link to climate change now 'virtually certain'

The decades-long dwindling of glaciers is "categorical evidence of climate change," a new study affirms.

The link between global warming and glacial retreat had previously garnered only a "likely," or at least 66 percent probability, rating from the Intergovernmental Panel on Climate Change. Comparing the long-term declines of 37 glaciers around the world, researchers estimate that all but one are "very likely" — or with at least 90 percent probability — the result of climate change. Natural variability and complex dynamics make sussing out climate change's role in glacial retreat difficult. Earth system scientist Gerard Roe of the University of Washington in Seattle and colleagues calculated the natural ups and downs for 37 glaciers, noting how far the glaciers have drifted from natural variability, then comparing that trend with changes in the nearby climate. For 21 glaciers, it is "virtually certain" that climate change caused the retreat, the team reported December 12. Glaciers hold about 75 percent of Earth's freshwater; their decline serves as a canary in a coal mine for climate change. — *Thomas Sumner*

EARTH & ENVIRONMENT

Data show no sign of methane boost

Carbon dioxide levels rising, though, in response to warming

BY THOMAS SUMNER

One climate doomsday scenario can be downgraded, new research suggests.

Decades of atmospheric measurements from a site in northern Alaska show that rapidly rising temperatures there have not significantly increased methane emissions from the neighboring permafrost-covered landscape, researchers reported December 15.

Some scientists feared that Arctic warming would unleash large amounts of methane, a potent greenhouse gas, into the atmosphere, worsening global warming. "The ticking time bomb of methane has clearly not manifested itself yet," said study coauthor Colm Sweeney, an atmospheric scientist at the University of Colorado Boulder. Emissions of carbon dioxide — a less potent greenhouse gas — did increase, the researchers found.

The CO_2 rise "is still bad, it's just not as bad" as a rise in methane, said Franz Meyer, a remote sensing scientist at the University of Alaska Fairbanks. The measurements were from just one site, though, so might not apply to the entire Arctic. "This location might not be representative," Meyer said.

Across the Arctic, the top three meters of permafrost contain 2.5 times as much carbon as the CO_2 released into the atmosphere by human activities since the start of the Industrial Revolution. As the Arctic rapidly warms, these thick layers of frozen soil will thaw and some of the carbon will be converted by hungry microbes into methane and CO_2, studies of artificially warmed permafrost have suggested. That carbon will have a bigger impact on Earth's climate as methane than it will as CO_2. Over a 100-year period, a ton of methane will cause more than 25 times as much warming as a ton of CO_2.

A research station in Alaska's northernmost city, Barrow, has been monitoring methane concentrations in the Arctic air since 1986 and CO_2 since 1973. An air intake on a tower about 16.5 meters off the ground constantly sniffs the air, taking measurements. Barrow has warmed more than twice as fast as the rest of the Arctic over the last 29 years. This rapid warming "makes this region of the Arctic a great little incubation test to see what happens when we have everything heating up much faster," Sweeney said.

Over the course of a year, methane concentrations in winds wafting from the nearby tundra rise and fall with temperatures, the Barrow data show. Since 1986, though, seasonal methane emissions have remained largely stable overall. But concentrations of CO_2 in air coming from over the tundra, compared with over the nearby Arctic Ocean, have increased by about 0.02 parts per million per year since 1973, the researchers reported.

The lack of an increase in methane concentrations could be caused by the thawing permafrost allowing water to escape and drying the Arctic soil, Sweeney proposed. Though warming may boost the activity of methane-producing microbes, drying may limit the microbes' productivity, perhaps counteracting the predicted effect. ■

LIFE & EVOLUTION

Microbes quick to occupy impact site

Species grew in waters above crater linked to dino deaths

BY THOMAS SUMNER

The first post-apocalypse tenants of ground zero of the dinosaur extinction didn't waste much time moving in.

Drilling into the crater left by the dino-devastating Chicxulub impact in Mexico revealed the fossilized remains of pioneering microbes. These "disaster species" colonized the harsh waters above the crater within hundreds of years of the impact, researchers reported December 12. The finding illuminates how life bounces back after cataclysmic events.

"This was a hostile, stressful environment for these organisms," said Oleg Abramov, a planetary scientist at the Planetary Science Institute in Tucson, Ariz., who was not involved with the work. "It's interesting that life came back so quickly to the site of the impact."

The impact itself was one of the worst calamities in Earth's history, releasing about 2 million times as much energy as the largest nuclear bomb ever detonated. It helped wipe out three-quarters of animal and plant species worldwide.

Not surprisingly, devastation was worst at the impact site, said Joanna Morgan, a geophysicist at Imperial College London who co-led the drilling project. Any life within 1,500 kilometers of the site was probably fried with thermal radiation.

Returning to the Chicxulub crater last April, Morgan and colleagues drilled into a now underwater ring of mountainous peaks that rises from the crater floor, off the coast of the Yucatán Peninsula (*SN Online: 11/17/16*). Stacked on top of this peak ring are hundreds of meters of sediments laid down since the crater formed. Fossils within these sediments offer a long-term history of life in the area.

Within hundreds of years of the impact, fossilized remains of two types of hardy plankton appear in the sediments. This is "at a time when the ocean is toxic and not very suitable for life," said Timothy Bralower, a geoscientist at Penn State. The plankton, members of *Thoracosphaera* and *Braarudosphaera*, probably settled in the area to capitalize on the lack of competition.

Analyzing Chicxulub rock samples for other signs of returning life continues. The impact generated hydrothermal systems in the ground that could have served as prime real estate for organisms that generate energy via chemical reactions, Abramov said. Similar impacts billions of years ago may have even fostered the emergence of life on Earth, he said. ■

MATTER & ENERGY

Names OK'd for 4 new elements

Countless periodic table posters are now obsolete. Meet the elements nihonium (Nh), moscovium (Mc), tennessine (Ts) and oganesson (Og). On November 28, the International Union of Pure and Applied Chemistry gave its seal of approval to the names proposed for the four elements, which take slots 113, 115, 117 and 118 on the periodic table. Unwieldy placeholder names — ununtrium, ununpentium, ununseptium and ununoctium, assigned when the elements were added to the table in December 2015 — can now be scrubbed.

The new names, proposed in June, underwent five months of public comment and review. Three of the elements were named for the places they were discovered. The name of element 113, nihonium, comes from "Nihon," a Japanese word for the country of Japan. Element 115 is dubbed "moscovium" after Moscow. And 117, tennessine, is named for Tennessee. Element 118, oganesson, honors physicist Yuri Oganessian. — *Emily Conover*

ATOM & COSMOS

First signs of boron on Mars

SAN FRANCISCO — Another element has been found in Mars' chemical arsenal. While sampling rocks from the Gale crater, the Curiosity rover detected boron concentrations of about 10 to 100 parts per billion. It's the first find of boron on the Red Planet and hints that the Martian subsurface may have once been habitable for microbes, scientists reported December 13 at the American Geophysical Union's fall meeting.

The boron was discovered in veins of calcium sulfate. Such features on Earth indicate that nonacidic groundwater with a temperature of around zero to 60° Celsius once flowed through the area — conditions favorable to microbial life. As groundwater evaporates, boron and calcium sulfate are left behind. How this process unfolded on Mars is uncertain; researchers expect more clues to be uncovered as Curiosity continues its trek (*SN: 5/2/15, p. 24*). — *Thomas Sumner*

MATTER & ENERGY

Antimatter hydrogen passes test

An antimatter atom abides by the same rules as its matter doppelgänger. Scientists studying antihydrogen have found that the energy needed to bump the atoms into an excited, or high-energy, state is the same as for normal hydrogen atoms.

Scientists at the European particle physics lab CERN in Geneva created antihydrogen atoms by combining antiprotons and positrons, the electron's antiparticle. Hitting the resulting atoms with a laser tuned to a particular frequency of light boosted the antihydrogen atoms to a higher energy. The frequency needed to induce this transition was the same as that for normal hydrogen atoms, indicating that the energy jump was the same, scientists from the ALPHA-2 experiment report December 19 in *Nature*.

Antihydrogen's similarity to hydrogen conforms to charge-parity-time, or CPT, symmetry — the idea that the laws of physics would be unchanged if the universe were reflected in a mirror, time reversed and particles swapped with antiparticles. Scientists have never seen a situation where this symmetry doesn't hold; antihydrogen provides a new precise check. — *Emily Conover*

EARTH & ENVIRONMENT

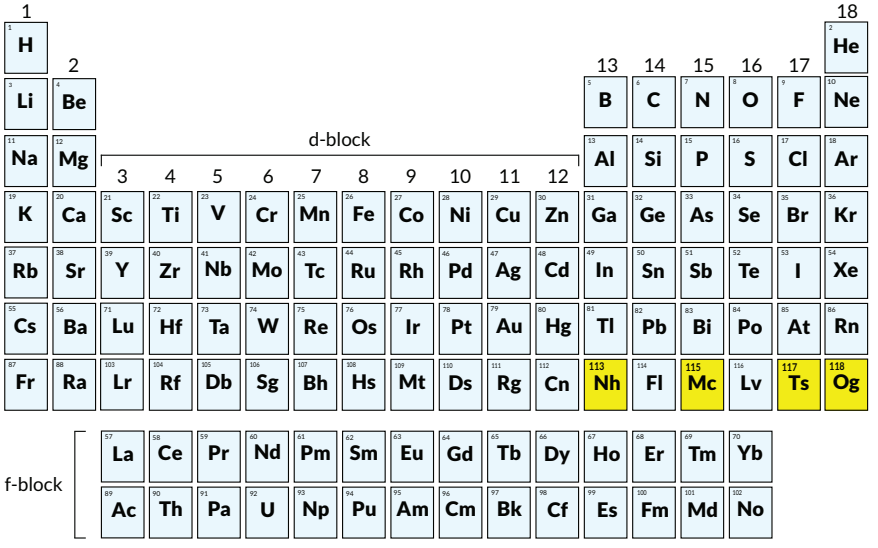
Third kind of quasicrystal found

Another "impossible" crystal has been found locked inside a Russian meteorite.

The specimen is a quasicrystal, a material that breaks the rules of crystallography by having an ordered — yet never-repeating — arrangement of atoms. The new find is only the third natural quasicrystal ever found and is the first discovered in nature before being synthesized in a lab, researchers report December 8 in *Scientific Reports*.

All three natural quasicrystals came from the same meteorite, discovered in eastern Russia (*SN: 11/3/12, p. 24*). University of Florence geologist Luca Bindi and colleagues found micrometers-wide bits of the new quasicrystal in a grain of the meteorite collected during a 2011 expedition. Probing the quasicrystal with electrons showed that it is composed of aluminum, copper and iron atoms arranged in a way that's similar to the pentagon-based pattern on a soccer ball.

Like its siblings, the new quasicrystal formed in space when a cosmic fender bender between two space rocks caused rapid melting and cooling under extreme pressures, the researchers propose. While natural quasicrystals remain rare, companies have tinkered with using lab-made versions in everything from electronics to frying pan coatings. — *Thomas Sumner*



New names The periodic table's newest elements now have official names. The International Union of Pure and Applied Chemistry approved the names nihonium (Nh), moscovium (Mc), tennessine (Ts) and oganesson (Og) on November 28.

E. OTWELL

BODY & BRAIN

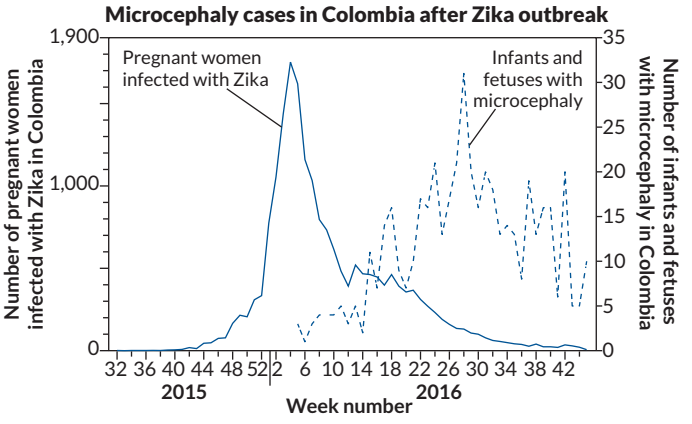
Microcephaly rises in Colombia

In 2016, Colombia saw a surge in babies with microcephaly — more than four times the number reported in 2015. The country documented 476 cases of the birth defect from January 31 to November 12, researchers note December 16 in *Morbidity and Mortality Weekly Report*, published by the U.S. Centers for Disease Control and Prevention. During the same period in 2015, there were just 110 cases. "This provides very compelling evidence that every country that experiences a large Zika outbreak is likely to see devastating outcomes on fetuses and infants," says CDC epidemiologist Peggy Honein.

Microcephaly cases hit a high point in Colombia in July 2016, about 24 weeks after Zika virus infections peaked there. The time lag suggests that Zika poses the greatest risk to pregnant women in the first and early second trimesters.

Colombia's dramatic uptick in microcephaly cases follows one reported in Brazil, which, in 2015, experienced a ninefold increase in cases compared with previous years. Scientists have concluded that Zika was a causal factor.

Some researchers wondered, though, about the extent of Zika's role in microcephaly in Colombia. Earlier this year, the country's tally of microcephaly cases seemed smaller than expected, given the reported rise in Zika infections. The new report suggests that, as in Brazil, Zika virus bears blame for Colombia's microcephaly epidemic too. — *Meghan Rosen*



Time lag Zika infections among pregnant women in Colombia (solid line and scale on left) spiked in January (around week 4). About six months later, the country saw a drastic rise in the number of infants and fetuses with microcephaly (dotted line and scale on right). SOURCE: CDC

BODY & BRAIN

Birth defect risk high for Zika infection in first trimester

For pregnant women infected with Zika virus in the first trimester, the future is foreboding. Nearly 11 percent of U.S. women likely exposed to Zika in the early weeks of or just before pregnancy had babies or fetuses with birth defects, researchers report online December 13 in *JAMA*. The study offers the first results from the U.S. Zika Pregnancy Registry.

As of November 30, the registry had reported more than 3,800 pregnant women in the United States and its territories with evidence of Zika infection. Out of 442 pregnancies tracked so far, 26 — or 6 percent — resulted in infants or fetuses with birth defects, including microcephaly and other brain abnormalities. Of the 85 pregnancies where women were exposed only in the first trimester, nine — or 11 percent — resulted in birth defects. Researchers reported no birth defects when women were exposed to Zika exclusively in the second or third trimester.

But the data might overlook babies with less obvious defects, pediatrician William Muller and obstetrician-gynecologist Emily Miller, both of Northwestern University Feinberg School of Medicine in Chicago, write in an accompanying editorial. And, they add, "longer-term neurologic outcomes are not yet available."

Still, until now, the magnitude of Zika's risk to pregnant women had been less certain. Earlier studies had estimated the risk of a baby developing microcephaly at between 1 and 13 percent for mothers infected in the first trimester.

The new study offers concrete numbers and clarifies another issue: Infected women with or without symptoms of Zika seem to be equally prone to bearing babies with birth defects. — *Meghan Rosen*

GENES & CELLS

Zika induces brain cell die-off

SAN FRANCISCO — Zika causes fetal brain cells neighboring an infected cell to commit suicide, David Doobin of Columbia University Medical Center reported December 6 at the annual meeting of the American Society for Cell Biology. In work with mice and rats, Doobin and colleagues found hints that the cell death might be the body's attempt to limit the virus' spread.

The scientists applied techniques they had used to investigate a genetic cause of the birth defect microcephaly to narrow when in pregnancy the virus is most likely to cause the brain to shrink. Timing of the virus's effect varied by strain. For one from Puerto Rico, brain cell die-off happened in mice only in the first two trimesters. But a strain from Honduras could kill developing brain cells later in pregnancy. — *Tina Hesman Saey*

GENES & CELLS

Disabling enzyme could block Zika

SAN FRANCISCO — Disrupting the Zika enzyme NS3 could help stop the virus. NS3 causes problems when it gloms on to centrioles, structures inside cells needed to divvy up chromosomes when cells divide, Andrew Kodani, a cell biologist at Boston Children's Hospital, reported December 6 at the American Society for Cell Biology's annual meeting.

Zika, dengue and other related viruses, known as flaviviruses, use a version of NS3 to chop joined proteins apart so they can do their jobs. (Before chopping, Zika's 10 proteins are made as one long protein.) But once NS3 finishes slicing virus proteins, it moves to the centrioles and can interfere with their assembly, Kodani and colleagues found. Something similar happens in some genetic forms of microcephaly.

Kodani and colleagues found that small amounts of a chemical called anthracene can prevent NS3 from tinkering with the centrioles. So far the work has been done only in lab dishes. — *Tina Hesman Saey*

T. TIBBITTS

Time after time
Continents break apart and rejoin over hundreds of millions of years, resculpting Earth's ever-changing face.

Nuna
1.4 billion years ago

Rodinia
750 million years ago

SUPERCONTINENT SUPERPUZZLE

Geologists trace the comings and goings of Earth's landmasses

By Alexandra Witze

Look at any map of the Atlantic Ocean, and you might feel the urge to slide South America and Africa together. The two continents just beg to nestle next to each other, with Brazil's bulge locking into West Africa's dimple. That visible clue, along with several others, prompted Alfred Wegener to propose over a century ago that the continents had once been joined in a single enormous landmass. He called it Pangaea, or "all lands."

Today, geologists know that Pangaea was just the most recent in a series of mighty supercontinents. Over hundreds of millions of years, enormous plates of Earth's crust have drifted together and then apart. Pangaea ruled from roughly 400 million to about 200 million years ago. But wind the clock further back, and other supercontinents emerge. Between 1.3 billion and 750 million years ago, all the continents amassed in a great land known as Rodinia. Go back even further, about 1.4 billion years or more, and the crustal shards had arranged themselves into a supercontinent called Nuna.

Using powerful computer programs and geologic clues from rocks around the world, researchers are painting a picture of these long-lost worlds. New studies of magnetic minerals in rock from Brazil, for instance, are helping pin the ancient Amazon to a spot it once occupied in Nuna. Other recent research reveals the geologic stresses that finally pulled Rodinia apart, some 750 million years ago. Scientists have even predicted the formation of the next supercontinent — an amalgam of North America and Asia, evocatively named Amasia — some 250 million years from now.

Reconstructing supercontinents is like trying to assemble a 1,000-piece jigsaw puzzle after you've lost a bunch of the pieces and your dog has chewed up others. Still, by figuring out which puzzle pieces went where, geologists have been able to illuminate some of earth science's most fundamental questions.

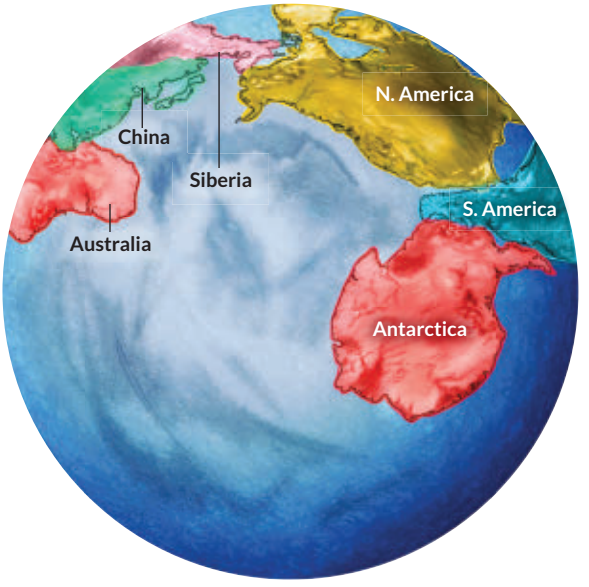
For one thing, continental drift, that gradual movement of landmasses across Earth's surface, profoundly affected life by allowing species to move into different parts of the world depending on what particular landmasses happened to be joined. (The global distribution of dinosaur fossils is dictated by how continents were assembled when those great animals roamed.)

Supercontinents can also help geologists hunting for mineral deposits — imagine discovering gold ore of a certain age in the Amazon and using it to find another gold deposit in a distant landmass that was once joined to the Amazon. More broadly, shifting landmasses have reshaped the face of the planet — as they form, supercontinents push up mountains like the Appalachians, and as they break apart, they create oceans like the Atlantic.

"The assembly and breakup of these continents

ART: NICOLLE RAGER FULLER; SOURCES: D.A.D. EVANS, Z.-X. LI AND J.B. MURPHY (EDS.)/ *SUPERCONTINENT CYCLES THROUGH EARTH HISTORY* 2016; D.A.D. EVANS; R. MITCHELL

Pangaea
200 million years ago



Amasia
250 million years from now

have profoundly influenced the evolution of the whole Earth," says Johanna Salminen, a geophysicist at the University of Helsinki in Finland.

Push or pull

For centuries, geologists, biogeographers and explorers have tried to explain various features of the natural world by invoking lost continents. Some of the wilder concepts included Lemuria, a sunken realm between Madagascar and India that offered an out-there rationale for the presence of lemurs and lemurlike fossils in both places, and Mu, an underwater land supposedly described in ancient Mayan manuscripts. While those fantastic notions have fallen out of favor, scientists are exploring the equally mind-bending story of the supercontinents that actually existed.

Earth's constantly shifting jigsaw puzzle of continents and oceans traces back to the fundamental forces of plate tectonics. The story begins in the centers of oceans, where hot molten rock wells up from deep inside the Earth along underwater mountain chains. The lava cools and solidifies into newborn ocean crust, which moves continually away from either side of the mountain ridge as if carried outward on a conveyor belt. Eventually, the moving ocean crust bumps into a continent, where it either stalls or begins diving beneath that continental crust in a process called subduction.

Those competing forces — pushing newborn crust away from the mid-ocean mountains and pulling older crust down through subduction — are constantly rearranging Earth's crustal plates. That's why North America and Europe are getting farther away from each other by a few centimeters each year as the Atlantic widens, and why the Pacific Ocean is shrinking, its seafloor sucked down by subduction along the Ring of Fire — looping from New Zealand to Japan, Alaska and Chile.

By running the process backward in time, geologists can begin to see how oceans and continents have jockeyed for position over millions of years. Computers calculate how plate positions shifted over time, based on the movements of today's plates as well as geologic data that hint at their past locations.

Those geologic clues — such as magnetic minerals in ancient rocks — are few and far between. But enough remain for researchers to start to cobble together the story of which crustal piece went where.

"To solve a jigsaw puzzle, you don't necessarily need 100 percent of the pieces before you can look at it and say it's the Mona Lisa," says Brendan Murphy, a geophysicist at St. Francis Xavier University in Antigonish, Nova Scotia. "But you need some key pieces." He adds: "With the eyes and nose, you have a chance."

No place like Nuna

For ancient Nuna, scientists are starting to find the first of those key pieces. They may not reveal the Mona Lisa's enigmatic smile, but they are at least starting to fill in a portrait of a long-vanished supercontinent.

Nuna came together starting around 2 billion years ago, with its heart a mash-up of Baltica (the landmass that today contains Scandinavia), Laurentia (which is now much of North America) and Siberia. Geologists argue over many things involving this first supercontinent, starting with its name. "Nuna" is from the Inuktitut language of

2.1 billion years ago: Landmasses begin assembling toward the first true known supercontinent, Nuna (also known as Columbia).

1.5 billion years ago: Nuna reaches its maximum landmass.

1.3 billion years ago: Nuna begins to fragment and the parts reassemble as Rodinia.

1 billion years ago: Rodinia reaches maximum landmass.

750 million years ago: Rodinia begins to break apart, creating the Pacific Ocean.

400 million years ago: Subducting ocean crust once again shifts landmasses toward one another, in early steps toward Pangaea.

300 million years ago: Pangaea reaches maximum landmass.

200 million years ago: Pangaea begins to break apart, creating the Atlantic Ocean.

Next big event: About 250 million years from now: North America and Asia will smash together with other land fragments to create the supercontinent Amasia.

SOURCES: D. EVANS; J. MEERT; Z.-X. LI, D.A.D. EVANS, J.B. MURPHY/ *SUPERCONTINENT CYCLES THROUGH EARTH HISTORY* 2016; M. YOSHIDA/ *GEOLOGY* 2016

the Arctic. It means lands bordering the northern oceans, so dubbed for the supercontinent's Arctic-fringing components. But some researchers prefer to call it Columbia after the Columbia region of North America's Pacific Northwest.

Whatever its moniker, Nuna/Columbia is an exercise in trying to get all the puzzle pieces to fit. Because Nuna existed so long ago, subduction has recycled many rocks of that age back into the deep Earth, erasing any record of what they were doing at the time. Geologists travel to rocks that remain in places like India, South America and North China, analyzing them for clues to where they were at the time of Nuna.

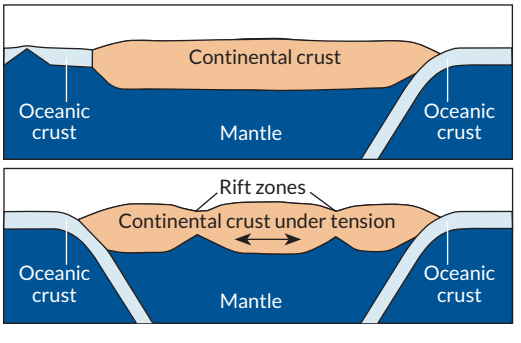
> "As soon as you start asking why [Pangaea] formed, how it formed and what processes are involved ... you run into problems."
>
> **BRENDAN MURPHY**

One of the most promising techniques targets magnetic minerals. Paleomagnetic studies use the minerals as tiny time capsule compasses, which recorded the direction of the magnetic field at the time the rocks formed. The minerals can reveal information about where those rocks used to be, including their latitude relative to where the Earth's north magnetic pole was at the time.

Salminen has been gathering paleomagnetic data from Nuna-age rocks in Brazil and western Africa. Not surprisingly, given their current lock-and-key configuration, these two chunks were once united as a single ancient continental block, known as the Congo/São Francisco craton. For millions of years, it shuffled around as a single geologic unit, occasionally merging with other blocks and then later splitting away.

Salminen has now figured out where the Congo/São Francisco puzzle piece fit in the jigsaw that made up Nuna. In 1.5-billion-year-old rocks in Brazil, she unearthed magnetic clues that placed the Congo/São Francisco craton at the southeastern tip of Baltica all those years ago. She and her colleagues reported the findings in November in *Precambrian Research*.

It is the first time scientists have gotten paleomagnetic information about where the craton may have been as far back as Nuna. "This is quite remarkable — it was really needed," she says. "Now we can say Congo could have been there." Like building out a jigsaw puzzle from its center, the work essentially expands Nuna's core.



Subduction's drag
Supercontinents assemble (top) as pieces of continental crust amass. Later they may break apart (bottom) when slabs of plunging oceanic crust (light blue) begin pulling the continent from either side, creating tensional forces that rift it apart.

Rodinia's radioactive decay

By around 1.3 billion years ago, Nuna was breaking apart, the pieces of the Mona Lisa face shattering and drifting away from each other. It took another 200 million years before they rejoined in the configuration known as Rodinia.

Recent research suggests that Rodinia may not have looked much different than Nuna, though. The Mona Lisa in its second incarnation may still have looked like the portrait of a woman — just maybe with a set of earrings dangling from her lobes.

A team led by geologist Richard Ernst of Carleton University in Ottawa, Canada, recently explored the relative positions of Laurentia and Siberia between 1.9 billion and 720 million years ago, a period that spans both Nuna and Rodinia. Ernst's group specializes in studying "large igneous provinces" — the huge outpourings of lava that build up over millions of years. Often the molten rock flows along sheetlike structures known as dikes, which funnel magma from deep in the Earth upward.

By using the radioactive decay of elements in the dike rock, such as uranium decaying to lead, scientists can precisely date when a dike formed. With enough dates on a particular dike, researchers can produce a sort of bar code that is unique to each dike. Later, when the dikes are broken apart and shifted over time, geologists can pinpoint the bar codes that match and thus line up parts of the crust that used to be together.

Ernst's team found that dikes from Laurentia and Siberia matched during four periods between 1.87 billion and 720 million years ago — suggesting they were connected for that entire span, the team reported in June in *Nature Geoscience*. Such a long-term relationship suggests that Siberia and Laurentia may have stuck together through the Nuna-Rodinia transition, Ernst says.

Other parts of the puzzle tend to end up in the same relative locations as well, says Joseph Meert, a paleomagnetist at the University of Florida in Gainesville. In each supercontinent, Laurentia, Siberia and Baltica knit themselves together in roughly the same arrangement: Siberia and Baltica nestle like two opposing knobs on one end of Laurentia's elongated blob. Meert calls these three continental fragments "strange attractors," since they appear conjoined time after time.

It's the outer edges of the jigsaw puzzle that

P.A. CAWOOD ET AL/EARTH AND PLANETARY SCIENCE LETTERS 2016

change. Fragments like north China and southern Africa end up in different locations around the supercontinent core. "I call those bits the lonely wanderers," Meert says.

Getting to know Pangaea

While some puzzle-makers try to sort out the reconstructions of past supercontinents, other geologists are exploring deeper questions about why big landmasses come together in the first place. And one place to look is Pangaea.

"Most people would accept what Pangaea looks like," Murphy says. "But as soon as you start asking why it formed, how it formed and what processes are involved — then all of a sudden you run into problems."

Around 550 million years ago, subduction zones around the edges of an ancient ocean began dragging that oceanic crust under continental crust. But around 400 million years ago, that subduction suddenly stopped. In a major shift, a different, much younger seafloor began to subduct instead beneath the continents. That young ocean crust kept getting sucked up until it all disappeared, and the continents were left merged in the giant mass of Pangaea.

Imagine in today's world, if the Pacific stopped shrinking and all of a sudden the Atlantic started shrinking instead. "That's quite a significant problem," Murphy says. In unpublished work, he has been exploring the physics of how plates of oceanic and continental crust — which have different densities, buoyancies and other physical characteristics — could have interacted with one another in the run-up to Pangaea.

Supercontinent breakups are similarly complicated. Once all the land amasses in a single big chunk, it cannot stay together forever. In one scenario, its sheer bulk acts as an electric blanket, allowing heat from the deep Earth to pond up beneath it until things get too hot and the supercontinent splinters (see Page 14). In another, physical stressors pull the supercontinent apart.

Peter Cawood, a geologist at the University of St. Andrews in Fife, Scotland, likes the second option. He has been studying mountain ranges that arose when the crustal plates that made up Rodinia collided, pushing up soaring peaks where they met. These include the Grenville mountain-building event of about 1 billion years ago, traces of which linger today in the eroded peaks of the Appalachians. Cawood and his colleagues analyzed the times at which such mountains appeared and put together a detailed timeline of what happened as Rodinia began to break apart.

They note that crustal plates began subducting around the edges of Rodinia right around the time of its breakup. That sucking down of crust caused the supercontinent to be pulled from all directions and eventually break apart, Cawood and his colleagues wrote in *Earth and Planetary Science Letters* in September. "The timing of major breakup corresponds with this timing of opposing subduction zones," he says.

The future is Amasia

That stressful situation is similar to what the Pacific Ocean finds itself in today. Because it is flanked by subduction zones around the Ring of Fire, the Pacific Plate is shrinking over time. Some geologists predict that it will vanish entirely in the future, leaving North America and Asia to merge into the next supercontinent, Amasia. Others have devised different possible paths to Amasia, such as closing the Arctic Ocean rather than the Pacific.

"Speculation about the future supercontinent Amasia is exactly that, speculation," says geologist Ross Mitchell of Curtin University in Perth, Australia, who in 2012 helped describe the mechanics of how Amasia might arise. "But there's hard science behind the conjecture."

For instance, Masaki Yoshida of the Japan Agency for Marine-Earth Science and Technology in Yokosuka recently used sophisticated computer models to analyze how today's continents would continue to move atop the flowing heat of the deep Earth. He combined modern-day plate motions with information on how that internal planetary heat churns in three dimensions, then ran the whole scenario into the future. In a paper in the September *Geology*, Yoshida describes how North America, Eurasia, Australia and Africa will end up merged in the Northern Hemisphere.

No matter where the continents are headed, they are destined to reassemble. Plate tectonics says it will happen — and a new supercontinent will shape the face of the Earth. It might not look like the Mona Lisa, but it might just be another masterpiece. ■

Explore more

- Z.-X. Li, D.A.D. Evans and J.B. Murphy (eds). *Supercontinent Cycles through Earth History*. Geological Society of London Special Publication, Vol. 424, 2016.
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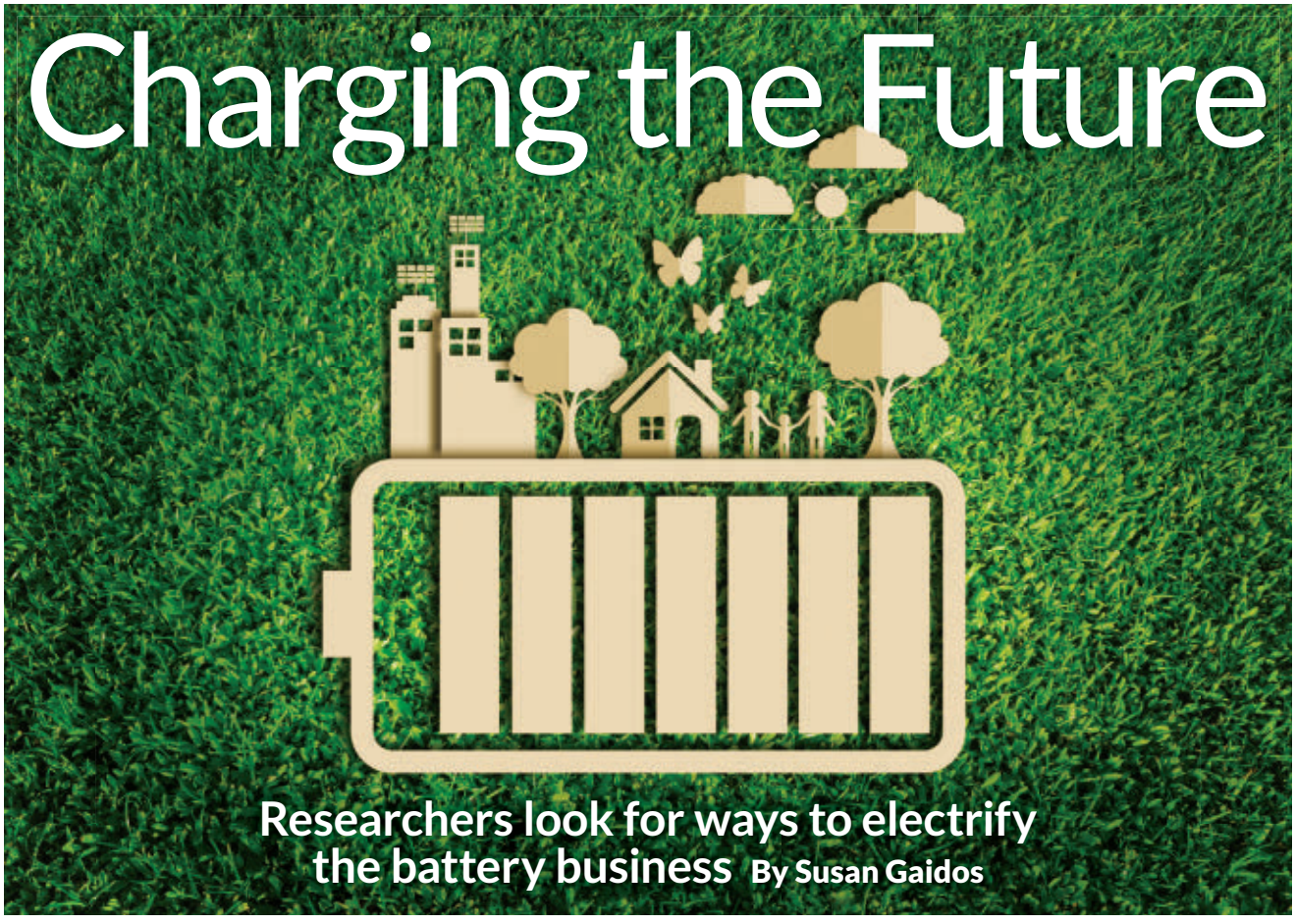
Volcanic features called dikes form when molten rock squirts into a crack and cools to form a long sheetlike feature. Matching dikes of the same age and chemical composition across continents can help geologists reconstruct maps of long-lost supercontinents. The dike above, at Singhbhum craton near Keonjhar, India, is about 1.7 billion years old.

COURTESY OF J. MEERT

Charging the Future



Researchers look for ways to electrify the battery business

By Susan Gaidos

Everybody wants more power from their batteries. Smartphones and laptops always need recharging. Electric car drivers must carefully plan their routes to avoid being stranded far from a charging station. Anyone who struggles with a tangle of chargers every night would prefer a battery that can last for weeks or months.

For researchers who specialize in batteries, though, the drive for a better battery is less about the luxury of an always-charged iPad (though that would be nice) and more about kicking our fossil fuel habit. Given the right battery, smog-belching cars and trucks could be replaced with vehicles that run whisper-quiet on electricity alone. No gasoline engine, no emissions. Even airplanes could go electric. And the power grid could be modernized to use cheaper, greener fuels such as sunlight or wind even on days when the sun doesn't shine bright enough or the wind doesn't blow hard enough to meet electricity demand.

A better battery has the potential to jolt people into the future, just like the lithium-ion battery did. When they became popular in the early 1990s, lithium-ion batteries offered twice as much energy as the next best alternative. They changed the way people communicate.

"What the lithium-ion battery did to personal electronics was transformational," says materials scientist George Crabtree, director of the Joint Center for Energy Storage Research at Argonne National Laboratory in Illinois. "The cell phone not only made landlines obsolete for many, but [the lithium-ion battery] put cameras and the internet into the hands of millions." That huge leap didn't happen overnight. "It was the sum of many incremental steps forward, and decades of work," says Crabtree, who coordinates battery research in dozens of U.S. labs.

Lithium-ion batteries have their limits, however, especially for use in the power grid and in electric vehicles. Fortunately, like their Energizer mascot, battery researchers never rest. Over the last 10 years, universities, tech companies and car manufacturers have explored hundreds of new battery technologies, reaching for an elusive and technically difficult goal: next-generation batteries that hold more energy, last longer and

VANATCHANAN/SHUTTERSTOCK

are cheaper, safer and easier to recharge.

A decade of incremental steps are beginning to pay off. In late 2017, scientists will introduce a handful of prototype batteries to be developed by manufacturers for potential commercialization. Some contain new ingredients — sulfur and magnesium — that help store energy more efficiently, delivering power for longer periods. Others will employ new designs.

"These prototypes are proof-of-principle batteries, miniature working versions," Crabtree says. Getting the batteries into consumer hands will take five to 10 years. Making leaps in battery technology, he says, is surprisingly hard to do.

Power struggle

Batteries operate like small chemical plants. Technically, a battery is a combination of two or more "electrochemical cells" in which energy released by chemical reactions produces a flow of electrons. The greater the energy produced by the chemical reactions, the greater the electron flow. Those electrons provide a current to whatever the battery is powering — kitchen clock, smoke alarm, car engine.

To power any such device, the electrons must flow through a circuit connecting two electrodes, known as an anode and a cathode, separated by a substance called an electrolyte. At the anode, chemical oxidation reactions release electrons. At the cathode, electrons are taken up in reduction reactions. The electrolyte enables ions created by the oxidation and reduction reactions to pass back and forth between the two electrodes, completing the circuit.

Depending on the materials used for the electrodes and the electrolyte, a battery may be recharged by supplying current that drives the chemical reactions in reverse. In creating new recipes for a rechargeable electrochemical soup, though, battery researchers must beware of side reactions that can spoil everything.

"There's the chemical reaction you want — the one that stores energy and releases it," Crabtree says. "But there are dozens of other ... reactions that also take place." Those side reactions can disable a battery, or worse, lead to a risk of catastrophic discharge. (Consider the recent fires in Samsung's Galaxy Note 7 smartphones.)

Early versions of the lithium-ion battery from the 1970s carried an anode made of pure lithium metal. Through repeated use, lithium ions were stripped off and replated onto the anode, creating fingerlike extensions that reached across to the cathode, shorting out the battery. Today's lithium-ion batteries have an anode made of graphite (a form of carbon) so that loose lithium ions can snuggle in between sheets of carbon atoms.

Lithium-ion batteries were originally developed with small electronics in mind; they weren't designed for storing electricity on the grid or powering electric vehicles. Electric cars need lots of power, a quick burst of energy to move from stop to start. Electric car manufacturers now bundle thousands of such batteries together to provide power for up to 200 miles before recharging, but that range still falls far short of what a tank of gas can offer. And lithium-ion batteries drain too quickly to feed long hours of demand on the grid.

Simply popping more batteries into a car or the grid isn't the answer, Crabtree says. Stockpiling doesn't improve the charging time or the lifetime of the battery. It's also bulky. Carmakers have to leave drivers room for their passengers plus some trunk space. To make electric vehicles competitive with, or better than, vehicles run by internal-combustion engines, manufacturers will need low-cost, high-energy batteries that last up to 15 years. Likewise, grid batteries need to store energy for later use at low cost, and stand up to decades of use.

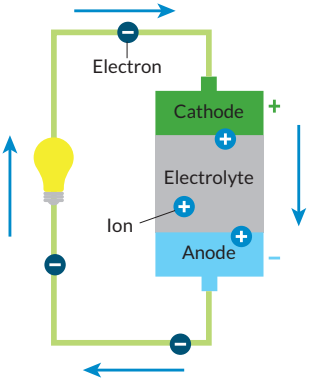
> "There's no one battery that's going to meet all our needs."
> YET-MING CHIANG

"There's no one battery that's going to meet all our needs," says MIT materials scientist Yet-Ming Chiang. Batteries needed for portable devices are very different from those needed for transportation or grid-scale storage. Expect to see a variety of new battery types, each designed for a specific application.

Switching to sulfur

For electric vehicles, lithium-sulfur batteries are the next great hope. The cathode is made mainly of sulfur, an industrial waste product that is cheap, abundant and environmentally friendly. The anode is made of lithium metal.

During discharge, lithium ions break away from the anode and swim through the liquid electrolyte to reach the sulfur cathode. There, the ions form a covalent bond with the sulfur atoms. Each sulfur atom bonds to two lithium ions, rather than just one, doubling the number of bonds in the cathode of the battery. More chemical bonds means more stored energy, so a lithium-sulfur battery creates more juice than a lithium-ion one. That, combined with sulfur's light weight, means that, in principle, manufacturers can pack more punch



Battery basics
Batteries have three main components: two electrodes (the anode or negative electrode, and the cathode, positive) and the electrolyte, which helps ions move inside the battery. Chemical reactions at the anode release electrons, which travel through an external circuit to power a lightbulb or other device.

NORTHWESTERN UNIV.; ADAPTED BY E. OTWELL

for a given amount of weight, storing four or five times as much energy per gram.

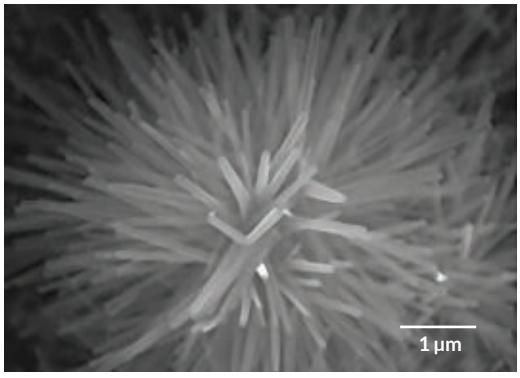
Ultimately, that upgrade could boost an electric vehicle's range up to as much as 500 miles on a single charge. But first, researchers have to get past the short lifetime of existing lithium-sulfur batteries, which, Crabtree says, is due to a loss of lithium and sulfur in each charge-discharge cycle.

When lithium combines with sulfur, it also forms compounds called polysulfides, which quickly gum up the battery's insides. Polysulfides form within the cathode during battery discharge, when stored energy is released. Once they dissolve in the battery's liquid electrolyte, the polysulfides shuttle to the anode and react with it, forming a film that renders the battery useless within a few dozen cycles — or one to two months of use.

At Sandia National Laboratories in Albuquerque, N.M., a team led by Kevin Zavadil is trying to block the formation of polysulfides in the electrolyte. The electrolyte consists of salt and a solvent, and current lithium-sulfur batteries require a large amount of electrolyte to achieve a moderate life span. Zavadil and his team are developing "lean" electrolyte mixtures less likely to dissolve the sulfur molecules that create polysulfides.

Described September 9 in *ACS Energy Letters*, the new electrolyte mix contains a higher-than-usual salt concentration and a "sparing" amount of solvent. The researchers also reduced the overall amount of electrolyte in the batteries. In test runs, the tweaks dropped the concentration of polysulfides by several orders of magnitude, Zavadil says.

"We [also] have some ideas on how to use membranes to protect the lithium surface to prevent polysulfides from happening in the first place,"



A cathode made of nanotubes aims to boost performance and lifetime of lithium-sulfur batteries. The highly conductive nanotubes (shown) trap troublesome polysulfides, by-products of the chemical reactions that power the battery.

JUN ZHANG *ET AL*/*NANO LETTERS* 2016

Next up Future batteries must be powerful enough to take a car 400 to 500 miles on a single charge and last up to 15 years. Affordable, long-lasting batteries also are needed for the electric power grid to handle increasing amounts of wind and solar power. No one battery can do it all, so scientists are investigating a variety of top contenders for next-generation batteries. SOURCE: ARGONNE NATIONAL LAB

Battery	How it works	What it's used for	Advantages	Obstacles
Lithium-sulfur	Lithium ions from the anode react with sulfur held in the cathode to produce electric current	Cars, cell phones, laptops	Sulfur is cheap and very light, good for packing more capacity into a lighter package	Current versions have short lifetimes and the electrolyte needs work — it tends to dissolve the cathode and react with the anode
Magnesium-ion	Similar to lithium-ion batteries, but magnesium ions do the work	Cars, cell phones, laptops	Magnesium, more plentiful than lithium, provides two electrons (vs. lithium's one) so it could provide twice as much juice	Chemistry not well understood yet; batteries have short lives
Flow batteries	Two tanks of liquid, one positively charged and one negative, are separated by a membrane. Where they meet, the ions react, generating electrons	Cars, grid, backup power	Separating the two parts of the battery makes it easier to design batteries with maximum power or lighter weight; some new designs eliminate pumps and use gravity to adjust speed of energy flow	Current versions can't hold as much energy as lithium-ion; when pumps are used, maintenance remains a problem
Lithium-air	Oxygen molecules from the air react with lithium ions in the anode to release energy. Recharging forces out the oxygen atoms, and the lithium is ready to start again	Cars	Could make a very light battery	Finding electrolytes that don't react with other components is a challenge; batteries have very short life span and may need extra safety engineering
Sodium-sulfur	A molten sodium core exchanges ions with sulfur through a solid electrolyte barrier	Large-scale energy storage (holding power generated from wind or solar)	Materials are cheap and abundant; fairly long lifetime	Must operate at high temperatures, so not possible to use in a car

Zavadil says. The goal is to produce a working prototype of the new battery — one that can last through thousands of cycles — by the end of 2017.

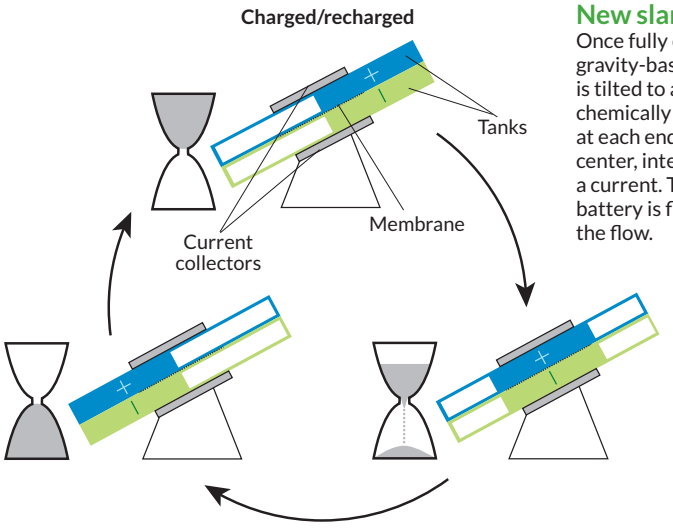
At the University of Texas at Austin, materials engineer Guihua Yu, along with colleagues at Zhejiang University of Technology in Hangzhou, China, is investigating another work-around for this battery type: replacing the solid sulfur cathode with an intricate structure that encapsulates the sulfur in an array of nanotubes. Reported in the November issue of *Nano Letters*, the nanotubes that encase the sulfur are fashioned from manganese dioxide, a material that can attract and hold on to polysulfides. The nanotubes are coated with polypyrrole, a conductive polymer that helps boost the flow of electrons.

This approach reduces buildup and boosts overall conductivity and efficiency, Yu says. So far, with the group's new architecture, the battery loses less than 0.07 percent of its capacity per charge and discharge cycle. After 500 cycles, the battery maintained about 65 percent of its original capacity, a great improvement over the short lifetime of current lithium-sulfur batteries. Still, for use in electric vehicles, scientists want batteries that can last through thousands of cycles, or 10 to 15 years.

Scientists at Argonne are constructing another battery type: one that replaces lithium ions at the anode with magnesium. This switch could instantly boost the electrical energy released for the same volume, says Argonne materials engineer Brian Ingram, noting that a magnesium ion has a charge of +2, double that of lithium's +1. Magnesium's ability to produce twice the electrical current of lithium ions could allow for smaller, more energy-dense batteries, Ingram says.

Magnesium comes with its own challenge, however. Whereas lithium ions zip through a battery's electrolyte, magnesium ions slowly trudge. A team of researchers at Argonne, Northwestern University and Oak Ridge National Laboratory shot high-energy X-rays at magnesium in various batteries and learned that the drag is due to interactions with molecules that the magnesium attracts within the electrolyte. Ingram and his group are experimenting with new materials to find a molecular recipe that reduces such drag.

Ingram's team is trying to nudge its "highly functioning, long-lasting" prototype to 3 volts by December. Today's typical lithium-ion battery has 3.8 to 4 volts. At 3 volts, Ingram says, the magnesium battery would pack more power than a 4-volt lithium-ion battery and "create a tremendous amount of excitement within the field."



New slant on flow
Once fully charged (top), a gravity-based flow battery is tilted to allow electrochemically active materials at each end to flow to the center, interact and create a current. To recharge, the battery is flipped to reverse the flow.

Going with the flow

Together, transportation and the electricity grid account for about two-thirds of U.S. energy use. But today, only 10 percent of the electricity on the grid is from renewable sources, according to the U.S. Energy Information Administration. If wind and solar power are ever to wrestle energy production away from fossil fuels, big changes must happen in energy storage.

What is needed, Crabtree says, is a battery that can store energy, and lots of it, for later use. "Though the sun shines in the middle of the afternoon, peak demand comes at sunset when people go home, turn on lights and cook dinner," he says.

To reliably supply electricity at night or on cloudy, windless days requires a different type of battery. By design, flow batteries fit the bill. Instead of having solid electrodes, flow batteries store energy in two separate tanks filled with chemicals — one positively charged, the other negatively charged. Pumps move the liquids from the tanks into a central chamber, or "stack," where dissolved molecules in the liquids undergo chemical reactions that store and give up energy. A membrane located in the stack keeps the positive and negative ions separated.

Flow batteries can store energy for a long time and provide power as needed. Because the energy-storing liquids are kept in external tanks, the batteries are unlikely to catch fire, and can be built large or small depending on need. To store more power, use a larger tank.

So far, however, flow batteries are expensive to make and maintain, and have had limited use for providing backup power on the grid. Today's flow batteries are packed with rare and toxic

This flow battery's seesaw movement means costly pumps aren't needed (prototype shown). A motor tips the battery so that gravity can shift energy-storing materials to the middle, where chemical energy is converted to electricity. Adjusting the angle can speed, slow or stop the flow.

BOTH: X. CHEN *ET AL*/*ENERGY ENVIRON. SCI.* 2016, ADAPTED BY E. OTWELL

metal components, usually vanadium. With many moving parts — tanks, pumps, seals and sensors — breakdowns and leakage are common.

At MIT, Chiang and colleagues are developing flow batteries that can bypass those drawbacks. One, an hourglass flow battery, does away with the need for costly and troublesome pumps. The stack where the chemical reactions occur is in the constricted middle, with tanks at either end. Gravity allows the liquids to flow through the stack, like sand in an hourglass. A motor adjusts the battery's angle to speed or slow the flow.

The hourglass design is like a "concept car," Chiang says. Though the final product is likely to take a slightly different shape, the design could serve as a model for future flow batteries. Simply changing the tilt of the device could add a short infusion of power to the grid during periods of peak demand, or slowly release energy over a period of many hours to keep air conditioners and heaters running when the sun is down.

In another design, the group has replaced vanadium with sulfur, which is inexpensive and abundant. Dissolved in water (also cheap and plentiful), sulfur is circulated into and out of the battery's stack, creating a reaction that stores or gives up energy, similar to commercial flow batteries. The group is now refining the battery, first described in 2014 in *Nano Letters*, aiming for higher levels of energy.

Another challenge in developing flow batteries is finding ways to keep active materials confined to their tanks. That's the job of the battery membrane, but because the organic molecules under consideration for battery use are almost always small, they too easily slip through the membrane, reducing the battery's lifetime and performance.

Rather than change the membrane, a group led by chemist Joaquín Rodríguez-López of the University of Illinois at Urbana-Champaign devised ways to bulk up the battery's active materials by changing their size or configuration. The scientists linked tens to millions of active molecules together to create large, ringed structures, long strings of molecules hooked onto a polymer backbone, or suspensions of polymers containing up to a billion molecules, they reported in the *Journal of the American Chemical Society* in 2014.

With the oversized molecules, even "simple, inexpensive porous membranes are effective at preventing crossover," Crabtree says. A prototype flow battery that provides low-cost power and lasts 20 to 30 years is expected to be completed in the coming year.

Getting air

Looking beyond 2017, scientists envision a new generation of batteries made of low-cost, or even no-cost, materials. The lithium-air battery, still in early development, uses oxygen sucked in from the atmosphere to drive the chemical reaction that produces electricity. In the process, oxygen combines with lithium ions to form a solid compound (lithium peroxide). During charging, solid oxygen reverts back to its gaseous form.

"Lithium-air potentially offers the highest energy density possible," says MIT materials engineer Ju Li. "You basically react lithium metal with oxygen in air, and in principle you get as much useful energy as gasoline."

Lithium-air has problems, though. The batteries are hard to recharge, losing much of their power during the process. And the chemical reaction that powers the battery generates heat, cutting the battery's energy-storage capacity and life span.

Using electron microscopy to study the reaction products of a lithium-air prototype, Li and his group came up with a possible solution: Keep oxygen in a solid form sealed within the battery to prevent the oxygen from forming a gas. By encasing oxygen and lithium in tiny glasslike particles, the scientists created a fully sealed battery. The new strategy, published July 25 online in *Nature Energy*, curbed energy loss during recharging and prevented heat buildup.

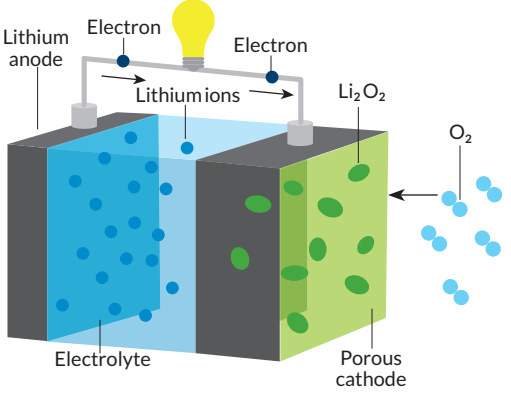
"If it works on a large scale, we would have an electrical vehicle that's competitive with gasoline-driven cars," Li says. Reaching that goal would be a big step toward a greener planet. ■

Explore more

- Battery University. www.batteryuniversity.com
- George Crabtree. Energy Storage. www.jcesr.org/energy-storage-george-crabtree/

Just add O_2

Lithium-air batteries use oxygen, which enters through the cathode (diagram, right side) to combine with lithium ions to form a solid chemical compound. But during charging, the oxygen becomes gaseous and the battery loses energy. Sealing the oxygen in nanoparticles may stabilize the system.



D. AURBACH *ET AL*/*NATURE ENERGY* 2016, ADAPTED BY E. OTWELL

Intel ISEF students imagine the future at White House Frontiers Conference

Envision what the United States and the world will be like in 50 years and beyond. That was the challenge President Barack Obama encouraged participants to take on at the daylong White House Frontiers Conference in Pittsburgh in October. The conference brought together "change-makers of tomorrow," including researchers, business leaders, technologists, philanthropists, local innovators and students. Six Intel International Science and Engineering Fair (ISEF) finalists were among that group — and they had the experience of a lifetime.

"The best part of the conference was the tangible atmosphere from the scientists and innovators all around me." **– JIWOO LEE, INTEL ISEF 2016 FINALIST**

"This conference not only opened my eyes to the creativity involved in scientific research, but also showed me that we can and should drive new sets of innovations in whatever field we are working on."

– SURABHI MUNDADA, INTEL ISEF 2016 FINALIST

"The White House Frontiers Conference really changed my views and my ideas on not only space but all areas of science." **– AMBER YANG, INTEL ISEF 2016 FINALIST**

"The spirit of discovery that was concentrated in that one room still blows me away."

– SYAMANTAK PAYRA, INTEL ISEF 2016 FINALIST, BROADCOM MASTERS 2014 SEMIFINALIST

"Attending the White House Frontiers Conference has made a lasting impact on my life."

– AARUSHI PENDHARKAR, INTEL ISEF 2016 FINALIST

"The conference showed me how important it is to take this extra step of bringing your work out into the world — to real people and communities who could benefit."

– MIHIR GARIMELLA, BROADCOM MASTERS 2013 FINALIST, INTEL ISEF 2015 FINALIST

From left: A SpaceX Dragon capsule sits outside of the White House Frontiers Conference in Pittsburgh; President Obama speaks to the conference audience, calling participants the "change-makers of tomorrow"; Intel ISEF finalist Surabhi Mundada tries on virtual reality goggles.

ALL: CARNEGIE MELLON UNIVERSITY

Katherine Johnson (played by Taraji P. Henson) shakes the hand of John Glenn (Glen Powell) in a new film about the role of female mathematicians in the U.S. space program.

FILM

Movie celebrates NASA 'computers'

Hollywood space flicks typically feature one type of hero: astronauts who defy the odds to soar into space and back again. But now a group of behind-the-scenes heroes from the early days of the U.S. space program are getting their due. Black female mathematicians performed essential calculations to safely send astronauts to and from Earth's surface — in defiance of flagrant racism and sexism.

These "computers" — as they were known before the electronic computer came into widespread use — are the stars of *Hidden Figures*. The film focuses on three black women — Katherine Johnson (played by Taraji P. Henson), Dorothy Vaughan (Octavia Spencer) and Mary Jackson (Janelle Monáe) — and their work at NASA's Langley Research Center in Hampton, Va., during the run-up to John Glenn's orbit of Earth in 1962.

Hidden Figures
NOW PLAYING
20TH CENTURY FOX

A mathematics virtuoso, Johnson calculated or verified the flight trajectories for many of the nation's space milestones. The film showcases her work on two: the first American in space (Alan Shepard) and the first American to orbit Earth (Glenn). But Johnson also had a hand in sending the first men to the moon, during the Apollo 11 mission, and when the Apollo 13 astronauts ran into trouble, Johnson's calculations helped them get home safely.

After a job as a computer, Mary Jackson became NASA's first black female engineer.

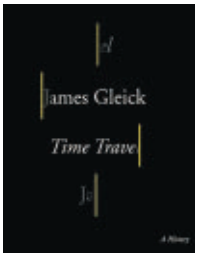
Jackson worked on wind tunnel experiments at Langley, where she tested how spacecraft responded to high winds. The film follows Jackson as she overcomes obstacles of the Jim Crow era to become NASA's first black female engineer. Though the movie focuses on her triumphant rise, after decades as an engineer, Jackson grew frustrated with the remaining glass ceilings and moved into an administrative role, helping women and minorities advance their careers at NASA.

Johnson and Jackson got their start under the leadership of Vaughan, who led the segregated group of black computers, assigning women to assist with calculations in various departments. As electronic computers became more essential, Vaughan recognized their importance and became an expert programmer. A scene where she surreptitiously takes a book from the whites-only section of a public library — a guide to the computing language FORTRAN — is a nod to Vaughan's prowess with the language.

Electronic computers were so unfamiliar in the 1960s that everyone from engineers to astronauts felt more confident when a human computer did the calculations. Glenn is said to have requested, after a room-sized IBM mainframe spit out figures for his trajectory, "Get the girl to check the numbers" — meaning Johnson. In the film, his request culminates in Johnson running a frantic last-minute check of the numbers and sprinting across the Langley campus while Glenn waits. In reality, that process took a day and a half.

For spaceflight fans, *Hidden Figures* provides a neglected perspective. The women's stories are uplifting, their resilience impressive and their retorts in response to those who underestimate them, witty.

But viewers should be aware that, although the main facts underpinning the plot are correct, liberties have been taken. Some of the NASA higher-ups in the film — including Johnson's supervisor Al Harrison (Kevin Costner) — are not real people. And presumably because number crunching tends to be a bit thin in the suspense department, the filmmakers have dramatized some scenes — Johnson is pictured in Mission Control during Glenn's flight, but in reality she watched it on television. The extra dramatization seems a shame because the contributions of these women don't need to be exaggerated to be momentous. — *Emily Conover*



Time Travel
James Gleick
PANTHEON, $26.95

BOOKSHELF

Time travel book tours a fascinating fiction

It's kind of daring to write a science book about something that — you must remind your readers — doesn't exist. That's James Gleick's task in *Time Travel*, an engaging and entertaining look at science that will always remain fiction.

It's lucidly written, a breeze to read and erudite in assessing a vast range of literary and popular media treatments of time travel as dream and desire. Gleick starts with, and often returns to, H.G. Wells' *The Time Machine*, the book (and later films) that introduced the concept of time travel in its modern science fiction sense.

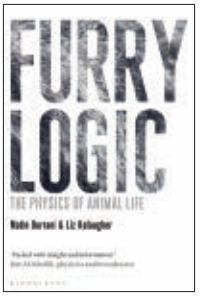
Much of Gleick's account focuses more on time than travel, though — examining the mystery of time's direction (*SN: 7/10/15, p. 15*) and the philosophy of time (as in, what is it?). One whole chapter discusses time capsules, which are not exactly as exciting as a TARDIS. But Gleick always turns back to time travel, if only to remind that it is fiction, not physics: "Time travel is a fantasy of the modern era."

Before the 19th century, "time travel" rarely occurred to anybody, because time didn't change things much. Activities in ancient and medieval times differed little from life in the 1700s. But then new technologies — steam engines, electricity, telephones among them — infused 19th century thinkers with visions of even more technological progress, and a future worth traveling to. Mark Twain's *A Connecticut Yankee in King Arthur's Court* was all about "the contrast of modern technology with the agrarian life that came before," Gleick writes.

His tour of the time travel fictional corpus includes mentions of Looney Tunes and Elmer Fudd, Mr. Peabody's WABAC machine and Arnold Schwarzenegger's Terminator. In addition to thorough analysis of Wells' Time Traveller, there are extended discussions of Robert Heinlein's "By His Bootstraps," Isaac Asimov's *The End of Eternity*, and "Blink," one of the most famous 21st century episodes of *Doctor Who*. At times, tidbits injected from films, novels and poetry seem too much, almost like a dictionary of famous time travel quotations, many quite lengthy. Sometimes you'd like to hear more from Gleick and less from everyone else.

It's also a bit disappointing that Gleick only briefly discusses actual science. There is a vast scientific literature on time travel, including many proposals for how to do it, that Gleick mostly ignores. He does cite a well-known paper by physicist Kip Thorne and colleagues and offers a brief account of logician Kurt Gödel's earlier work on time loops (possibly permitted by Einstein's general relativity). And Gleick discusses Stephen Hawking's "chronology protection conjecture" to emphasize once again that time travel really can't happen.

Those who remember the rich depth of Gleick's groundbreaking book *Chaos* and his insightful biography of Richard Feynman will find much less science here. But there is plenty of science fiction. And as Gleick points out, "the rules of time travel have been written not by scientists but by storytellers." — *Tom Siegfried*



Furry Logic
Matin Durrani and Liz Kalaugher
BLOOMSBURY, $27

BOOKSHELF

How animals exploit physical phenomena

Warning: *Furry Logic* is not, as the title might suggest, a detailed exploration of mammals' reasoning skills. Instead, it's a fun, informative chronicle of how myriad animals take advantage of the laws of physics.

Science writers Matin Durrani and Liz Kalaugher cite a trove of recent (and often surprising) research findings. They draw on their backgrounds — Durrani is a physicist, Kalaugher a materials scientist — to explain how animals exploit sound, light, electricity and magnetism, among other things, in pursuit of food, sex and survival. These creatures don't consciously use physics the way that humans design and use tools, of course, but they are evolutionary marvels nonetheless.

Peacocks, for example, produce low-frequency sounds while shimmying their tail feathers. The birds use these sounds — and not just the sight of those colorful plumes — to impress females and fend off competing males. At the other end of the sonic spectrum, some bats use stealth echolocation to track down their preferred prey. Moths targeted by these bats have sensors that can pick up these ultrasonic calls, but the bats squeak so softly that a moth can't hear its stalker until it is less than a half-second's flight away.

Durrani and Kalaugher let readers know when the science isn't settled. Researchers aren't quite sure how peahens pick up males' infrasonic signals, for example. Scientists also haven't figured out how the archerfish spits so precisely (*SN: 10/4/14, p. 8*), knocking prey off low-hanging branches above the water as often as 94 percent of the time. The submerged fish must somehow gauge the angle at which light bends as it enters the water and then accurately compensate for refraction while spewing a stream of water. Amazingly, this feat may be innate rather than learned via trial and error.

Readers need not understand the intricacies of polarized light, Earth's magnetic field or surface tension to enjoy *Furry Logic*. Nor is this book an exhaustive account of the characteristics and behavior of every animal that uses such phenomena in interesting ways. There should be plenty of material for a sequel to this fascinating book. — *Sid Perkins*

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NOVEMBER 12, 2016

NOVEMBER 26, 2016

Robot revolution

From touch to sight, robots large and small are getting major sensory upgrades that will enable them to perform more complicated tasks, **Meghan Rosen** reported in "Robot awakening" (*SN: 11/12/16, p. 18*). Watch the bots in action at bit.ly/SN_robottouch.

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Prehistoric tweet

Researchers uncovered the fossilized voice box, called a syrinx, of an ancient bird that lived 68 million to 66 million years ago. The bird may have sounded like a honking duck, ***Meghan Rosen*** *reported in "Ancient avian voice box unearthed"* (SN: 11/12/16, p. 7). Online reader **David Spector** wondered if researchers could 3-D print the syrinx to replicate the ancient bird's squawks. "I'll bet such sounds would make researchers 'chortle' even more," he wrote.

Re-creating rigid rings of the syrinx is probably doable, but researchers still may not hear how the bird sounded. The organ's soft tissue is crucial for making noise. Scientists might be able to create synthetic membranes that mimic natural ones to get a better idea of ancient bird calls, **Rosen** says. But as far as she knows, no one has done that yet.

In the dark

Results of three experiments are forcing physicists to consider broader possibilities for what dark matter might be, ***Emily Conover*** *reported in "Dark matter searches come up empty"* (SN: 11/12/16, p. 14). Reader **Stuart Boehmer** thought physicists' focus on particles could be hindering their search. He suggested dark matter could be a mix of particles, or might not be particles at all. "Dark matter and dark energy are unknowns, and an open and disciplined mind would recognize this and regard it with a sense of awe and mystery rather than an anxious attempt to provide immediate answers," **Boehmer** wrote. "As Nietzsche implied, sometimes you just have to know when you don't know: Never to seek; only to find."

"It is possible that dark matter could be more than one type of particle," **Conover** says. "The matter we know about in the universe isn't all one thing, and dark matter could be similar. That's one reason this idea has begun to attract some interest from scientists." But researchers are still looking for one type of particle at a time because different detectors are required for each type. "Scientists still maintain their awe over the existence of dark matter, but awe alone won't answer the question," she says. Scientists are searching for particles that they consider the most likely candidates as well as those that are easiest to detect. "I don't think anyone has shut the door on other options, even those yet to be theorized, despite focusing their experimental efforts on a few types of particles."

Survey says

The combined rate of three sexually transmitted diseases in the United States reached historic highs in 2015, ***Cassie Martin*** *reported in "Progress against STDs backslides"* (SN: 11/26/16, p. 5). **Michael Carpenter** thought that lumping together rates of gonorrhea and syphilis, which have persisted at low and relatively stable levels, with skyrocketing rates of chlamydia was misleading. "I would conclude that 0.5 percent incidence per capita of chlamydia indicates that citizens and medical professionals are not taking that disease as seriously as they should," he wrote.

Although gonorrhea and syphilis rates are still low compared with chlamydia rates, there have been recent increases. Researchers think those numbers may continue to rise, **Martin** says. Drug-resistant gonorrhea is a growing threat, and condom use has declined among some of the groups most affected by these STDs, the U.S. Centers for Disease Control and Prevention reports.

Chlamydia rates may be rising because screening methods have improved. It's also possible that access to STD treatment and prevention programs plays a role. State and local budget cuts to these services are associated with higher infection rates, says **Gail Bolan**, an STD expert with the CDC.

Clarification

Some readers pointed out that the caption for the cover of the November 26, 2016 issue implied that the snow-covered mountain shown in the image was Mount Hood. It is Mount Jefferson, as seen from Mount Hood National Forest in Oregon.

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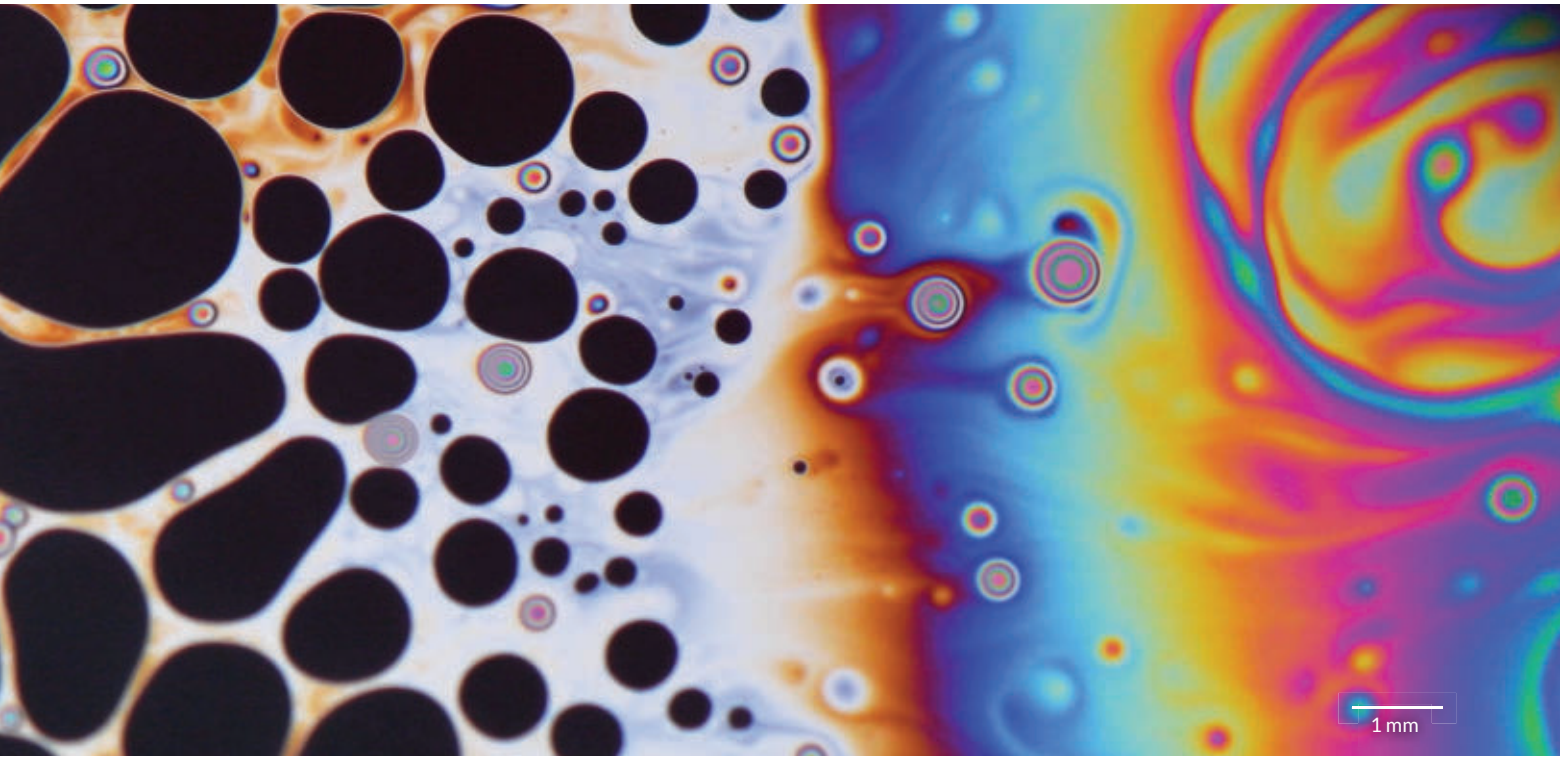

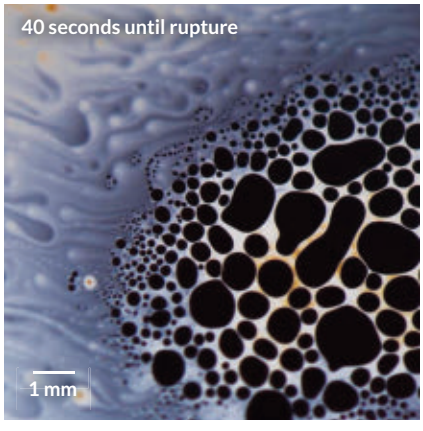

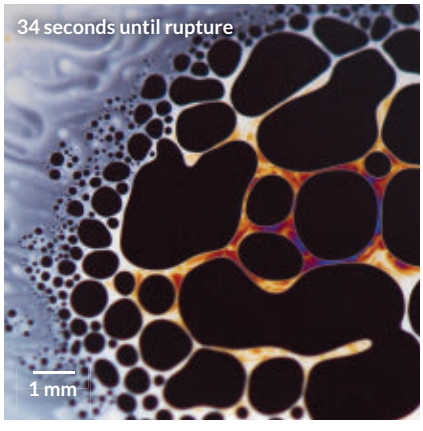

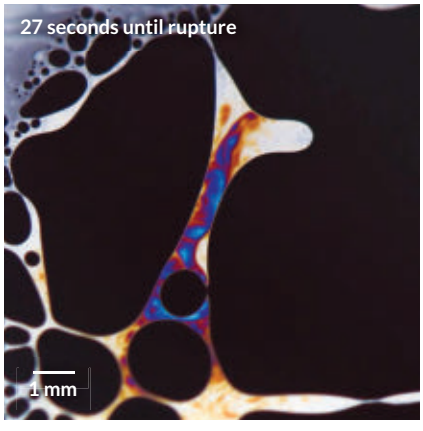

Soap bubbles show their dark side

Zoom in on a soap bubble just before it bursts and brilliant, complex patterns emerge. Shimmery rainbows appear in thicker portions of the soap film, while clusters of dark spots appear in the thinnest regions.

The thickness of the soap film determines the color seen. Light rays that reflect off of the top and bottom of the film combine to amplify particular wavelengths, an effect known as constructive interference. In thicker areas of the film, longer wavelength colors appear, producing a rainbow (top image). Under gravity's pull, the soap film flows, causing the patterns to shift over time until finally the bubble pops.

When the film becomes even thinner than the shortest wavelength of visible light, dark spots appear, due to destructive interference that cancels out light reflecting off the bubble's surface. Over about a minute, those spots grow and merge (series, bottom row), physicist Li Shen of Imperial College London and colleagues reported November 22 at the American Physical Society's Division of Fluid Dynamics meeting in Portland, Ore.

This effect, known as "coarsening," pops up in other places, too. Shake up a vinaigrette salad dressing and it will gradually separate, as oil and vinegar droplets form and coalesce. This is the first time the effect has been observed in bubbles, says Shen, who used dishwashing detergent and a digital camera to study the phenomenon.

Bad news for the bubbles: The melding black spots are precursors to their demise. These bubbles popped shortly after the images were taken. — *Emily Conover*

L. SHEN

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