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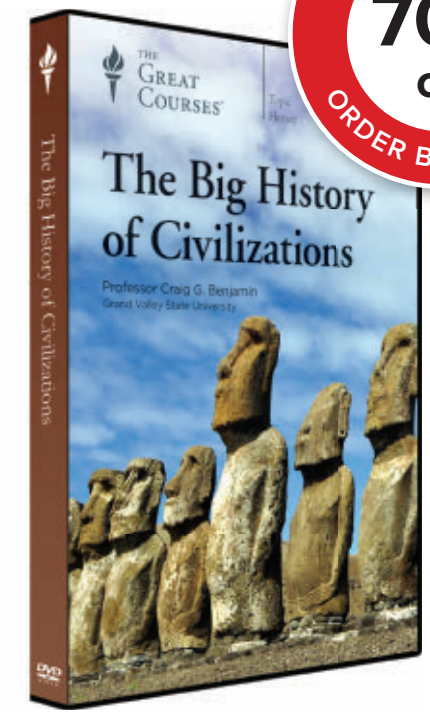

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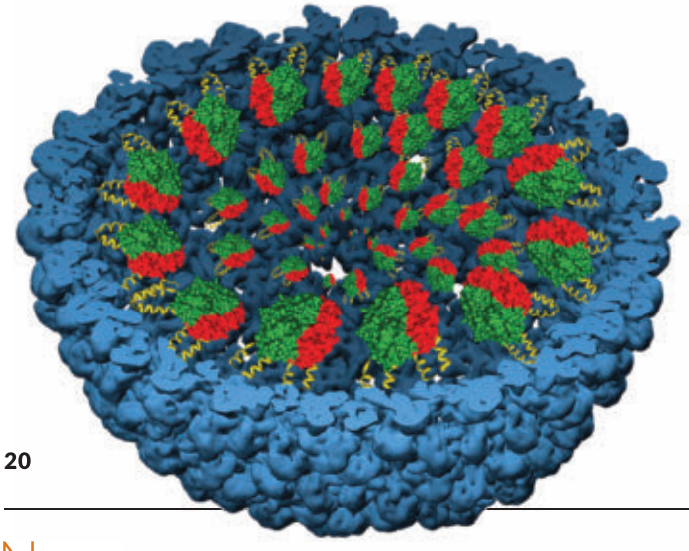

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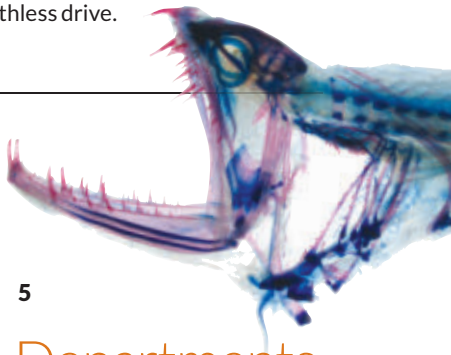

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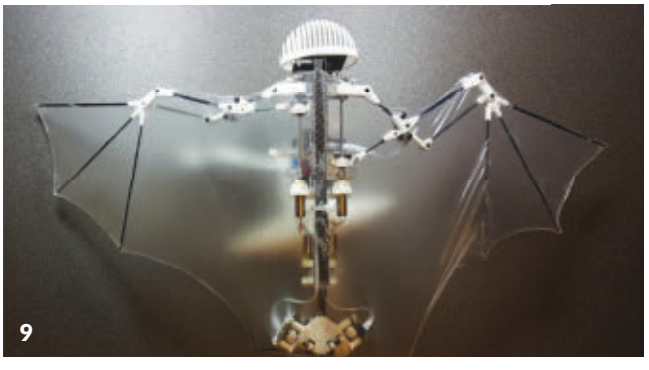
News



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Departments

COVER In this mouse breast cancer, growth outpaces oxygen supply. Areas of low oxygen are green; blood vessels, red. *Steve Seung-Young Lee, National Cancer Institute, Univ. of Chicago Comprehensive Cancer Center*

CLOCKWISE FROM TOP: P.C. JORDAN *ET AL/NATURE CHEMISTRY* 2016; N. SCHNELL/MNHN; A. RAMEZANI, S.-J. CHUNG AND S. HUTCHINSON/*SCIENCE ROBOTICS* 2017

Science's questions rarely have clear, easy answers

There are few simple answers in science. Even seemingly straightforward questions, when probed by people in search of proof, lead to more questions. Those questions lead to nuances, layers of complexity and, more often than we might expect, conclusions that contradict initial intuition.

In the 1990s, researchers asking "How do we fight oxygen-hungry cancer cells?" offered an obvious solution: Starve them of oxygen by cutting off their blood supply. But as Laura Beil describes on Page 24, oxygen deprivation actually drives cancer to grow and spread. Scientists have responded by seeking new strategies: Block the formation of collagen highways, for instance, or even, as Beil writes, give the cells "more blood, not less."

On Page 6, Tina Hesman Saey reports on the complications of classifying species. Genetic analyses alone, she writes, can detect too many differences, overestimating species numbers. Some tools appear to be, as Darwin would have put it, "hair-splitters" rather than "lumpers." Identifying species is hard in part because "What is a species?" has no single answer. The notion of reproductive isolation, which splits species according to whether they can produce fertile offspring, has little meaning for asexual organisms, for instance. And isolation itself is a matter of degree. Accounting for speciation in progress is yet another challenge. At what point is a split declared official?

There are countless more examples. The question of what led to the dinosaurs' demise was solved years ago, we thought. But remaining mysteries inspired a special report earlier this year (*SN: 2/4/17, p. 16*). And don't even get me started on "How long does a neutron last?" in a story by Emily Conover on Page 13.

In *The Pursuit of Simplicity*, physicist Edward Teller described science as a search for simplicity. If that's the case, the quest is never-ending. With each new insight comes yearning for further insights. I cannot, at this moment, think of a single question that doesn't demand more exploration. There are answers to be sure, and scientific truths, but for what line of questioning are all the details resolved? Where isn't there a lingering "why" or "how"? (Think that I'm wrong? Send your ideas to editors@sciencenews.org.)

Wanting to know is innate. Children ask "Why is the sky blue?" or "Where do babies come from?" And parents struggle to answer at the right level of detail. Where does the question begin, and where does it end? What is the best angle of approach? As kids grow up, their questions become more specific, and the answers they receive more complex. Perhaps it's the students who most appreciate complexity who decide to become scientists. They learn to use the tools of science, which uncovered the complexity in the first place, to try to tame it — diving in ever deeper. And so people end up studying dim and distant galaxies to understand "How did the universe evolve?" (Page 10), and vats of microbes and methylmercury (Page 12) to ask "How will climate change affect food webs?"

Simplicity may be a gift, but I think complexity is much more interesting. It is one of the great joys of doing science — and of writing about it.

— Elizabeth Quill, Acting Editor in Chief

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RED ROCK CANYON NATIONAL CONSERVATION AREA

The natural feature most famously associated with Las Vegas is Red Rock Canyon National Conservation Area, on the west side of the Las Vegas Valley. To reach the 2,000-foot-high sandstone cliffs, head west on Charleston Boulevard, which turns into NV 159. A one-way loop road on the north side of NV 159 provides access to the sandstone, overlooks, picnic areas, and hiking and climbing trails. The visitor center at the entrance to the loop road has several informative displays regarding the natural environment and is a good place to start your visit.

An overlook on NV 159 between milepost 8 and milepost 9, uphill from the visitor center, provides many insights into the geologic setting of Red Rock Canyon. The red and tan cliffs are Aztec Sandstone, which consolidated from a large field of sand dunes in Jurassic time. Among the distinctive features of the sandstone are the bold bands of color across the cliff faces. The movement of fluids through the sandstone after consolidation formed the color. If the coloration follows bedding planes, it is coincidental, or perhaps because the bedding plane provided either an easy flat flow path or a barrier to flow. On the skyline in the distance behind the cliffs is gray limestone of Paleozoic age, part of the Keystone thrust sheet that was shoved over the top of the Aztec Sandstone in Cretaceous time.

The north-trending line of towering sandstone cliffs ends abruptly to the north of the overlook. The La Madre fault, a normal fault that trends perpendicular to the Keystone thrust, has dropped the sandstone down about 4,000 feet, accounting for its disappearance. The Keystone thrust is displaced only 300 to 600 feet across the La Madre fault, indicating that most of the offset along the La Madre fault occurred prior to emplacement of the Keystone thrust. The La Madre fault extends 30 miles from NV 159 northwestward across the Spring Mountains. Jurassic-age rocks can be seen on the north side of the fault in the Calico Basin area.

Another geomorphic feature clearly seen from the overlook is the vast quantity of alluvial fan material that has been eroded, mostly from the limestone mountains to the north. At least four ages of alluvial fans are visible from the overlook.

You can also see red Jurassic sandstone and thrust faults on the north side of Calico Basin, an oasis in the desert created where springs emerge from the base of the sandstone. As you head west from Las Vegas on NV 159, turn north toward Calico Basin just west of the campground turnoff and before reaching Red Rock Canyon. Straight ahead down the road to Calico Basin is a mountain with the dark red and tan of the Aztec Sandstone exposed in the lower two-thirds of the slope overlain by tan-gray limestone of the Cambrian-age Bonanza King Formation in the upper third of the mountain. The horizontal line separating the two units is the Red Spring thrust fault, which predates the Keystone thrusting. With binoculars, it is possible to discern a thin, dark-brown to brownish-pink unit, the conglomerate of Brownstone Basin, between the sandstone and the overlying limestone. Streams deposited this conglomerate, usually in a matrix of reworked Aztec sand, on the weathered surface of Aztec Sandstone.

View west from Red Rock Overlook toward cliffs of Aztec Sandstone of Jurassic age. Paleozoic limestone forms the skyline in distance behind the cliffs.

The easternmost limestone ridge at Calico Basin is not faulted over the sandstone but rather is breccia of a debris flow. About 11 million years ago, a debris flow carrying limestone rock fragments flowed down a narrow canyon in the sandstone. Over time, the sandstone eroded to the current level, and the more resistant limestone debris flow forms the capping rock. Note how the contact between the gray breccia and the underlying pinkish sandstone is irregular.

Excerpt from the March 4, 1967 issue of *Science News*

50 YEARS AGO

Computers that hear

Computer engineers have dreamed of a machine that would translate speech into something that a vacuum tube or transistor could understand. Now at last, some promising hardware is being developed.... It is still a long way from the kind of science fiction computer that can understand sentences or long speeches.

UPDATE: That 1967 device knew the words *one* through *nine*. Earlier speech recognition devices sliced a word into segments and analyzed them for absolute loudness. But this machine, developed by Genung L. Clapper at IBM, identified the volume of a pitch segment compared with its neighbors to account for the variability of human speech. Today's speech recognition goes much further, dividing words into distinct units of sound and syntax. The software decodes speech by applying pattern recognition and a statistical method called the hidden Markov model to the sounds. We rely on speech recognition to open an app to order groceries or to send a text to ask someone at home if we need more milk. Hello, Siri.

Birgus latro, the largest known crab species on land, scavenges with a mighty left claw strong enough to crack a coconut.

IT'S ALIVE

Don't shake hands with this crab

A big coconut crab snaps its outsized left claw as hard as a lion can bite, new measurements suggest. So what does a land crab the size of a small house cat do with all that pinch power?

For starters, it protests having its claw-force measured, says Shin-ichiro Oka of the Okinawa Churashima Foundation in Motobu, Japan. "The coconut crab is very shy," he says. It doesn't attack people unprovoked. But wrangling 29 wild *Birgus latro* crabs on Okinawa and getting them to grip a measurement probe inspired much snapping at scientists. Oka's hand got pinched twice (no broken bones). "Although it was just a few minutes," he says, "I felt eternal hell."

The strongest claw grip the researchers measured squeezed with a force of about 1,765 newtons, worse than crushing a toe under the force of the full weight of a fridge. For comparison, a lion's canines bite with 1,315 newtons and some of its molars can crunch with 2,024 newtons, a 2007 study calculated. Because grip strength increases with body size, crabs bigger than those measured in the study might surpass the bite force of most land predators, Oka and colleagues proposed last year in *PLOS ONE*.

On Okinawa in Japan, researchers — gloves on — carefully maneuvered coconut crabs into grasping a pinch-measuring sensor.

Coconut crabs, however, start life about as scary as a soggy grain of rice. Fertilized eggs hatch in seawater and bob around planktonlike in the western Pacific and Indian oceans. The crabs eventually return to land, where they spend most of their long lives, up to 50 (or maybe 100) years, as landlubbers that will drown if forced back into water for too long. Yet females have to risk the ocean's edge each time they lay the next generation of eggs.

Both moms and dads grow a powerful left claw, handy for dismembering whatever the omnivorous scavengers find: roadkill and other dead stuff, innards of palm trees and nuts. The crabs can break open coconuts, but the job "takes hours," says Jakob Krieger of the University of Greifswald in Germany. Cracking open a red crab, however, takes seconds.

Coconut crabs not only scavenge red crabs but also hunt them on Christmas Island in the Indian Ocean, Krieger says. Only the strictest vegetarian would ignore the 44 million or so red crabs scuttling around, and even small coconut crabs get a taste. Krieger watched an underpowered coconut crab grab hold of and wrestle its prey. The red crab abandoned its trapped limb and fled. But the little coconut crab scored a crab-leg dinner. — *Susan Milius*

THE -EST

Early baglike worm had pleated mouth

A creature that may have skimmed shorelines roughly 540 million years ago was a real oddball.

Dozens of peculiar, roundish fossils discovered in what is now southern China represent the earliest known deuterostomes, a gigantic category of creatures that includes everything from humans to sea cucumbers.

No bigger than a pinhead, the fossils have wrinkly, baglike bodies and mouths that are pleated around the edges like an accordion, researchers report in the Feb. 9 *Nature*.

Unlike most other deuterostomes, the animals don't seem to have an anus. Instead, the ancient oddities, named *Saccorhytus coronarius*, may have leaked waste (and other bodily fluids like mucus and sex cells) out of tiny holes lining their sides. These holes may have later evolved into gill slits.

A tough, flexible skin would have protected *S. coronarius* as it wriggled through grains of dirt, the authors suggest. The find supports previous suggestions that the earliest deuterostomes were actually a kind of water-dwelling worm. — *Meghan Rosen*

This 540-million-year-old fossil preserves a tiny creature with an accordion mouth. The animal, *Saccorhytus coronarius*, may have been a worm.

TEASER

How to sap a tsunami's strength

A tsunami's immense wall of water may not be stoppable. But there may be a way to take the ferocious force of nature down a few notches, using a pair of counterwaves.

If released at the right moment, a type of sound wave known as an acoustic-gravity wave could subdue a tsunami, applied mathematician Usama Kadri of Cardiff University in Wales reports January 23 in *Heliyon*. These acoustic-gravity waves, which reach deep below the ocean's surface, can stretch tens or hundreds of kilometers and easily travel long distances at high speeds.

In Kadri's plan, two acoustic-gravity waves would be launched through the water at the earthquake-triggered ocean surge. The waves would be tuned to exchange energy with the tsunami as they speed past, spreading the tsunami out by redistributing its energy and thereby decreasing its maximum height.

The tsunami sapper is still theoretical — scientists don't yet have a way to create the high-energy waves needed. But Kadri suggests his approach could have shrunk the amplitude of the devastating 2004 Indian Ocean tsunami by almost 30 percent. Such a reduction translates to a five-meter decrease in the height the water reached above sea level, enough to potentially save lives and property. — *Emily Conover*

Firing a pair of sound waves at a tsunami, like this one that hit Japan in 2011, could weaken the wall of water and decrease its height, a researcher proposes.

CLOCKWISE FROM TOP: J. HAN *ET AL*/*NATURE* 2017; N. SCHNELL/MNHN; REUTERS, MAINICHI SHIMBUN

MYSTERY SOLVED

Dragonfish swallow big thanks to flexible neck

Dragonfish are the stuff of nightmares, with their oversized jaws and rows of fanglike teeth. The deep-sea creatures may be only several centimeters long, but they can trap and swallow sizable prey. How these tiny terrors manage to open their mouths so wide has puzzled scientists, until now.

In most fish, the skull is fused to the backbone, limiting their gape. But a barbeled dragonfish can pop open its jaw like a Pez dispenser — up to 120 degrees — thanks to elastic tissue that connects the fish's head and spine, researchers report February 1 in *PLOS ONE*.

Small but scary dragonfish open their mouths wide using a unique joint at the base of the skull.

Nalani Schnell of the Muséum National d'Histoire Naturelle in Paris and Dave Johnson of the National Museum of Natural History in Washington, D.C., examined preserved specimens of nine barbeled dragonfish genera. Five genera had a flexible rod, called a notochord, covered by extra connective tissue that bridged their vertebrae and skulls. When Schnell and Johnson opened the mouths of the fish, the connective tissue stretched out. The joint may provide just enough give for dragonfish to swallow a whole crustacean or lantern fish close to their own size. — *Cassie Martin*

Watch a video of a dragonfish jaw open wide at **bit.ly/SN_dragonfish**

LIFE & EVOLUTION

DNA tests inflate species counts

Classification requires many types of data, researchers say

BY TINA HESMAN SAEY

Genetic methods for counting new species may be a little too good at their jobs.

Computer programs that rely on genetic data alone split populations of organisms into five to 13 times as many species as actually exist, researchers report online January 30 in *Proceedings of the National Academy of Sciences*. These overestimates may muddy researchers' views of how species evolve and undermine conservation efforts by claiming protections for species that don't really exist, say computational evolutionary biologist Jeet Sukumaran and evolutionary biologist L. Lacey Knowles.

The lesson, says Knowles, "is that we shouldn't use genetic data alone" to draw lines between species.

Scientists have historically used data about organisms' ecological distribution, appearance and behavior to classify species. But the number of experts in taxonomy is dwindling, and researchers have turned increasingly to genetics to help them draw distinctions. Large genetic datasets and powerful computer programs can quickly sort out groups that have become or are in the process of becoming different species. That's especially important in analyzing organisms for which scientists don't have much ecological data, such as insects in remote locations or recently extinct organisms.

Knowles and Sukumaran, both of the University of Michigan in Ann Arbor, examined a commonly used computer analysis method, called the multispecies coalescent model, which can pick out genetic differences among individuals that have arisen recently in evolutionary time. Such differences could indicate that a population of organisms is becoming a separate species. The researchers simulated populations of hypothetical species to test the program's ability to correctly predict the right number of species given certain variables. The program is good — maybe too good — at detecting the differences, Knowles says. If scientists don't take other factors, such as geographical separation, into account, they may call genetically different groups separate species when they are merely subgroups of the same species.

Then again, it depends on what you mean by a "species," says Rampal Etienne, an evolutionary community ecologist at the University of Groningen in the Netherlands. He developed the method that Knowles and Sukumaran analyzed. By one definition, a species is a genetically distinct lineage. "If that's your species concept, then, no, it's not true that there are more species discovered by this method than there actually are," he says.

Biologists have long defined species primarily based on mating behavior and physical traits, not genetic similarity. Species are said to be reproductively isolated when they don't mate, either because they can't or don't for some reason (such as female fish choosing to mate with only red or blue males). Reproductive isolation doesn't exclude two species from mating once in a while, says evolutionary biologist Ole Seehausen of the University of Bern in Switzerland. What's important is that species that breed in the same area remain distinct.

What's more, "speciation is not a one-way road," Seehausen says. When ecological conditions change, groups that had been going their separate ways may breed with each other again. For instance, female fish that choose mates based on color may breed with males of the nonpreferred color when water becomes murky and obscures their vision. Computer programs can tell when speciation has started but can't forecast whether the groups will remain separate, Seehausen says.

Using the biological criteria, the genetic method may seem to fall short, but genetic analyses simply aren't designed to address such questions, Seehausen says. He agrees with Knowles and Sukumaran that genetic data should be used in combination with ecological and other studies to identify species.

Scientists have had difficulty determining whether Hercules beetles, such as these, all belong to the same species. Genetic analysis alone may split populations into species that don't exist by other criteria, researchers say.

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Characterizing species based on their genes could still be a useful conservation tool, Etienne says, helping to preserve genetic diversity. A diverse set of genes can help a species adapt to changing environments, while a lack of diversity may doom it to extinction. Identifying diverse groups within a population could help researchers decide where to focus conservation efforts, Etienne says. "Whether they are two species or not is less important," he says.

Estimates of global biodiversity are not affected by any shortcomings with the genetic analysis programs, Knowles says. Scientists use many types of data to determine the total number of species in a region or on Earth. ■

Lasting mental health may be unusual

Most people studied endured at least one episode of a disorder

BY BRUCE BOWER

Abnormal is the new normal in mental health.

A small, poorly understood segment of the population stays mentally healthy from age 11 to 38, a new study of New Zealanders finds. Everyone else encounters either temporary or long-lasting mental disorders.

Only 171 of 988 participants, or 17 percent, experienced no anxiety disorders, depression or other mental ailments from late childhood to middle age, researchers report in the February *Journal of Abnormal Psychology*. Of the rest, about half experienced a transient mental disorder, typically just a single bout of depression, anxiety or substance abuse by middle age.

"For many, an episode of mental disorder is like influenza, bronchitis, kidney stones, a broken bone or other highly prevalent conditions," says study coauthor Jonathan Schaefer, a psychologist at Duke University. "Sufferers experience impaired functioning, many seek medical care, but most recover."

The remaining 408 individuals (41 percent) experienced one or more mental disorders that lasted several years or more. Their diagnoses included more severe conditions such as bipolar and psychotic disorders.

Researchers analyzed data for individuals born between April 1972 and March 1973 in Dunedin, New Zealand. Researchers assessed each participant's general health and behavior 13 times from birth to age 38. Eight mental health assessments occurred from age 11 to 38.

Surprisingly, those who experienced lasting mental health did not display several characteristics previously linked to a lower likelihood of developing mental disorders. Those attributes consist of growing up in unusually affluent families, enjoying especially sound physical health and scoring exceptionally high on intelligence tests.

Instead, mentally healthy participants tended to possess advantageous personality traits starting in childhood, Schaefer and colleagues found. These participants rarely expressed strongly negative emotions, had lots of friends and displayed superior self-control. Kiwis with rock-solid mental health also had fewer first- and second-degree relatives with mental disorders compared with their peers.

As adults, participants with enduring mental health reported, on average, more education, better jobs, higher-quality relationships and more satisfaction with their lives than their peers did. But lasting mental health doesn't guarantee an exceptional sense of well-being, Schaefer says. Nearly one-quarter of never-diagnosed individuals scored below the entire sample's average score for life satisfaction.

Less surprising was the 83 percent overall prevalence rate for mental disorders. That coincides with recent estimates from four other long-term projects. In those investigations — two in the United States, one in Switzerland and another in New Zealand — 61 to 85 percent of participants developed mental disorders over 12- to 30-year spans.

Comparably high rates of emotional disorders were reported in 1962 for randomly selected Manhattan residents. At the time, many researchers doubted those findings, which relied on a diagnostic system that was less strict than the three versions of psychiatry's diagnostic manual that were introduced and used to evaluate New Zealand participants as they got older, says psychiatric epidemiologist William Eaton. But the Manhattan study appears to have been on the right track, says Eaton, of Johns Hopkins Bloomberg School of Public Health.

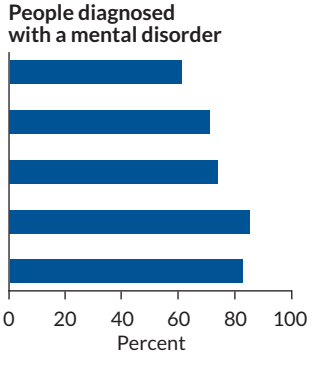
Increased awareness that most people will eventually develop a mental disorder (*SN: 10/10/09, p. 5*), at least briefly, can reduce stigma attached to these conditions (*SN Online: 10/13/16*), Eaton suspects.

Psychiatric epidemiologist Ronald Kessler thinks the numbers of people experiencing a mental disorder may be even higher than reported. Many participants deemed to have enduring mental health probably developed brief mental disorders that got overlooked, such as a couple of weeks of serious depression after a romantic breakup, says Kessler, of Harvard Medical School, who directs surveys of mental disorders in the United States. Rather than focusing on rare cases of lasting mental health, he says, "the more interesting thing is to compare people with persistent mental illness to those with temporary disorders." ■

Common ills Five long-term prevalence studies have found high rates of mental disorders in populations from the United States, Switzerland and New Zealand. The latest analysis from a Dunedin, New Zealand, investigation also uncovered distinctive traits — including high self-control and upbeat personalities — among the small number of people with lasting mental health.

SOURCE: J.D. SCHAEFER *ET AL/JOURNAL OF ABNORMAL PSYCHOLOGY* 2017

Study	Subjects	Start age	Number of assessments	Length of follow-up
Great Smoky Mountains	1,420	9–14	Up to 9	12 years
Oregon	816	~17	4	14 years
Zurich	591	19–20	7	30 years
Christchurch	1,041	15	7	20 years
Dunedin	988	11	8	27 years



J. HIRSHFELD

ATOM & COSMOS

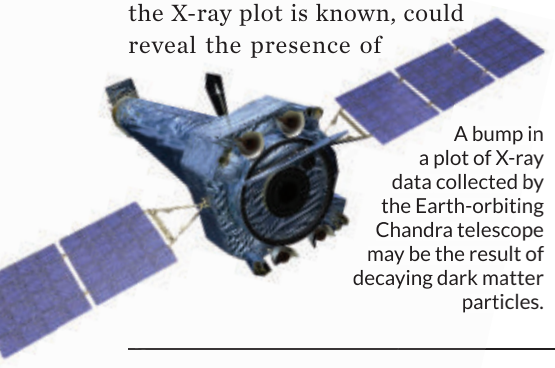
X-ray 'bump' hints at dark matter

New measurements eliminate some alternative explanations

BY EMILY CONOVER

A strange X-ray signal has popped up again in new measurements, raising hopes that it could be a sign of dark matter.

Data from NASA's Chandra X-ray Observatory reveal an excess of X-rays at a particular energy, scientists report online January 29 at arXiv.org. The X-ray "line," as the bump created in the X-ray plot is known, could reveal the presence of dark matter, an unknown substance that scientists believe constitutes most of the matter in the cosmos.



A bump in a plot of X-ray data collected by the Earth-orbiting Chandra telescope may be the result of decaying dark matter particles.

While the X-ray line has been found previously using several different telescopes, some searches have come up empty (*SN: 9/3/16, p. 17*). The new observation strengthens the case that the odd feature is real and eliminates some possible mundane explanations.

"This is a very exciting thing," says study coauthor Nico Cappelluti, an astrophysicist at Yale University. "This is another measurement that sees the line in another direction."

The new analysis used data taken when the telescope was observing deep space, rather than pointing at a particular cluster of galaxies. So if the signal indicated dark matter, it would be due to particles in the region surrounding the Milky Way, known as its halo. Hypothetical dark matter particles called sterile neutrinos are one possibility. Their decay could produce X-rays at the energy of the line, about 3,500 electron volts (*SN Online: 12/11/15*).

Cappelluti and colleagues found that the relative intensity of the line in the halo and the line previously found at the center of the Milky Way was consistent with the expected variation in concentration of dark matter in various parts of the galaxy.

Dark matter isn't the only possible explanation — standard physics might also explain the line. "There's definitely a lot of debate," says astroparticle physicist Shunsaku Horiuchi of Virginia Tech in Blacksburg, who was not involved with the new work. The line "looks like it's real, but then I don't know if it's dark matter or some atomic physics."

Although there's still a small chance that the result could be a statistical fluke, the analysis does eliminate some other possible explanations. Scientists had proposed that the line could be the result of sulfur ions grabbing an electron from hydrogen atoms in space, but that process couldn't explain the new data, Cappelluti and colleagues concluded. Likewise, a quirk of the telescope itself couldn't explain the line, they determined.

"It's kind of getting other people excited," Horiuchi says. ■

ATOM & COSMOS

Black holes may make good neighbors

Conditions near Milky Way's center seem ripe for star formation

BY ASHLEY YEAGER

Blobs of gas near the Milky Way's center may be just the right mass to harbor small, young stars and possibly planets, too. Any such budding stellar systems would face an uphill battle, developing only about two light-years from the galaxy's central supermassive black hole with its intense gravity and ultraviolet radiation. But it's not impossible for the small stars to survive in the hostile place, a new study suggests.

"Nature is very clever. It finds ways to work in extreme environments," says Farhad Yusef-Zadeh, an astrophysicist at Northwestern University in Evanston, Ill. Large stars millions of years old have been spotted near the galactic center before. But young, small stars would suggest star formation is ongoing, Yusef-Zadeh and colleagues report online January 20 at arXiv.org. The paper is also slated for publication in the *Monthly Notices of the Royal Astronomical Society*.

"It is fairly likely that planets and low-mass stars do form near the galactic center. But we do not know it for sure at the moment," says Avi Loeb, an astrophysicist at Harvard University. Loeb, who was not involved in the study, says the new evidence is "tentative at best."

Yusef-Zadeh and colleagues used ALMA, the Atacama Large Millimeter/submillimeter Array, in Chile, to study emissions from five of the 44 blobs of gas that the team discovered in 2014 (*SN Online: 3/24/15*). Four of the clouds had 0.03 to 0.05 as much mass as the sun, the team calculated. That's in line with what's needed to generate low-mass stars — about the size of the sun or a little bigger — and orbiting planets, Yusef-Zadeh says. He notes that the team has not detected these stars or planets, just that conditions are ripe for them to exist.

Loeb points out that the researchers had to infer the clouds' entire masses from the ALMA measurements, which may reveal only a surface look. The clouds may actually be denser; as a result, they would form more massive stars, challenging the team's claim that young, low-mass stars are developing.

Yusef-Zadeh and colleagues are planning additional studies with ALMA and are working on research that suggests that black holes may, in fact, help star formation. "It's paradoxical," Yusef-Zadeh says. "Black holes eat everything that comes too close to them. They tear everything apart. But they may actually make the formation of stars more efficient." ■

NGST

EARTH & ENVIRONMENT

Earth's big oxygen boost pushed back

Volcanism, glaciations coincided with Great Oxidation Event

BY THOMAS SUMNER

The breath of oxygen that enabled the emergence of complex life kicked off around 100 million years earlier than previously thought, new dating suggests.

Previous studies pegged the first appearance of relatively abundant oxygen in Earth's atmosphere, known as the Great Oxidation Event, at a little over 2.3 billion years ago. But new dating of ancient volcanic outpourings suggests that oxygen levels began a wobbly upsurge by 2.426 billion years ago, scientists report online February 6 in *Proceedings of the National Academy of Sciences*.

The date shakes up scientists' view of the environmental conditions that led to the oxygen rise, which prompted the evolution of life-forms called eukaryotes, says geologist Andrey Bekker of the University of California, Riverside. Volcanic eruptions at the time poured fresh rock over a supercontinent near the equator, and the planet dipped into a frigid period known as a Snowball Earth.

Similar events about 700 million years ago coincided with a second rise of oxygen, to near-modern levels, and some eukaryotes evolved into the first animals. Both oxygen upswings pushed life toward complexity, Bekker says. "For the first time, we see parallels between these two time intervals."

Oxygen-producing microbes probably first appeared over 3 billion years ago. But oxygen remained scant until, for unknown reasons, atmospheric concentrations rose from near zero to about 0.1 percent of modern levels. Dating the oxidation event's start has been tricky; few rocks from back then remain. Bekker and colleagues studied volcanic rocks in South Africa that neighbor a layer of minerals that need oxygen to form. Using an old method, geologists had dated the volcanic rocks to 2.222 billion years ago, well after the oxidation event's proposed start.

With modern methods that measure the radioactive decay of uranium in rocks, the researchers revised the volcanism's timing to 2.426 billion years ago. The new date — plus a separate eruption dated to 2.460 billion years ago that clearly happened before the oxygen rise — helps constrain the onset of the oxidation event.

The new work also tweaks the timing of another global event. The oldest known evidence of a Snowball Earth lies under and along the South African rocks. The new dating pushes that global glaciation event earlier as well — to around the same time as the oxidation event's start.

The oxygen rise and temperature drop may be related. The new data and existing evidence suggest that oxygen levels wavered between pitiful and plentiful several times during the Great Oxidation Event. (Oxygen levels stabilized 2.250 billion years ago until rising again more than a billion years later.) These oxygen ups and downs coincided with glacial and volcanic events, says geologist and study coauthor Ashley Gumsley of Lund University in Sweden.

Climate, oxygen and volcanism were linked during oxygen's rise, the researchers propose: Volcanic eruptions covered the supercontinent with fresh rock. That rock formed near the equator where heavy rains weathered the rock, drawing carbon dioxide from the air and washing nutrients into the ocean. Those nutrients nourished photosynthetic microbes, which produced an abundance of oxygen. Oxygen built up in the atmosphere and reacted with methane, reducing levels of that greenhouse gas. With less CO_2 and methane to warm the climate, Earth froze and oxygen-producing biological activity decreased. Volcanism spewed replacement CO_2 into the atmosphere over time and eventually reheated the planet.

Noah Planavsky, a Yale University geochemist, says he's uncertain about weathering's role in controlling the oxygen, but the new age is crucial to determining why oxygen's rise began when it did. Without dates, he says, that's impossible. ■

MATH & TECHNOLOGY

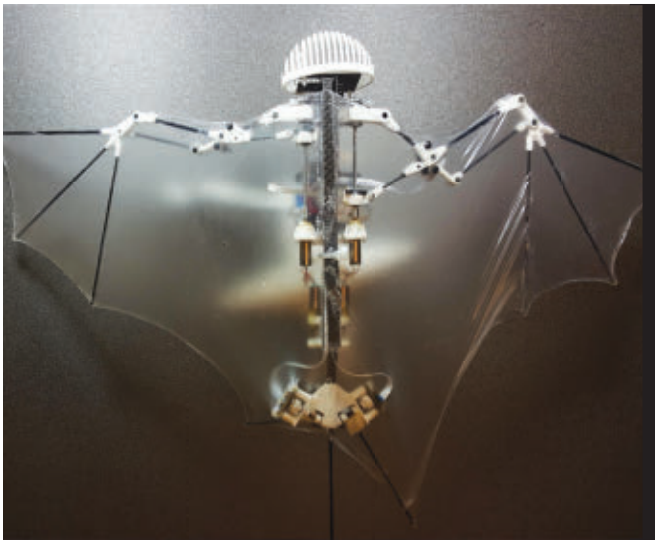
Bat robot takes wing

Fancy flight tricks are a breeze for a new robot. Bat Bot, a lightweight flier with silicone wings stretched over a carbon fiber skeleton, can cruise, dive and bank turn just like its namesake, researchers report February 1 in *Science Robotics*.

Numerous wing joints give bats exquisite control over their flight maneuvers. The researchers re-created nine of these joints so Bat Bot could flap its wings in sync, fold each wing independently and move each hind leg up and down.

Agile aerial machines like Bat Bot could one day soar over construction sites to track progress, study coauthor Seth Hutchinson of the University of Illinois at Urbana-Champaign said in a news briefing January 31.

— Meghan Rosen



A. RAMEZANI, S.-J. CHUNG AND S. HUTCHINSON/*SCIENCE ROBOTICS* 2017

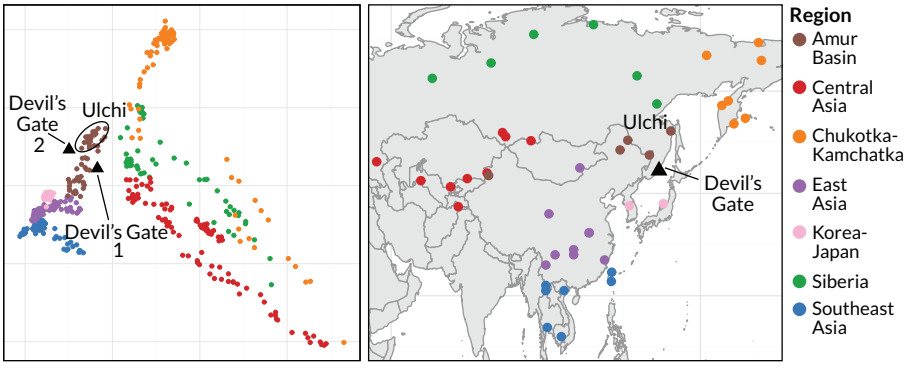
See how the robotic bat soars at **bit.ly/SN_BatBot**

HUMANS & SOCIETY

Genetic stability found in Russia

Far Eastern group wasn't swamped by incoming farmers

BY MEGHAN ROSEN



Matching up An analysis of 561 people from populations across Asia (colored dots represent individuals, left, corresponding to different populations, right) reveals that two ancient women (black triangles) from Devil's Gate Cave in Russia had DNA similar to modern Ulchi hunter-fishers.

In a remote corner of eastern Russia, where long winters bring temperatures that rarely flicker above freezing, the genetic legacy of ancient hunter-gatherers endures.

DNA from the 7,700-year-old remains of two women is surprisingly similar to that of people living in that area today, researchers report February 1 in *Science Advances*. That finding suggests that at least some people in East Asia haven't changed much over the last 8,000 years or so — a time when other parts of the world saw waves of migrants settle in.

"The continuity is remarkable," says paleogeneticist Carles Lalueza-Fox of the Institute of Evolutionary Biology in Barcelona. "It's a big contrast to what has been found in Europe."

In Western Europe especially, scientists studying ancient DNA have put together a picture of flux, says study coauthor Andrea Manica. "Every few thousand years, there are major turnovers of people." Around 8,000 years ago, he says, migrating farmers replaced hunter-gatherers in the area. And a few thousand years after that, Bronze Age migrants from Central Asia swept in.

In DNA from the bones and teeth of these ancient peoples, scientists can spot genetic signatures of different populations. When a population of farmers balloons, Lalueza-Fox says, the signatures of hunter-gatherers are mostly erased.

But whether that's true globally is unclear, says Manica, of the University of Cambridge. "We wanted to see what happened in other places.... Asia is huge compared to Europe, and it's been neglected."

Manica's team collected DNA from the skeletons of five ancient people found in a cave called Devil's Gate. The cave rests in a far east finger of Russia, tucked along the border of China and North Korea, and holds human remains, scraps of textiles and bits of broken pottery.

Researchers gathered enough DNA from two of the people to piece together about 6 percent of the genome, the complete set of genetic instructions inside a cell's nucleus. That's not much, Manica says, but it's enough to compare the Devil's Gate denizens with other people.

ATOM & COSMOS

Cause of cosmic makeover reassessed

Tiny galaxies played big role in reionization, researchers claim

BY ASHLEY YEAGER

Two cosmic magnifying glasses are giving astronomers a glimpse of some extremely faint galaxies that existed as far back as 600 million years after the Big Bang, which occurred 13.8 billion years ago. Such views suggest that tiny galaxies in the early universe played a crucial role in cosmic reionization — when ultraviolet radiation stripped electrons from hydrogen atoms in the cosmos.

"That we detected galaxies as faint as we did supports the idea that a lot of little galaxies reionized the early universe and that these galaxies may have played a bigger role in reionization than we thought," says Rachael Livermore, an astronomer at the University of Texas at Austin. She and colleagues report the results in the Feb. 1 *Astrophysical Journal*.

The team identified the dim galaxies in images taken with the Hubble Space Telescope while it was pointed at two closer galaxy clusters. Those clusters act as a gravitational lens, brightening and magnifying the light of fainter objects farther away. Subtracting the clusters' light revealed distant galaxies up to one-tenth as bright as those spotted previously.

Finding such faint galaxies implies that stars can form in much smaller galaxies than models have predicted and that there were enough of these small galaxies producing ultraviolet light to drive reionization almost entirely. Reionization refashioned the universe so that charged atoms instead of neutral ones pervaded space. Understanding that transition may help astronomers explain how stars and galaxies arose in the early universe.

"Such measurements are really challenging to make," says astronomer Brant Robertson of the University of California, Santa Cruz, who was not involved with the study. "They're really at the forefront of this field, so there are some questions about the techniques."

Astronomers led by Rychard Bouwens of Leiden University in the Netherlands argues that Livermore and colleagues haven't, in fact, detected galaxies quite as faint as they have claimed. Bouwens' team outlined its arguments online October 2

V. SISKA ET AL/SCIENCE ADVANCES 2017

The researchers analyzed DNA of people strewn across the far reaches of the continent — from the Dolgan in Siberia to the Thai thousands of kilometers south.

Genetically, the 7,700-year-old women closely resembled the Ulchi, a small group of hunter-fishers who still live off the land today. Manica can't say whether the Ulchi are direct descendants of the two Devil's Gate women, or just closely related. But the find suggests a pocket of stability in East Asia — a place where hunter-gatherers weren't swept out by, or folded into, booming groups of farmers.

Perhaps farming didn't take off there because the cold climate wasn't good for growing crops, Manica says. Or maybe the ideas and technologies from farmers and other migrants made it to the Ulchi without an accompanying influx of people. (The Ulchi aren't like hunter-gatherers of the past. They farm a bit and have adopted new ways to fish, hunt and store food, Manica points out.) "This shows that ideas can travel without people moving with them," Manica says.

That makes sense, Lalueza-Fox says. But scientists need more data from East Asia, and Southeast Asia, too, he says. "I have a feeling the whole story will be much more complicated." ■

at arXiv.org and in a paper submitted to the *Astrophysical Journal*. If the team is correct, that keeps the door open for other objects, such as black holes accreting matter and spitting out bright light, to have played a part in reionization.

Robertson says the disagreements motivate further work, noting that Livermore's team used a clever approach to spot what appear to be superfaint galaxies in the early universe. Now, both teams will have to see if that technique stands the test of time.

Livermore and colleagues plan to use the technique to search for faint galaxies lensed by other clusters Hubble has seen. Astronomers are also looking to the 2018 launch of the James Webb Space Telescope, which should be able to spot even fainter and more distant galaxies, to determine what drove reionization. ■

A.C. NOEL *ET AL*/*JOURNAL OF THE ROYAL SOCIETY INTERFACE* 2017

LIFE & EVOLUTION

What gives frogs the gift of grab

Quick-switch saliva, squishy tongue help catch prey

BY SUSAN MILIUS

Frogs' remarkable power to tongue-grab prey — some as big as mice or as oddly shaped as tarantulas — stems from a combo of peculiar saliva and a super-squishy tongue.

The first detailed analysis of the stickiness of frog saliva shows that the fluid can shift rather abruptly from gooey to runny, says mechanical engineer Alexis Noel of Georgia Tech in Atlanta. Those quick changes come in handy during the various phases of a single tongue strike. And it all works because the tongue itself is so soft, Noel and colleagues report February 1 in the *Journal of the Royal Society Interface*.

Internet videos of frogs feasting sparked Noel's curiosity about their ability "to eat furry things, hairy things, slimy things," she says, and to do so with speed and power. A frog tongue strikes five times as quickly as a human can blink.

But frog tongue tissue is so soft that none of the standard equipment on campus could measure it without special modifications. Noel eventually discovered that this tissue is as soft as a brain, which is itself softer than a marshmallow.

When the tongue shoots out at, say, a fly, the soft frog tissue splats on impact, spreading and curling around the prey. This action "massively increases the contact area" of frog tissue that can stick to the fly, enhancing grip, Noel says. Then frog saliva intensifies the effect.

Frogs don't have salivary glands spread around inside their mouths that drip saliva on their tongues. Instead, the glands are in the tongue itself. To see how sticky frog saliva might be, Noel spent several hours scraping some 15 frog tongues to put together enough spit for a single sample.

Noel and colleagues found that this saliva is what's called a shear-thinning liquid, which grows thinner and easier to stir or smear around when force is applied. Smacking into a fly jolts saliva from its sticky phase — more viscous than honey, Noel says — into the more "liquidy" phase "flowing into all the small cracks" of the insect body. As the tongue returns to the mouth, the spit thickens again, intensifying the grip.

To nab a snack, a frog shoots out its tongue, which wraps around the insect. Changeable saliva helps the tongue keep a firm grip on prey.

During that tongue jerk, acceleration can increase to 12 times the pull of Earth's gravity. Still, in spite of the spit's stickiness, the insect could be flung loose at this point, Noel calculated. But the soft stretchiness of the tongue, a natural bungee cord that retracts without too much of a jolt, prevents the loss, she says.

But once the fly is in the mouth, the tongue's grip needs to loosen so the fly can slide down the gullet. "Frogs actually use their eyeballs while swallowing," Noel says. Eyeballs sink into the head, turning from bulges to barely bumps and pushing food back toward the throat. The impact of the eyes jars the saliva into a runnier phase, easing its grip on the prey.

Frogs aren't the only hunters that tongue-snatch their prey. Chameleon tongues also can be very sticky, says Pascal Damman, who studies the physics of soft matter (including chameleon tongues) at the University of Mons in Belgium. He says the new findings remind him of how chameleons catch prey using gooey mucus and a stretchy tongue. ■

Watch high-speed video of frogs grabbing bugs at **bit.ly/SN_frogtongue**

ATOM & COSMOS

Mars may feature a stagnant interior

Meteorites' chemistry offers glimpse inside Red Planet

BY THOMAS SUMNER

An enduring source of magma on Mars fueled volcanic eruptions for billions of years, clues inside a rock flung from the Red Planet reveal.

The rock belongs to a batch of meteorites called shergottites that all came from the same volcanic system, researchers report February 1 in *Science Advances*. But the rock is much older than its counterparts. Previously discovered shergottites solidified from Martian magma 427 million to 574 million years ago; the newfound rock formed about 2.4 billion years ago, chemical analyses show.

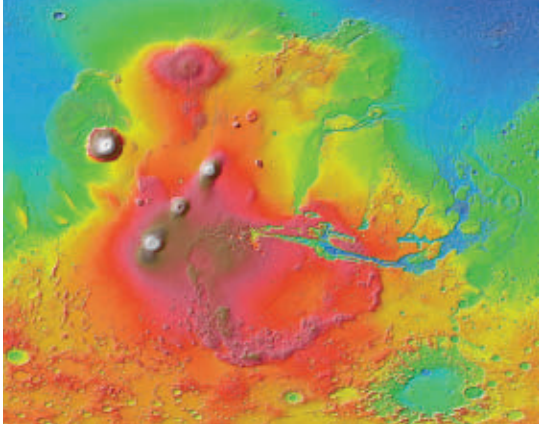
Such a range of ages means that a volcanic system on Mars churned out hot rocks from a stable magma source for nearly half of the planet's history, says Thomas Lapen, a geologist at the University of Houston. That endurance could help scientists better understand Mars' interior. "These are some of the longest-lived volcanoes in the solar system," Lapen says.

Lapen and colleagues studied a Martian meteorite found in Algerian desert in 2012. Elements in the rock serve as stopwatches that record the rock's history. Beryllium and aluminum isotopes, formed during exposure to cosmic rays, reveal that the rock zipped through space for about 1 million years. To pinpoint when the rock blasted off Mars, the researchers also had to figure out when the meteorite landed on Earth. The steady decay of carbon 14, left behind after cosmic ray collisions, suggests that happened about 2,300 years ago. The researchers suspect that, a little over a million years ago, a big impact in Mars' volcano-filled Tharsis region sent the meteorite and other shergottites into space.

The rocks share more than their exodus. Chemical similarities suggest that they all originated from the same source of hot rock deep within the Red Planet. That's surprising given that the mix of radioactive elements inside the newfound meteorite suggests it solidified 1.8 billion years earlier than the next oldest shergottite, Lapen says.

Mars has many volcanic systems, some of which have operated for perhaps billions of years. Many scientists had assumed that the magma feeding this volcanism changed over time as the interior mixed. But the absence of differences in the shergottites' composition suggests the interior is fairly stagnant. That may result from Mars' lack of plate tectonics, a process that helps blend Earth's innards, Lapen says. Understanding differences between Earth and Mars could reveal why the planets are so different today.

Similarities between the shergottites could have another explanation, says planetary scientist Stephanie Werner of the University of Oslo. Large impacts can melt rocks, resetting their age. The shergottites may have formed at the same time billions of years ago and then impacts altered some of their ages, she proposes. ■



A source of magma beneath volcanoes in Mars' Tharsis region (warmer colors denote higher elevations in this map) remained largely unchanged for billions of years, researchers say.

JPL-CALTECH/NASA, ARIZONA STATE UNIV.

EARTH & ENVIRONMENT

Sea life's mercury woes could grow

Climate change may alter food webs, boost neurotoxin

BY THOMAS SUMNER

Muddying of coastal waters by climate change could drastically increase levels of neurotoxic mercury in sea life, contaminating food supplies.

Shifting rainfall patterns may send 10 to 50 percent more water filled with dissolved bits of organic debris into some coastal areas by 2100. The material can cloud water, disrupting ecosystems by shifting the balance of microbes at the base of the food web, lab experiments suggest. That disruption can at least double methylmercury concentrations in tiny grazers called zooplankton, scientists report January 27 in *Science Advances*.

The extra mercury could travel up the food web to fish that humans eat, says Erik Björn, a biogeochemist at Umeå University in Sweden. Even small amounts of methylmercury, a form of the metal easily absorbed by animals, can cause birth defects and kidney damage.

Pollution from human activities such as fossil fuel burning has already tripled the amount of mercury that has settled in the ocean's top layer since the Industrial Revolution's start. At the same time, climate changes are washing more dark organic matter into the oceans by, for instance, boosting winter rainfall in some areas.

Björn's group replicated this increased runoff scenario with 5-meter-tall vats filled with marine microbes and dashes of methylmercury. Vats also darkened by extra organic matter showed a shift from light-loving phytoplankton to dark-dwelling bacteria that eat the extra material.

Zooplankton nosh on phytoplankton but not the bacteria. Instead the bacteria are eaten by protozoa, which zooplankton then hunt. Methylmercury is known to accumulate with each step up the food web. The researchers found that the addition of the protozoa middle step resulted in zooplankton methylmercury levels two to seven times higher than in vats without the extra organic matter.

Curbing mercury contamination is more complicated than controlling emissions, says Alexandre Poulain, a microbiologist at the University of Ottawa. "First we need to control emissions, but we also need to account for climate change." ■

MATTER & ENERGY

Neutron longevity remains elusive

New projects aim to pin down subatomic particle's decay rate

BY EMILY CONOVER

Lone neutrons quickly decay, but scientists don't agree on how long the particles stick around before their demise. New experiments could resolve the dispute — or deepen the mystery.

Outside of an atomic nucleus, neutrons survive only about 15 minutes on average. They quickly decay into a proton, an electron and an antineutrino. Two methods used for measuring the neutron lifetime with precision disagree, leaving scientists uncertain about the subatomic particle's true longevity (*SN: 5/19/12, p. 20*).

One technique involves containing chilled neutrons in a trap, or "bottle," waiting awhile and counting the remaining neutrons to determine how many decayed. Other experiments monitor beams of neutrons and count the number of decays by detecting the protons emitted. Bottle measurements come up with lifetimes about nine seconds shorter than beam measurements.

"This is actually fairly important for a number of things," physicist Robert Pattie said January 29. In particular, pinning down the neutron's lifetime is necessary for understanding how atomic nuclei began forming after the Big Bang. Scientists' neutron befuddlement makes it harder to calculate the properties of the early universe.

One drawback of typical bottle experiments is that neutrons can be absorbed or otherwise lost when they hit the wall of the bottle. So Pattie, of the Los Alamos National Laboratory in New Mexico, and colleagues are working on an updated bottle-style measurement using a magnetic field to keep neutrons from hitting the bottom of the trap, while gravity keeps them from flying out of the top.

Craig Huffer, a physicist at North Carolina State University in Raleigh, and colleagues are working on another style of bottle experiment that uses a magnetic field to trap neutrons. Rather than counting neutrons at the end, the researchers detect flashes of light produced as neutrons inside the bottle decay away.

In beam experiments, accuracy depends on making a careful count of the neutrons beamed in and the protons produced in the decays, Shannon Fogwell Hoogerheide, a physicist at the National Institute of Standards and Technology in Gaithersburg, Md., explained January 30. She and colleagues are refining their beam measurement to better enumerate protons and neutrons.

Some scientists have suggested the discrepancy could have deeper meaning. The short lifetime in bottle measurements could indicate that neutrons are somehow disappearing unexpectedly, making the lifetime appear shorter than it really is. "Kind of an out-there mechanism is that they've gone into some kind of alternative reality, which we call the mirror world," said physicist Ben Rybolt of the University of Tennessee. In such a world, all the particles we know of would be duplicated — mirror protons, neutrons and electrons could exist, and would interact only very slightly with the particles we know.

Jumping to such an explanation for the neutron lifetime discrepancy is "a little bit of a leap," Rybolt acknowledged, but such mirror particles could also explain the conundrum of dark matter, an unseen substance indicated by the motions of stars inside galaxies. To test the idea, Rybolt and colleagues are proposing to shoot beams of neutrons at a barrier and check if any make it through, which could indicate the particles had briefly become mirror neutrons.

The problem of measuring the neutron's lifetime is complex enough that a variety of new techniques are under preparation to unravel the issue. "I don't think one additional experiment can resolve the discrepancy," Huffer said. Instead, multiple new measurements with different techniques should eventually converge on the correct value. ■

MEETING NOTES

Blazars set distance record

A quintet of gamma-ray blazars — supremely bright galaxies that host supermassive black holes — are the most distant ever spotted, at more than 11.8 billion light-years away.

The blazars, seen by NASA's Fermi Gamma-ray Space Telescope, must have had whopper black holes, the biggest weighing 7 billion times the sun's mass, Roopesh Ojha of NASA's Goddard Space Flight Center in Greenbelt, Md., reported January 30.

As a blazar's black hole swallows up matter, bright jets shoot out high-energy light. The blazars are so distant that the universe was less than 2 billion years old when their light was emitted. To reach huge masses in such a short time, the black holes somehow gobbled up matter at a breakneck pace. — *Emily Conover*

Spin may tell black hole history

Scientists have devised a test to see if pairs of black holes — famous for creating gravitational waves when they merge — themselves formed from multiple, smaller black hole mergers.

The Advanced Laser Interferometer Gravitational-Wave Observatory, LIGO, has detected spacetime ripples from two sets of merging black holes. Scientists typically assume that black holes of the size that LIGO can detect formed in the collapse of a massive star. But in crowded patches of the universe, black holes could have formed over generations of unions, Maya Fishbach of the University of Chicago explained January 28.

In simulations, black holes that repeatedly merged reached a high spin rate. The spins of LIGO's black holes are lower than the predictions, suggesting that these black holes probably didn't form from multiple mergers. But the process could be so rare that testing it requires tens to hundreds of black hole detections, Fishbach said. — *Emily Conover*

BODY & BRAIN

Researchers close in on ricin antidote

Blend of antibodies could stem toxic effects, tests in mice show

BY MEGHAN ROSEN

It has been used by an assassin wielding an umbrella gun and sent in a suspicious letter to a president. Ricin, the potent toxin and bioterrorism agent, has no antidote and can cause death within days. But a cocktail of antibodies could one day offer victims at least a slim window for treatment.

A new study presented February 7 describes a ricin antidote that, in mice, works even days after exposure to the toxin. Another new study, presented the same day, offers a potential explanation for how such an antidote might work.

Doctors need some way to deal with ricin poisoning, said Patrick Cherubin, a cell biologist at the University of Central Florida in Orlando. Immunologist Nicholas Mantis of the New York State Department of Health in Albany agreed: "There is no specific treatment or therapy whatsoever."

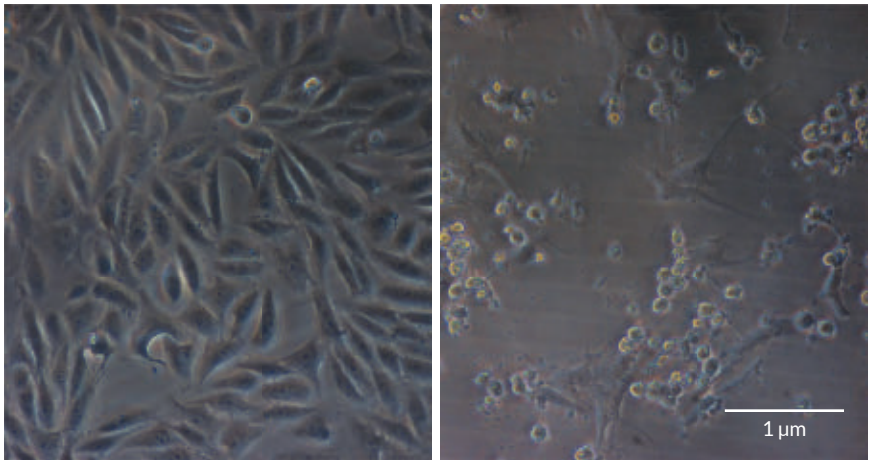
Though ricin has an innocuous origin (it's found in castor beans), the poison is anything but harmless. It's dangerous and relatively easy to spread — rated by the U.S. Centers for Disease Control and Prevention as a category B bioterrorism agent, just behind the highest-risk category A agents such as anthrax, plague and Ebola.

Ricin poisoning is rare but has been featured in some high-profile cases. In 1978, Bulgarian writer Georgi Markov was hit in the thigh with a ricin-poisoned pellet shot from an umbrella gun. A few days later, he was dead. In 2013, a letter addressed to President Barack Obama tested positive for granules of the deadly toxin. A Texas woman had ordered castor bean seeds and lye online for a do-it-yourself approach to making ricin. No one was injured.

> With antibodies hanging onto its back, ricin has trouble slipping into cells and wreaking its usual havoc.

Symptoms of ricin poisoning depend on how the toxin enters the body, and how much gets in. Inhaling ricin can make breathing so difficult that the skin turns blue. Ingesting ricin can cause diarrhea, vomiting and seizures. Death can come as soon as 36 hours after exposure.

Ricin is known as an RIP — a scary-sounding acronym that stands for ribosome-inactivating protein, said Mantis. In the cell, ribosomes serve as tiny protein factories. After ricin exposure, "the whole machinery comes to a screeching halt," he said. For cells, shutting down protein factories for too long is a death sentence.



Healthy monkey kidney cells (left) spread out across the bottom of a lab dish. Adding ricin to the cells (right) makes them detach from the dish and float, which can be a sign of sickness or death.

K. TETER LAB

Scientists have developed two promising vaccine candidates for ricin, though neither is available yet for use in humans. A vaccine may be "good for soldiers going into the field," said biochemist Ohad Mazor of the Israel Institute for Biological Research in Ness Ziona. But unvaccinated people are out of luck.

Mazor and colleagues developed a new treatment that could potentially help. The treatment is a mixture of three proteins called neutralizing antibodies; they grab onto ricin and don't easily let go. With antibodies hanging onto its back, ricin has trouble slipping into cells and wreaking its usual havoc.

Even 48 hours after inhaling ricin, 22 out of 30, or 73 percent, of mice treated with the antibodies survived, the team reported. The results will also appear in the March 1 *Toxicon*. Untreated mice died within a week.

Previously investigated antibody treatments for ricin work well only if mice are treated within hours after exposure, Mazor said. For poisoned humans, that may not be long enough to diagnose the problem. Mazor doesn't know how his antibodies might work in people, but he'd like to follow up his mouse work with studies in monkeys or pigs.

Scientists haven't figured out exactly how antibodies help animals recover, but another new study offers a clue. Cherubin and colleagues added ricin to monkey kidney cells in a dish, and then tracked how much protein was manufactured by the cells.

At high enough levels, ricin exposure shuttered the factories as expected. But when the researchers stopped exposing the cells to the toxin, protein synthesis started up again and the cells recovered.

"You need ongoing toxin delivery to eventually kill the cell," Cherubin said. It's possible that antibody treatments could cut off ricin delivery to cells, letting them bounce back from poisoning, said study coauthor Ken Teter, also a cell biologist at Central Florida. ■

MEETING NOTES

Zika virus 'spillback' into monkeys raises risk of future outbreaks

Scientists usually worry that animal diseases could spill over into humans. But "spillback" of Zika virus into monkeys in South America could be just as dangerous.

In areas where Zika infections are prevalent among humans and mosquitoes are abundant, the virus may be transmitted to wild primates, disease ecologist Barbara Han said February 6. If the disease gets established in monkeys or other wild primates, the animals may serve as reservoirs for future human outbreaks. That could make it nearly impossible to get rid of the virus, said Han, of the Cary Institute of Ecosystem Studies in Millbrook, N.Y.

Han and colleagues calculated the risk of Zika entering South American monkey populations using criteria that include species range, body size and diet.

Two contenders on her list of at-risk species — black-striped capuchin monkeys and common marmosets — had been found by other researchers to be infected with Zika viruses matching the human strain in Brazil. The finding indicates the spillback has already started. Capuchin monkeys are of particular concern because they are often kept as pets and used to attract tourists. "The possibility for close contact with humans is already there," Han said.
— Tina Hesman Saey

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Zika virus circulating among people in Brazil has been found to have also infected capuchin monkeys (*Sapajus libidinosus*, shown), which are often kept as pets, and marmosets (*Callithrix jacchus*). Other primates may also be at risk of contracting the virus. Scientists worry that the animals could serve as a Zika reservoir for outbreaks in the future.

Cold plasma puts the chill on norovirus particles

A nasty stomach virus that can linger on fruits and veggies may have met its match in cold plasma.

In experiments, the ionized gas, created by filtering room-temperature air through an electric field, virtually eliminated norovirus from lettuce, researchers reported February 7.

Norovirus is the leading cause of foodborne illness in the United States, infecting more than 20 million people every year. Sterilizing food with heat is one way to kill the virus, but that approach doesn't work for fresh produce. Cold plasma could be a way to sterilize fruits and vegetables without damaging them, said Hamada Aboubakr, a food microbiologist at the University of Minnesota in St. Paul.

Aboubakr and colleagues used a cold plasma device to blast contaminated romaine lettuce leaves and stainless steel surfaces. After five minutes, the plasma wiped out about 99 percent of norovirus particles.

The researchers are testing the device on other foodborne viruses such as hepatitis A, which sickened more than 140 people in the United States last year after they ate contaminated strawberries. Unpublished experiments have shown that cold plasma also can destroy antibiotic-resistant bacteria on chicken breasts and other leafy greens. Aboubakr hopes to adapt the technology for use in restaurants, on cruise ships and in the produce aisles of grocery stores.
— Cassie Martin

Rapid Ebola test to detect early infection in the works

Diagnosing Ebola earlier is becoming almost as easy as taking a home pregnancy test.

Scientists are developing antibodies for a test that can sniff out the deadly virus more quickly and efficiently than current tests, researchers reported February 6.

Detecting Ebola's genetic material in patients' blood samples now takes 12 to 24 hours and requires access to a specialized laboratory. Simpler and speedier tests are available. They use antibodies — specialized proteins that latch onto and flag virus particles — and work somewhat like a pregnancy test. Within 10 or 15 minutes of dabbing a blood sample onto a piece of paper, a colored line confirms the presence of the virus. But currently these tests do not give accurate results until the patient has been sick for a while, said immunologist Haley DeMers of the University of Nevada, Reno School of Medicine.

Antibodies more strongly attracted to the virus could track it down in a blood sample with just a few circulating viral particles, detecting disease before the virus takes over, DeMers and colleagues suspected. Their test uses two such antibodies. One, tagged with gold nanoparticles, drags the virus particles out of a sample. A piece of paper wicks up the tagged bits of virus, where they're ensnared by the second antibody, which reveals their presence as a colored line. These antibody pairs need to work well together, grabbing different parts of the virus particle so they don't interfere with each other.

After generating candidate antibodies in mice, DeMers and colleagues tested over 1,000 pairings. The researchers are now fine-tuning the five most effective combinations. *— Laurel Hamers*

BODY & BRAIN

Brain protein's grip on LSD imaged

Receptor's structure explains why acid trips last so long

BY MEGHAN ROSEN

Locked inside a human brain protein, LSD takes an extra-long trip.

New X-ray crystallography images reveal how a molecule of the hallucinogen gets trapped in a protein that senses serotonin, a key chemical messenger in the brain. The protein, a serotonin receptor, belongs to a family of proteins involved in everything from perception to mood.

The work is the first to decipher the structure of such a receptor bound to LSD, which gets snared in the protein for hours. That could be the reason for lengthy "acid trips," Bryan Roth and colleagues report in the Jan. 26 *Cell*. It's "the first snapshot of LSD in action," he says. "Until now, we had no idea how it worked at the molecular level."

But the results might not be that relevant to people, warns Cornell University biophysicist Harel Weinstein.

Roth's group didn't capture the main target of LSD, a serotonin receptor called 5-HT_{2A}, instead imaging the related receptor 5-HT_{2B}. That receptor is "important in rodents, but not that important in humans," Weinstein says.

Roth's team has worked for decades on 5-HT_{2A}, but the receptor has "thus far been impossible to crystallize," he says. Predictions of 5-HT_{2A}'s structure, though, are similar to that of 5-HT_{2B}.

LSD, or lysergic acid diethylamide, was first cooked up in a chemist's lab in 1938. It was popular (and legal) for recreational use in the early 1960s, but the United States later banned the drug.

It's known for altering perception and mood — and for its unusually long-lasting effects. An acid trip can run some 15 hours; at high doses, effects can linger for days. "It's an extraordinarily potent drug," says Roth, a psychiatrist and pharmacologist at the University of North Carolina School of Medicine in Chapel Hill.

Scientists have long known that LSD targeted serotonin receptors in the brain. These proteins, which are also found in the intestine and elsewhere in the body, lodge within nerve cells' outer membranes and relay signals to the cells' interiors. But no one knew exactly how LSD fit into the receptors. Roth and colleagues' work shows the drug hunkered deep inside a pocket of its receptor, grabbing onto an amino acid that acts like a handle to pull down a lid.

Tweaking that handle so that LSD could no longer hang on allowed the drug to slip out of the pocket faster than when the handle was intact, Roth says. The results suggest that LSD's grip on the receptor is what keeps it trapped inside. "That explains to a great extent why LSD is so potent and why it's so long-lasting," Roth says.

David Nutt, a neuropsychopharmacologist at Imperial College London, agrees. He calls the work an "elegant use of molecular science." ■

EARTH & ENVIRONMENT

Hot nests a major sea turtle threat

Preponderance of females isn't worst climate change effect

BY SUSAN MILIUS

Worries about climate change threatening sea turtles may be misdirected.

Warming that could lead to far more female hatchlings than males isn't the biggest danger from climate shifts. Lethally overheated beach nests are more problematic, researchers argue in the Feb. 8 *Proceedings of the Royal Society B*.

Climate change can meddle with sex ratios of the seven species of sea turtles because their embryos start life without a genetically fixed sex. Nest temperatures higher than about 29° Celsius tip the ratio toward more female hatchlings, explains study coauthor Graeme Hays, a marine ecologist at Deakin University in Warrnambool, Australia.

Warm the nesting beaches enough, and sea turtle populations with few to no male mates might get feminized to extinction, biologists have warned. Yet records from 75 nesting sites around the world show female-biased populations are thriving. "That's not really the No. 1 concern," Hays says. "A few male turtles already go a long way." Youngsters dying in overheated nests seems to be a more serious problem, Hays and colleagues say.

One reason heavily female populations haven't crashed is the difference between male and female breeding frequency. A male shows up to mate in the waters off the nesting beach roughly twice as frequently as a female does, perhaps every two years instead of every four, Hays says.

Disproportionately higher death rates among female hatchlings also could temper the female bias generated by higher nesting beach temperatures. Warmer spots more likely to make embryos turn female are also more likely to cook them.

In sandy beach nests, temperatures affect both sex and survival of sea turtle hatchlings.

KOSTAS PAPAFITSOROS

At extreme temperatures, however, everybody loses. Should a nest reach 35° C, a group of 100 eggs would yield on average only five living female hatchlings plus a ghost of a fraction of a male, mathematical simulations predict.

Computer simulations suggest that as a leatherback turtle nesting site in Costa Rica overheats, dwindling survival of young turtles could nearly wipe out the population within a century, says Vincent Saba, a biological oceanographer with the National Oceanic and Atmospheric Administration's Northeast Fisheries Science Center at Princeton University. ■

HUMANS & SOCIETY

Iron Age trade secrets revealed

Crypt links Central Europe to Mediterranean cultures

BY BRUCE BOWER

Discoveries in a richly appointed 2,600-year-old burial chamber point to surprisingly close ties between Central Europe's earliest cities and Mediterranean societies. Dated to 583 B.C., this grave also helps pin down when people inhabited what may have been the first city north of the Alps.

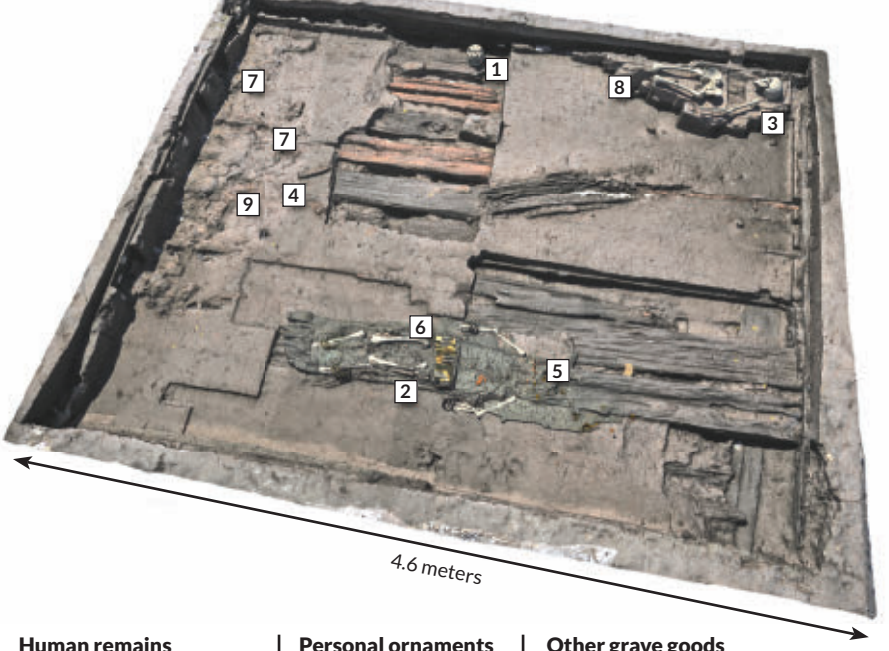
An array of fine jewelry, luxury goods and even a rare piece of horse armor found in the grave indicates that "there were craftsmen working in the early Celtic centers north of the Alps who learned their crafts south of the Alps," says archaeologist Dirk Krausse of the Archaeological State Office of Baden-Württemberg, Germany.

Previous research has established that speakers of Celtic languages inhabited parts of Europe as early as 3,300 years ago. Celtic iron makers appeared in Central Europe by around 2,700 years ago — marking the beginning of that region's Iron Age — and founded what's now called the Hallstatt culture.

The grave and a smaller adjoining burial lie in a German cemetery across the Danube River from an early Iron Age hill fort called the Heuneburg. Along with yielding insights into long-distance trade, these graves provide the earliest evidence of Hallstatt people elaborately interring women and even children, Krausse and colleagues report in the February *Antiquity*.

This gold sphere (two angles shown) from a burial dated to the Iron Age in Germany shows Mediterranean influences.

"The main burial represents one of the oldest examples of an exceptionally rich female grave and serves as further testimony of the important social role of certain women in Hallstatt communities," says archaeologist Manuel Fernández-Götz of the University of Edinburgh.



Human remains	Personal ornaments	Other grave goods
1. Female skull	**4.** Gold pinhead	**7.** Wild boar tusks
2. Headless female skeleton	**5.** Gold spheres	**8.** Bronze forehead armor for horse
3. Other female skeleton	**6.** Bronze belt plate	**9.** Knife

Burial digs A laser scanner produced this 3-D view of a 2,600-year-old burial chamber from Central Europe. It includes a headless female skeleton surrounded by jewelry, the female's skull, another woman, mounted boar tusks and bronze forehead armor for a horse, among other items. The grave offers clues to the important status of some women in Iron Age societies.

While surveying earthen mounds covering graves at the site in 2005, Krausse's team noticed a fragment of a gold-plated bronze brooch on the ground. Excavation revealed that the brooch came from the grave of a child whose skeleton was surrounded by gold and gold-plated jewelry.

The grave was an addition to a larger burial chamber. Because farming activity threatened the site, cranes were used in 2010 to hoist out the chamber and surrounding soil in a block weighing 80 metric tons.

Planks of oak and silver fir formed the chamber. Comparisons of growth rings in the planks with previously dated tree rings in the region indicate the tomb was built in 583 B.C. Earlier excavations had suggested that the Heuneburg and several other early Iron Age settlements in Germany and France were the first cities north of the Alps, but the grave provides the most precise date yet. Previously, settlements dating to between 2,200 and 2,000 years ago had been considered the first Central European cities.

Inside the chamber, the team discovered a 30- to 40-year-old woman's headless skeleton. Her lower jaw and skull were found at two other spots in the grave. Objects placed on and around the skeleton included gold, bronze, amber and jet jewelry. Decorative styles of some items showed Mediterranean influences. Researchers also found two pairs of boar tusks mounted on large pendants.

Another woman's skeleton and pieces of bronze jewelry rested in a corner of the chamber. It's unclear whether both bodies were buried at the same time.

A decorated bronze sheet found near the second skeleton's feet was a piece of armor, called a chamfron, that covered a horse's forehead, the researchers say. Traces of plant netting and fur preserved on the sheet's inside surface come from padding, they suspect. CT scans revealed remains of an iron horse bit at one end of the sheet, where it fit in the mouth. It's the first chamfron found at a Hallstatt site, and it resembles horse armor from around the same time found in several Mediterranean cultures, Krausse says.

"The tide is finally shifting," says anthropologist Bettina Arnold of the University of Wisconsin–Milwaukee, toward accepting links between early European Iron Age cities and societies south of the Alps. ■

ATOM & COSMOS

Oxygen from Earth bombards moon

Life on Earth may have made its mark on the moon billions of years before Neil Armstrong's famous first step.

Observations by Japan's moon-orbiting Kaguya spacecraft suggest that oxygen atoms from Earth's upper atmosphere bombard the moon's surface for a few days each month. This oxygen onslaught began in earnest around 2.4 billion years ago when photosynthetic microbes first flooded the atmosphere with the gas (see Page 9), planetary scientist Kentaro Terada of Osaka University in Japan and colleagues propose January 30 in *Nature Astronomy*.

The oxygen atoms begin their incredible journey in the upper atmosphere, where they are ionized by ultraviolet radiation, the researchers suggest. Electric fields or plasma waves accelerate the oxygen ions into the magnetic cocoon that envelops Earth. One side of that magnetosphere stretches away from the sun like a flag in the wind. For five days each lunar cycle, the moon passes through the magnetosphere and is barraged by earthly ions, including oxygen.

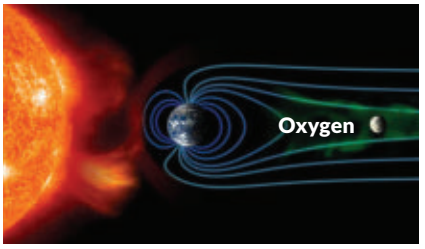
Based on Kaguya's measurements of this space-traveling oxygen in 2008, Terada and colleagues estimate that at least 26,000 oxygen ions per second hit each square centimeter of the lunar surface during the five-day period. The uppermost lunar soil may therefore preserve bits of Earth's ancient atmosphere, the researchers write, though determining which atoms blew over from Earth versus the sun would be difficult.
— Thomas Sumner

GENES & CELLS

Gene editing helps cows fight tuberculosis infections

Mooooove over CRISPR chickens, pigs and goats. The powerful gene-editing tool is another step closer to transforming the barnyard.

Researchers at China's Northwest Agriculture and Forestry University tailored a CRISPR/Cas9 technique to give cloned dairy cows a leg up against the bacteria behind bovine tuberculosis (*Mycobacterium bovis*), a threat to cows in many parts of the world. Last year, another group used TALENs, an older gene-editing technology, to create two cows without horns, but this is the first time scientists have reported using CRISPR to insert a gene in cattle.



Oxygen atoms in Earth's upper atmosphere escape into the planet's magnetosphere (blue lines). When passing through the magnetosphere, the moon gets bombarded by the oxygen (green haze), researchers propose.

The team cut and pasted a bovine gene that codes for NRAMP1, a protein linked to resistance against TB and other bacterial infections, into the genomes of fetal dairy cow cells. Through cloning, mother cows gave birth to 20 calves with the *NRAMP1* gene. Of the 11 calves that survived past three months, six were tested for TB resistance and showed heightened TB-fighting abilities, the team reports February 1 in *Genome Biology*. *— Helen Thompson*

MATTER & ENERGY

Gold ion smashups create most swirly fluid ever

High-energy ion collisions have produced the swirliest fluid ever discovered, in a state of matter that mimics the early universe.

To create the überwhirly liquid, scientists slammed gold ions together at velocities approaching the speed of light at Brookhaven National Laboratory in Upton, N.Y. Such collisions, performed in Brookhaven's Relativistic Heavy Ion Collider, cook up an ultrahot fluid, re-creating the state of the universe millionths of a second after the Big Bang, before protons and neutrons had formed. In this fluid, known as a quark-gluon plasma, the constituents of protons and neutrons — quarks and gluons — intermingle freely (*SN: 12/10/16, p. 9*).

Scientists already knew that this fluid is the hottest ever produced in a laboratory, and that it has almost no viscosity. Now, physicists can add one more unusual property to the list. The quark-gluon plasma created in such collisions has an average vorticity — or swirliness — of about 9 billion trillion radians per second, researchers from the STAR Collaboration report online January 23 at arXiv.org. That's vastly more than other known fluids. Even the core of a supercell tornado has a vorticity of only 0.1 radians per second.

To measure vorticity, the scientists studied a quantum mechanical property called spin from particles produced in the collision known as lambda baryons. The spin, an intrinsic type of angular momentum, tends to align with the vorticity of the fluid, providing a window into the plasma's gyrations.
— Emily Conover

ATOM & COSMOS

New data fuel further debate on universe's expansion rate

A new estimate of how fast the universe is expanding supports one side of an ongoing debate, favoring a more rapid expansion.

Observations of type 1a supernovas imply a faster expansion rate (known as the Hubble constant) than studies of the cosmic microwave background — light that originated early in cosmic history (*SN: 8/6/16, p. 10*). Scientists with the H0LiCOW collaboration have now weighed in using quasars, ultrabright light sources stirred up by supermassive black holes.

Supernova measurements indicate that distant galaxies are separating from one another by 73 kilometers per second for each megaparsec (about 3.3 million light-years) of distance between them. Cosmic microwave background experiments peg the number at 67 km/s per megaparsec. The new quasar measurement, 72 km/s per megaparsec, agrees with the supernova result, the scientists report in the March issue of *Monthly Notices of the Royal Astronomical Society*.

The scientists observed five distant quasars. Between each quasar and Earth is a large, massive galaxy. That intervening mass bends light like a lens, splitting each

OSAKA UNIV., NASA

quasar's light into multiple images.

Light from each image took a different path to Earth, so travel time differed, too. The quasars' flickers allowed scientists to measure the delays — images from the same quasar flickered at different times due to the different paths taken. Because the light's travel time also depends on how fast the universe is expanding, scientists could calculate the Hubble constant by monitoring the delays.

If the disagreement persists, it could indicate something amiss in scientists' understanding of the cosmos, perhaps related to the mysterious dark energy that is accelerating the universe's expansion. — *Emily Conover*

LIFE & EVOLUTION

Cone snails wander in circles, lose focus with boosted CO_2

Cone snails, normally stealthy hunters, become clumsy and unfocused in water with increased levels of carbon dioxide.

As atmospheric CO_2 levels rise, so do levels in the ocean, changing the chemistry of the seawater and causing ocean acidification. Cone snails (*Conus marmoreus*) that spent several weeks in water dosed to simulate CO_2 levels predicted for the end of the 21st century had trouble catching their favorite snack, jumping snails. Only 10 percent caught and ate their prey, compared with 60 percent of snails living in water with current CO_2 levels, researchers report February 1 in *Biology Letters*.

While the higher-CO_2 snails were more active in general, they moved in "wiggly lines, and some even went in a circle," says study coauthor and marine biologist Sue-Ann Watson of James Cook University in Townsville, Australia.

In a previous study, Watson showed that jumping snails were less able to escape attacking cone snails when exposed to higher levels of CO_2 (*SN Online: 11/12/13*). Together, the studies are the first to show the effects of ocean acidification on the behavior of both invertebrate predators and their prey, Watson says. — *Elizabeth S. Eaton*

EARTH & ENVIRONMENT

3-billion-year-old crystals hint at lost continent's fate

Relics of a long-lost continent may lurk beneath the Indian Ocean.

Zircon crystals coughed up by volcanic eruptions on the island of Mauritius are around 2.5 billion to 3 billion years old. That's billions of years older than the island itself, researchers report January 31 in *Nature Communications*. The zircons, the researchers propose, are remnants of an ancient continent called Mauritia that formed part of the nexus of Madagascar and India before the two landmasses split apart around 84 million years ago (*SN: 1/21/17, p. 18*).

Comparing the crystals' ages with those of nearby landmasses, petrologist Lewis Ashwal of the University of the Witwatersrand in Johannesburg and colleagues traced Mauritia's fate. Volcanic eruptions and shifting tectonic plates fragmented Mauritia, the researchers say, and the land was eventually buried under thick layers of lava. Some of that land, including the zircon crystals, was recycled into the rising plume of magma that fueled the eruptions that eventually built Mauritius.

A handful of zircons dating back nearly 2 billion years had already been uncovered in the island's sands. Some scientists raised concerns that those crystals were brought to the island from elsewhere as part of ship ballast or construction material. Ashwal and colleagues pried the newfound crystals from rocky outcrops on the island, erasing any doubts of the zircons' origins. — *Thomas Sumner*

LIFE & EVOLUTION

Mechanical force helps guide hydra regeneration process

Hydras, petite pond polyps known for their seemingly eternal youth, exemplify the art of bouncing back (*SN: 7/23/16, p. 26*). The animals' cellular scaffolding, or cytoskeleton, can regrow from a slice of tissue that's just 2 percent of the original hydra's full body size. Researchers thought that molecular signals told cells where and how to rebuild, but new evidence suggests there are other forces at play.

Physicist Anton Livshits and colleagues at the Technion-Israel Institute of Technology in Haifa genetically engineered *Hydra vulgaris* specimens so that stretchy protein fibers called actins, which form the cytoskeleton, lit up under a microscope. Then, the team sliced and diced to look for mechanical patterns in the regeneration process.

Actin fibers in pieces of hydra exert mechanical force that lines up new cells and guides the growth of the animal's head and tentacles, the researchers found. Turning off motor proteins that move actin stopped regeneration, and physically manipulating actin fiber alignment resulted in hydras with multiple heads. Providing hydras with further structural stability encouraged tissue slices to grow normally. Both mechanical and molecular forces may mold hydras in regeneration, the researchers report in the Feb. 7 *Cell Reports*. — *Helen Thompson*

Cone snails (right) hunt jumping snails (left). Research suggests that the behavior of both predator and prey will be affected by ocean acidification.

ARC CENTRE OF EXCELLENCE IN CORAL REEF STUDIES

Built for SPEED

More sustainable approaches could get reactions moving

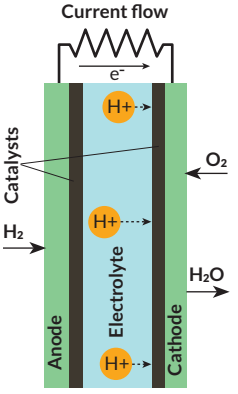
By Laurel Hamers

Platinum, one of the rarest and most expensive metals on Earth, may soon find itself out of a job. Known for its allure in engagement rings, platinum is also treasured for its ability to jump-start chemical reactions. It's an excellent catalyst, able to turn standoffish molecules into fast friends. But Earth's supply of the metal is limited, so scientists are trying to coax materials that aren't platinum — aren't even metals — into acting like they are.

For years, platinum has been offering behind-the-scenes hustle in catalytic converters, which remove harmful pollutants from auto exhaust. It's also one of a handful of rare metals that move along chemical reactions in many well-established industries. And now, clean energy technology opens a new and growing market for the metal. Energy-converting devices like fuel cells being developed to power some types of electric vehicles rely on platinum's catalytic properties to transform hydrogen into electricity. Even generating the hydrogen fuel itself depends on platinum.

Without a cheaper substitute for platinum, these clean energy technologies won't be able to compete against fossil fuels, says Liming Dai, a materials scientist at Case Western Reserve University in Cleveland.

To reduce the pressure on platinum, Dai and others are engineering new materials that have the same catalytic powers as platinum and other metals — without the high price tag. Some researchers are replacing expensive metals with cheaper, more abundant building blocks, like carbon. Others are turning to biology, using catalysts perfected by years of evolution as inspiration. And when platinum really is best for a job, researchers are retooling how it is used to get more bang for the buck.



Adding zip In a fuel cell, catalysts help hydrogen and oxygen atoms reshuffle, forming water. In the process shown, hydrogen ions move through an electrolyte while hydrogen's electrons generate current. Hydrogen and oxygen meet at the cathode.

Moving right along

Catalysts are the unsung heroes of the chemical reactions that make human society tick. These molecular matchmakers are used in manufacturing plastics and pharmaceuticals, petroleum and coal processing and now clean energy technology. Catalysts are even inside our bodies, in the form of enzymes that break food into nutrients and help cells make energy.

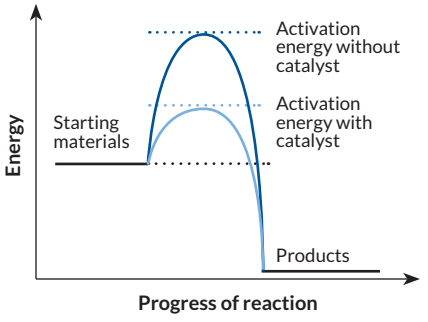
During any chemical reaction, molecules break chemical bonds between their atomic building blocks and then make new bonds with different atoms — like swapping partners at a square dance. Sometimes, those partnerships are easy to break: A molecule has certain properties that let it lure away atoms from another molecule. But in stable partnerships, the molecules are content as they are. Left together for a very long period of time, a few might eventually switch partners. But there's no mass frenzy of bond breaking and rebuilding.

Catalysts make this breaking and rebuilding happen more efficiently by lowering the activation energy — the threshold amount of energy needed to make a chemical reaction go. Starting and ending products stay the same; the catalyst just changes the path, building a paved highway to bypass a bumpy dirt road. With an easier route, molecules that might take years to react can do so in seconds instead. A catalyst doesn't get used up in the reaction, though. Like a wingman, it incentivizes other molecules to react, and then it bows out.

A hydrogen fuel cell, for example, works by reacting hydrogen gas (H_2) with oxygen gas (O_2) to make water (H_2O) and electricity. The fuel cell needs to break apart the atoms of the hydrogen and oxygen molecules and reshuffle them into new molecules. Without some assistance, the reshuffling happens very slowly. Platinum propels those reactions along.

Platinum works well in fuel cell reactions because it interacts just the right amount with both hydrogen and oxygen. That is, the platinum surface attracts the gas molecules, pulling them close together to speed along the reaction. But then it lets its handiwork float free. Chemists call that "turnover" — how efficiently a catalyst can draw in molecules, help them react, then send them back out into the world.

Platinum isn't the only superstar catalyst. Other metals with similar chemical properties also get the job done — palladium, ruthenium and iridium, for example. But those elements are also expensive and hard to get. They are so good at what they do that it's hard to find a substitute. But promising new options are in the works.



A lesser effort Catalysts lower the amount of energy needed to make a chemical reaction run. The starting materials and ending products are the same, but the catalyst offers an easier route to get between the two.

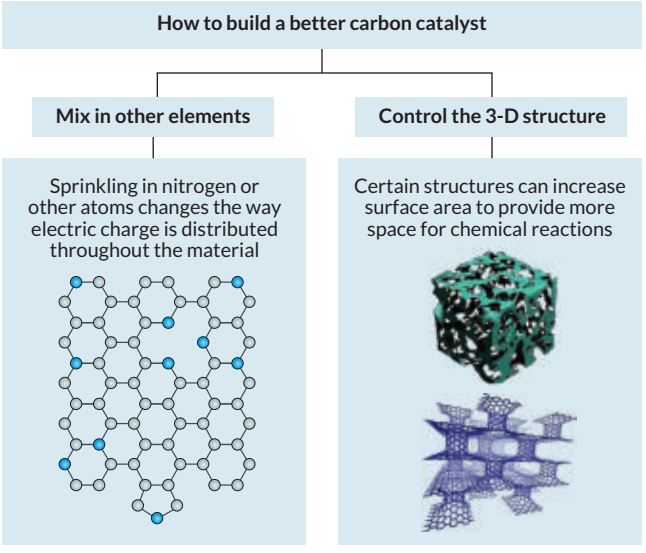
Carbon is key

Carbon is a particularly attractive alternative to precious metals like platinum because it's cheap, abundant and can be assembled into many different structures.

Carbon atoms can arrange themselves into flat sheets of orderly hexagonal rings, like chicken wire. Rolling these chicken wire sheets — known as graphene — into hollow tubes makes carbon nanotubes, which are stronger than steel for their weight. But carbon-only structures don't make great catalysts.

"Really pure graphene isn't catalytically active," says

OPPOSITE: JAMES PROVOST; THIS PAGE, BOTH: E. OTWELL



Carbon and then some By itself, carbon is not a great catalyst. But mixing in other elements (left) and changing its three-dimensional structure (right) give it new powers. Scientists can vary these parameters to design carbon catalysts suited to different situations.

Huixin He, a chemist at Rutgers University in Newark, N.J. But replacing some of the carbon atoms in the framework with nitrogen, phosphorus or other atoms changes the way electric charge is distributed throughout the material. And that can make carbon behave more like a metal. For example, nitrogen atoms sprinkled like chocolate chips into the carbon structure draw negatively charged electrons away from the carbon atoms. The carbon atoms are left with a more positive charge, making them more attractive to the reaction that needs a nudge.

That movement of electrical charge is a prerequisite for a material to act as a catalyst, says Dai, who has pioneered the development of carbon-based, metal-free catalysts. His lab group demonstrated in 2009 in *Science* that clumps of nitrogen-containing carbon nanotubes aligned vertically — like a fistful of uncooked spaghetti — could stand in for platinum to help break apart oxygen inside fuel cells.

To perfect the technology, which he has patented, Dai has been swapping in different atoms in different combinations and experimenting with various carbon structures. Should the catalyst be a flat sheet of graphene or a forest of rolled up nanotubes, or some hybrid of both? Should it contain just nitrogen and carbon, or a smorgasbord of other elements, too? The answer depends on the specific application.

In 2015 in *Science Advances*, Dai demonstrated that nitrogen-studded nanotubes worked in acid-containing fuel cells, one of the most promising designs for electric vehicles.

Other researchers are playing their own riffs on the carbon concept. To produce graphene's orderly structure requires just the right temperature and specific reaction conditions. Amorphous carbon materials — in which the atoms are randomly clumped together — can be easier to make, Rutgers' He says.

In one experiment, He's team started with liquid phytic acid, a substance made of carbon, oxygen and phosphorus. Microwaving the liquid for less than a minute transformed it into a sooty black powder that she describes as a sticky sort of sand.

"Phytic acid strongly absorbs microwave energy and changes it to heat so fast," she says. The heat rearranges the atoms into a jumbled carbon structure studded with phosphorus atoms. Like the nitrogen atoms in Dai's nanotubes, the phosphorus atoms changed the movement of electric charge through the material and made it catalytically active, He and colleagues reported last year in *ACS Nano*.

The sooty phytic acid–based catalyst could help move along a different form of clean energy: It sped up a reaction that turns a big, hard-to-use molecule found in cellulose — a tough, woody component of plants — into something that can react with other molecules. That product could then be used to make fuel or other chemicals. He is still tweaking the catalyst to make it work better.

He's catalyst particles get mixed into the chemical reaction (and later need to be strained out). These more jumbled carbon structures with nitrogen or phosphorus sprinkled in can work in fuel cells, too — and, she says, they're easier to make than graphene.

Enzyme-inspired energy

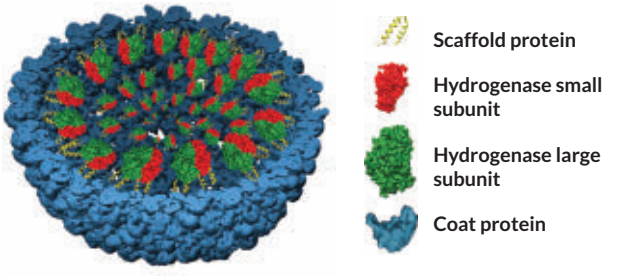
Rather than design new materials from the bottom up, some scientists are repurposing catalysts already used in nature: enzymes. Inside living things, enzymes are involved in everything from copying genetic material to breaking down food and nutrients.

Enzymes have a few advantages as catalysts, says M.G. Finn, a chemist at Georgia Tech. They tend to be very specific for a particular reaction, so they won't waste much energy propelling undesired side reactions. And because they can evolve, enzymes can be tailored to meet different needs.

On their own, enzymes can be too fragile to use in industrial manufacturing, says Trevor Douglas, a chemist at Indiana University in Bloomington. For a solution, his team looked to viruses, which already package enzymes and other proteins inside protective cases.

"We can use these compartments to stabilize the enzymes, to protect them from things that might chew them up in the

Taking from nature Scientists have engineered bacteria to pump out biological catalysts called hydrogenase enzymes (red and green) packaged inside protective casings (blue). The packaging could help the fragile enzymes work as catalysts in an industrial setting.



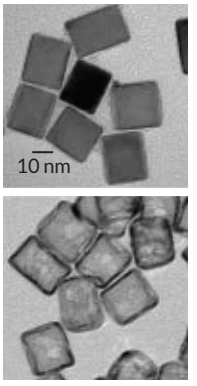
FROM TOP: X. LIU, L. DAI/*NATURE REVIEWS MATERIALS* 2016; P.C. JORDAN *ET AL*/*NATURE CHEMISTRY* 2016

environment," Douglas says. The researchers are engineering bacteria to churn out virus-inspired capsules that can be used as catalysts in a variety of applications.

His team mostly uses enzymes called hydrogenases, but other enzymes can work, too. The researchers put the genetic instructions for making the enzymes and for building a protective coating into *Escherichia coli* bacteria. The bacteria go into production mode, pumping out particles with the hydrogenase enzymes protected inside, Douglas and colleagues reported last year in *Nature*. The protective coating keeps chunky enzymes contained, but lets the molecules they assist get in and out.

"What we've done is co-opt the biological processes," Douglas says. "All we have to do is grow the bacteria and turn on these genes." Bacteria, he points out, tend to grow quite easily. It's a sustainable system, and one that's easily tailored to different reactions by swapping out one enzyme for another.

The enzyme-containing particles can speed along generation of the hydrogen fuel, he has found. But there are still technical challenges: These catalysts last only a couple of days, and figuring out how to replace them inside a consumer device is hard.



Etching out the insides of solid metal cubes (top) leaves nanocage catalysts (bottom) that use less platinum.

Other scientists are using existing enzymes as templates for catalysts of their own design. The same family of hydrogenase enzymes that Douglas is packaging into capsules can be a launching point for lab-built catalysts that are even more efficient than their natural counterparts.

One of these hydrogenases has an iron core plus an amine — a nitrogen-containing string of atoms — hanging off. Just as the nitrogen worked into Dai's carbon nanotubes affected the way electrons were distributed throughout the material, the amine changes the way the rest of the molecule acts as a catalyst.

Morris Bullock, a researcher at Pacific Northwest National Laboratory in Richland, Wash., is trying to figure out exactly how that interaction plays out. He and colleagues are building catalysts with cheap and abundant metals like iron and nickel at their core, paired with different types of amines. By systematically varying the metal core and the structure and position of the amine, they're testing which combinations work best.

These amine-containing catalysts aren't ready for prime time yet — Bullock's team is focused on understanding how the catalysts work rather than on perfecting them for industry. But the findings provide a springboard for other scientists to push these catalysts toward commercialization.

Sticking with the metals

These new types of catalysts are promising — many of them can speed up reactions almost as well as a traditional platinum catalyst. But even researchers working on platinum alternatives agree that making sustainable and low-cost catalysts isn't always as simple as removing the expensive and rare metals.

"The calculation of sustainability is not completely straightforward," Finn says. Though he works with enzymes in his lab, he says, "a platinum-based catalyst that lasts for years is probably going to be more sustainable than an enzyme that degrades." It might end up being cheaper in the long run, too. That's why researchers working on these alternative catalysts are pushing to make their products more stable and longer-lasting.

It's also why many scientists haven't given up on metal. "I don't think you can say, 'Let's do without metals,' " says James Clark, a chemist at the University of York in England. "Certain metals have a certain functionality that's going to be very hard to replace." But, he adds, there are ways to use metals more efficiently, such as using nanoparticle-sized pieces that have a higher surface area than a flat sheet, or strategically combining small amounts of a rare metal with cheaper, more abundant nickel or iron. Changing the structure of the material on a nanoscale level also can make a difference.

"If you think about a catalyst, it's really the atoms on the surface that participate in the reaction. Those in the bulk may just provide mechanical support or are just wasted," says Younan Xia, a chemist at Georgia Tech. Xia is working on minimizing that waste.

One promising approach is to shape platinum into what Xia dubs "nanocages" — instead of a solid cube of metal, just the edges remain, like a frame.

In one experiment, Xia started with cubes of a different rare metal, palladium. He coated the palladium cubes with a thin layer of platinum just a few atoms thick — a pretty straightforward process. Then, a chemical etched away the palladium inside, leaving a hollow platinum skeleton. Because the palladium is removed from the final product, it can be used again and again. And the nanocage structure leaves less unused metal buried inside than a large flat sheet or a solid cube, Xia reported in 2015 in *Science*.

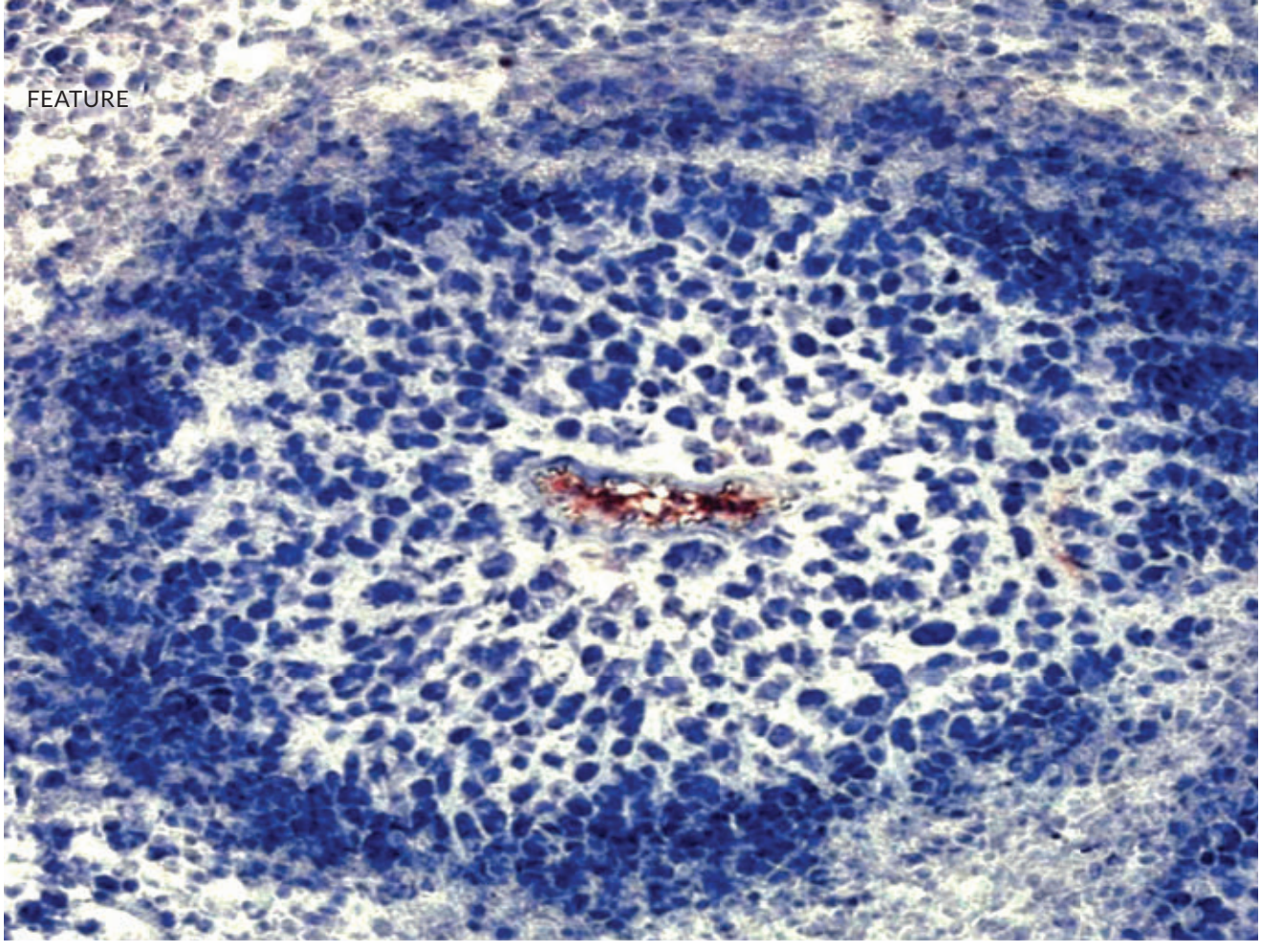
Since then, Xia's team has been developing more complex shapes for the nanocages. An icosahedron, a ball with 20 triangular faces, worked especially well. The slight disorder to the structure — the atoms don't crystallize quite perfectly — helped make it four times as active as a commercial platinum catalyst. He has made similar cages out of other rare metals like rhodium that could work as catalysts for other reactions.

It'll take more work before any of these new catalysts fully dethrone platinum and other precious metals. But once they do, that'll leave more precious metals to use in places where they can truly shine. ■

Explore more

- Xien Liu and Liming Dai. "Carbon-based metal-free catalysts." *Nature Reviews Materials*. September 13, 2016.

L. ZHANG ET AL/SCIENCE 2015



DEFLATING CANCER

New approaches to low oxygen may thwart tumors

By Laura Beil

Like many living things, a cancer cell cannot survive without oxygen. When young and tiny, a malignancy nestles inside a bed of blood vessels that keep it fed. As the mass grows, however, its demand for oxygen outpaces supply. Pockets within the tumor become deprived and send emergency signals for new vessel growth, a process called angiogenesis. In the 1990s, a popular cancer-fighting theory proposed interfering with angiogenesis to starve tumors to death. One magazine writer in 2000 called the strategy "the most important single insight about cancer of the past 50 years." It made such intuitive sense.

Rakesh Jain viewed angiogenesis through a different lens. Trained as an engineer, not a biologist, Jain was studying tumor vasculature during the height of excitement about drugs that could impede vessel growth. He was bothered by the fact that capillaries that arise in the tumor aren't normal; they're gnarled and porous, incapable of effective blood flow in the same way a leaky pipe is lousy at delivering water. The expanding tumor squeezes smaller vessels, making them even less able to transport blood.

"The mantra was, 'Let's starve tumors,'" recalls Jain, director of the Edwin L. Steele Laboratories for Tumor Biology at Harvard Medical School. "I said, 'No, we need to do the opposite.'" In 2001, he published a commentary in *Nature Medicine* predicting that angiogenesis inhibitors would not entirely shrivel the tumor. Instead, he argued, starving tumors might make them harder to treat. "I was sticking my neck out and saying this is not a good thing to do," he says. "I had tremendous resistance."

Cancer cells (shown in blue) surround a blood vessel (red) in a mouse tumor. Cells on the tumor's edge are dying, starved of oxygen. But treatments to starve tumors have come up short.

C. MICHIELS, C. TELLIER AND O. FERON/*BIOCHIMICA ET BIOPHYSICA ACTA* 2016

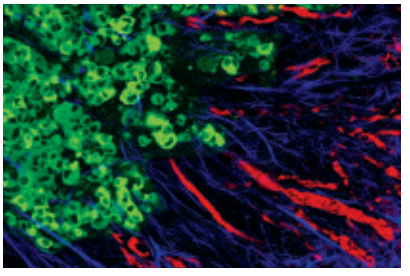
Time has proved him right. Once they came on the market, anti-angiogenesis drugs were not the boon doctors had hoped for. Most disturbing, some patients saw their tumors shrink, only to have the disease return with renewed vengeance.

Today, more than a decade after the introduction of the first tumor-starving drug, researchers have a far greater understanding of the role of oxygen deprivation in cancer. Instead of slowing tumors, hypoxia appears to trigger a metabolic panic that can drive growth, drug resistance and metastasis. Rescue proteins called hypoxia-inducible factors, or HIFs, open a bag of tricks so tumors can adapt and outrun the body's defenses.

But there's now reason for hope: Recent insights into the effects of oxygen deprivation in cancer are sparking new ideas and providing the blueprint for treatments that could short-circuit a cancer's ability to survive and spread, and help make existing drugs more effective.

Hypoxia hysteria

While the idea of starving cancer made sense, the approach may have underestimated the strength and complexity of a tumor's resilience. Since oxygen is essential for so much of life, nature equips cells with elaborate safeguards that kick in when the oxygen-rich blood supply dwindles — whether the cells are part of a tumor or part of a muscle straining for one last push of strength. When oxygen levels drop, newly minted proteins stampede throughout the cell, turning on a frenzy of chemical reactions that offer protection from the crisis.



When oxygen is scarce, collagen fibers (blue in this mouse tissue) can form and offer conduits for cancer cells (green) to escape into blood vessels (red) and spread.

Cancer cells distort this natural coping mechanism for their own means. Growing new vessels is just one move in an elaborate strategy. Many changes accompany hypoxia, including: The malignant cells loosen from each other and become less adhesive, ready to break free; tendrils of collagen, a natural binding substance, form and start to reach out to nearby vessels; and proteins appear on the cell surface to pump out lactic acid, a product of the tumor's switch from primarily aerobic to anaerobic respiration. Researchers now think stopping enough of these and other changes could cripple the cancer. Much of the research focuses on the proteins that are among the first to deploy when a cell senses a danger of asphyxiation.

"At zero oxygen, the cell can't survive," says Daniele Gilkes of Johns Hopkins University School of Medicine. "Inside a tumor you will see these regions of necrosis," or dead cells. But those cells that are low on oxygen but still alive will produce new proteins: Key among them are HIF-1 and HIF-2. Both are transcription factors — they help transcribe DNA instructions into RNA. Under normal conditions, the genes that make HIF proteins are mostly silent. Once HIF proteins are made, they turn on genes — Gilkes estimates there are hundreds — that enable cells to live when oxygen concentrations are low.

Collagen highways

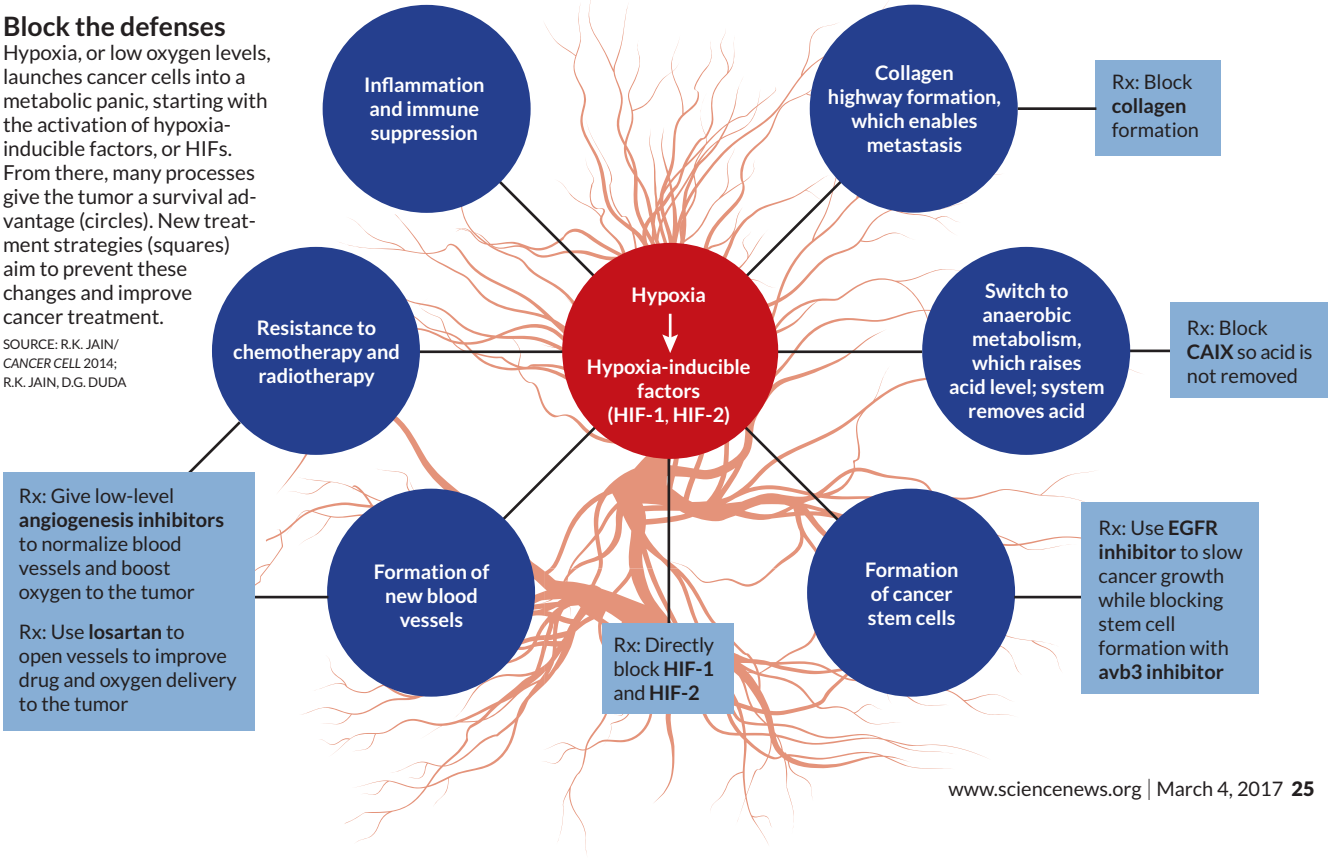
Gilkes' target of choice is HIF-1. It is not only a first responder, but the protein also appears to be key to cancer's spread. Tumors with high levels of HIF-1, particularly when concentrated at the invasive outer edge of the mass, are more likely to become metastatic, invading other parts of the body. The reverse is also true: Human tumors transplanted into mice that genetically can't produce HIF-1 are less likely to spread. The reasons are complicated, Gilkes says, but she considers one thing really interesting: HIF-1 is involved with a lot of enzymes in collagen formation.

The collagen appears to provide a means of escape.

Block the defenses

Hypoxia, or low oxygen levels, launches cancer cells into a metabolic panic, starting with the activation of hypoxia-inducible factors, or HIFs. From there, many processes give the tumor a survival advantage (circles). New treatment strategies (squares) aim to prevent these changes and improve cancer treatment.

SOURCE: R.K. JAIN/ *CANCER CELL* 2014; R.K. JAIN, D.G. DUDA



TOP: MADELEINE OUDIN AND JEFF WYCKOFF/MIT; BOTTOM: WEKTORYGRAFIKA/ISTOCKPHOTO

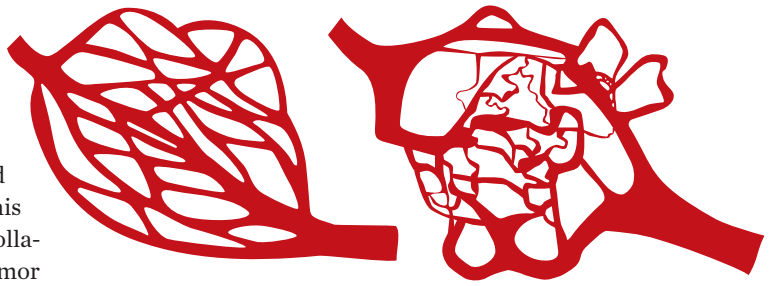
Last year, in a review in the *International Journal of Molecular Sciences*, Gilkes described genes, found by her lab group and others, that breast tumors activate to degrade the surrounding environment. In turn, the tumor wraps itself in a stringy web of collagen. As the collagen forms, the strands stretch outward from the tumor and latch onto nearby vessels. "We think cancer cells will find this collagen and use it to migrate and glide." She calls them "collagen highways." Her laboratory captured video of human tumor cells migrating along a fibrous strand. "To see them move is really scary."

Once they've broken from their home tumor, many types of cancer, including prostate and breast cancers, commonly move into bones. This is no coincidence, Gilkes says. Bones lack the dense thickets of blood vessels that run through soft tissues. That means cancer cells migrating from a hypoxic environment, and therefore already trained for low oxygen, would find hospitable surroundings in the bone. Her lab group is now looking for ways to block collagen formation to close the travel lanes and perhaps keep the cancer from spreading. She and others are also working to find a way to inhibit HIF-1 directly, but so far those efforts have proved challenging.

HIF-1's accomplice, HIF-2, may be a more available target. HIF-2 is a molecule made of two parts that clamp onto DNA to trigger production of other proteins that make tumors tougher to kill. In 2009, structural biologists at University of Texas Southwestern Medical Center in Dallas discovered that the HIF-2 protein had a large cavity. "Usually proteins don't have holes inside them," says James Brugarolas, leader of UT Southwestern's kidney cancer program. With the discovery, researchers began working on a way to use the gap as a foothold for drugs.

Now in development, the experimental drug PT2399 slips inside HIF-2 and effectively breaks the molecule in two. Brugarolas and colleagues from six other institutions and the biotech company Peloton Therapeutics Inc. in Dallas published results of the first animal tests of the compound in *Nature* in November. In mice with implanted grafts of human kidney tumors, PT2399 split HIF-2 and slowed growth in 56 percent of tumors — better than a standard treatment. Brugarolas hypothesizes that the drug worked only about half the time because the other half of tumors relied more heavily on HIF-1.

A similar HIF-2–busting drug is now in Phase I safety testing in humans, described in June in Chicago at the annual meeting of the American Society of Clinical Oncology. While Phase I studies are not designed to test whether the treatment works, the drug showed few side effects among 51 people with advanced kidney cancer who took the drug at ever-increasing doses. The patients had already been through multiple types of treatments, one as many as seven. After taking the drug, 16 patients experienced a slowing in disease progression, three more had a partial response and one a complete reversal. Given the dearth of treatments for advanced kidney cancer, Brugarolas says, "this is a big deal."



Tortured flow Healthy vessels (illustrated, left) have an orderly distribution and size. Vessels that sprout inside a tumor in response to hypoxia (right) are porous, gnarled and inefficient at delivering blood.

BOTH: T. TIBBITTS

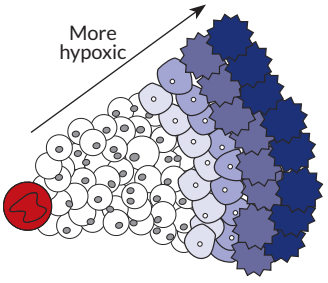
Low blows

Still more molecules throw a lifeline to hypoxic tumors in ways that scientists are just beginning to understand. In 2008, pathologist David Cheresh and colleagues at the University of California, San Diego announced a curious discovery in *Nature*: Depriving cells of vascular endothelial growth factor, or VEGF — the key protein responsible for new vessel growth in a tumor and the main target of drugs that block angiogenesis — could actually make tumors more aggressive.

His team went on to discover the same was true for another popular class of drugs, which work by depriving a tumor cell of nutrients in the same way anti-angiogenesis drugs limit oxygen. The drugs, called EGFR inhibitors, were capable of doing the opposite of what was expected: They could make tumors stronger.

Cheresh believes that hypoxia — and other stresses of low blood supply, like nutrient deprivation — inflict a wound on the tumor. When normal tissues sustain an injury (like a cut), they immediately enter a period of healing and regeneration. The bleeding stops and the skin grows back. Low oxygen delivers a blow to tumor cells, sending them into a similar state of rejuvenation, he says. "They're now prepared to survive not only the hypoxia, but everything else thrown at it."

In 2014, Cheresh published his take on why this occurs, at least in some cases, in *Nature Cell Biology*. He and his team described a molecule called avb3 found on the surface of drug-resistant tumors that appears to reprogram tumor cells into a stem cell–like state. As embers of the original tumor that are often impermeable to treatment, these stem cell–like cells can lie quietly for a time and then reignite. The discovery of avb3 has redefined how Cheresh thinks about resistance. He no longer believes that tumors defy chemotherapy in the way



Survival story Tumor cells farthest from the blood supply (red) have lower concentrations of oxygen. Some will die; others will make metabolic adjustments to survive, which may make them harder to treat. SOURCE: N.C. DENKO/*NATURE REVIEWS CANCER* 2008

bacteria overcome antibiotics, with only the strongest cells surviving and then roaring back to become dominant.

"The tumor cells are adapting, changing in real time," Cheresh says. In short, his data suggest that when EGFR inhibitors deprive a cell of nutrients, some cells survive not because they are naturally tougher, but because the appearance of avb3 transforms them into drug-resistant stem cells. The good news is that laboratory tests suggest an experimental drug might block this reprogramming, and it may even prevent chemotherapy resistance. A clinical trial will soon begin that combines usual cancer treatment with this avb3-disabling drug, in a one-two punch aimed at reversing or delaying resistance so the treatment can do its job.

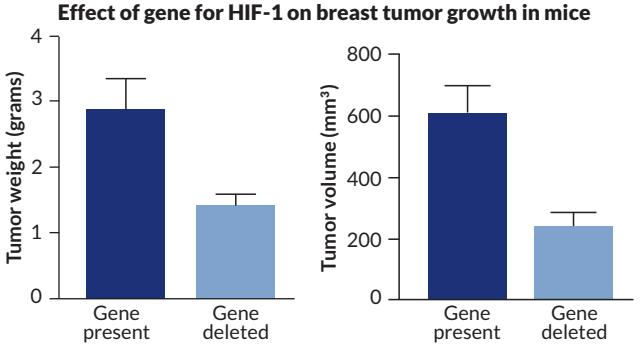
There are still more ways tumors withstand low oxygen. They start eating leftovers. HIF-1 triggers a switch from oxygen-based aerobic respiration to anaerobic respiration using pyruvate, a product of glucose breaking down. The strategy works in the short term; it's the reason your muscles keep pumping for a time, even when you're gasping for air on the last few yards of a sprint. Problem is, anaerobic respiration leaves a trail of lactic acid. A lot of it.

"Lactic acid buildup leads to a precipitous drop in pH inside of the tumor," says Shoukat Dedhar of the BC Cancer Research Centre in Vancouver. To compensate, HIF-1 deploys a fleet of proteins that remove the acid so it won't accumulate and burn up the cell.

Dedhar's laboratory didn't start out studying hypoxia. "We had tumors that were readily metastatic and genetically related tumors that couldn't metastasize," he says. Those tumors that easily spread were producing HIF-1, along with products from other genes. Searching for the functions of those genes, his group and others found two proteins important in pH balance. The first, MCT-4, acts like a molecular sump pump, bailing out lactic acid. But it's not enough to normalize the pH, Dedhar says.

That job goes to the second protein, carbonic anhydrase 9, or CAIX. "Its job is simply to convert carbon dioxide to bicarbonate, which then neutralizes the acid," he says. In March 2016, in a review in *Frontiers in Cell and Developmental Biology*, Dedhar and colleagues described how to improve cancer treatment by taking away some of the tools for hypoxia survival — that is, keeping the cell from neutralizing acid — while simultaneously giving drugs that boost the immune system. His team has developed new compounds that specifically block CAIX. Since CAIX is almost exclusively produced in tumor cells, CAIX inhibitors should theoretically have few side effects. A Phase I safety trial is testing possible drugs now.

The ringleader When the gene for HIF-1 is knocked out in breast cancer cells that are transplanted into mice, tumors don't grow as large as tumors containing the gene. SOURCE: L.P. SCHWAB *ET AL/BREAST CANCER RES.* 2012



J. HIRSHFELD

Open to destruction

Harvard's Jain is still making the case for bathing the tumors in oxygen, giving them more blood, not less. This could keep the tumor from becoming hypoxic and throwing up a new series of defenses, including a flood of angiogenesis-promoting proteins, which produce tormented circulation. When he proposed that concept in 2001, "I thought abnormal vessels were bad," he says. "I now think they are worse."

> "I thought abnormal vessels were bad. I now think they are worse."
>
> RAKESH JAIN

His idea is to make tumor vasculature more normal, using the very drugs that he was concerned about almost two decades ago. His research suggests that giving anti-angiogenesis drugs in modest doses will keep the vessels from becoming abnormal, making them less tortured and more capable of normal blood flow (*SN: 10/5/13, p. 20*). He believes the restored oxygen not only shuts down the hypoxic response that gives the cancer a survival advantage, but also serves as a conduit for chemotherapy drugs and immune cells to penetrate deeper into the tumor. Oxygen is also necessary for radiation to work.

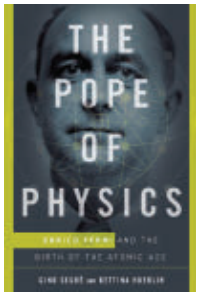
His latest experiments take the concept of more oxygen, not less, even further. He combined two chemotherapy drugs with losartan, a generic medicine used to control blood pressure. The result, reported in *Nature Communications* in 2013, was a delay in pancreatic and breast tumor growth in mice. Another experiment from Jain and colleagues, published in 2016 in *Translational Oncology*, had similar results.

"We are finding every therapy works better when we do this," he says. A clinical trial is now under way at Massachusetts General Hospital testing whether giving losartan during radiation and chemotherapy will improve results for pancreatic cancer patients.

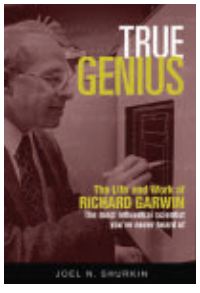
The concept still remains unproven, but Jain has reason for optimism. And he is no longer in the scientific minority. Last May, he received the National Medal of Science from President Barack Obama, who commended Jain for "groundbreaking discoveries of principles leading to the development and novel use of drugs for treatment of cancer." Jain hopes to see the day, not long in the future, when hypoxic tumors are defeated by giving them the very thing they need the most. ■

Explore more

- Caroline Wigerup, Sven Påhlman and Daniel Bexell. "Therapeutic targeting of hypoxia and hypoxia-inducible factors in cancer." *Pharmacology & Therapeutics*. August 2016.



The Pope of Physics
Gino Segrè and Bettina Hoerlin
HENRY HOLT, $30



True Genius
Joel N. Shurkin
PROMETHEUS, $25

BOOKSHELF

Physics greats mixed science, public service

The 20th century will go down in history — it pretty much already has — as the century of the physicist. Physicists' revolutionizing of the scientific world view with relativity and quantum mechanics might have been enough to warrant that conclusion. Future historians may emphasize even more, though, the role of physicists in war and government. Two such physicists, one born at the century's beginning and one still living today, typify that role through their work in developing weapons, advising politicians and shaping policy while still performing outstanding science.

Best known of the two is Enrico Fermi, the Italian intellectual giant who escaped from fascist Italy to America after winning a Nobel Prize for his research in nuclear physics.

When he arrived in the United States in 1939, Fermi almost immediately went to work studying nuclear fission, discovered only weeks earlier in Hitler's Germany. Eventually Fermi took a major role in the Manhattan Project, leading the team that first demonstrated a controlled nuclear fission chain reaction.

Fermi, a foreigner, assumed a lead role because he was so widely recognized among the world's physicists as infallible — hence his nickname "the pope." In *The Pope of Physics*, Gino Segrè and Bettina Hoerlin chronicle Fermi's life and science with insight and rich detail.

Fermi is often cited as the last of the great physicists who excelled both at theory and experiment. His theory of the weak nuclear interactions, produced in the early 1930s, remains a key segment of modern physicists' understanding of matter and forces. His experimental work on neutrons won the Nobel (even though aspects of those experiments turned out to have been incorrectly interpreted).

Segrè (whose uncle was a collaborator of Fermi's) and Hoerlin explore the personal and political influences on Fermi's science and relate in detail his experiences in the effort during World War II to develop the atomic bomb. His postwar government service included membership on the General Advisory Committee to the new U.S. Atomic Energy Commission. He was also on the University of Chicago faculty until his abrupt death in 1954 from stomach cancer. He was 53.

Briefly mentioned in Segrè and Hoerlin's account is a visit near the end of Fermi's life from one of his former graduate students, Richard Garwin. To Garwin, Fermi mentioned regret at not having been even more involved in public policy. Perhaps, Segrè and Hoerlin suggest, that conversation inspired Garwin, "who went on to have an extraordinarily distinguished career as a presidential adviser on science and security issues."

As Fermi's postdoc at Chicago, Garwin also spent time at the lab in Los Alamos, N.M., where the atomic bomb had been built. By 1951, the lab's focus was on the hydrogen bomb, or the Super, powered by fusion in addition to fission. Despite input from Fermi and significant insights from the mathematician Stanislaw Ulam and physicist Edward Teller, designing the Super had proven an insuperable problem. Garwin offered to help; Teller assigned him the task of designing an experiment demonstrating how the Super could work. In a couple of weeks, Garwin handed in the blueprint for the actual bomb itself.

In *True Genius*, veteran science writer Joel Shurkin recounts this story in detail for the first time. For decades, popularizations credited Teller with the development of the hydrogen bomb; Garwin's role was long classified. Late in life, Teller, who died in 2003, revealed Garwin's crucial role, which was eventually reported in the *New York Times*.

As Shurkin emphasizes, Garwin designed the bomb because it was a technical problem that he knew how to solve. But he spent the rest of his career devoted to arms control (both as an adviser inside government and a critic from the outside).

Garwin made significant contributions to physics as well — many modern technological conveniences, such as the GPS satellite system, owe their existence to Garwin's insights. Last November, in recognition of all these achievements, President Barack Obama awarded Garwin the Presidential Medal of Freedom.

Shurkin's account of Garwin's life is detailed but often hard to follow, sometimes jumping from decade to decade (not always in order) in the space of a few paragraphs. And the book is marred by poor fact-checking (tritium is certainly not an isotope of lithium; Otto Hahn was a chemist, not a physicist; and Niels Bohr's mother was Jewish, not his father). And peculiarly the title, the book's publicity material says, refers to Fermi's description of Garwin as a "true genius," while the text of the book quotes Fermi as calling Garwin a "real" genius.

Nevertheless, Shurkin's account is by far the best (virtually only) complete record of the life of a scientist who devoted his career to serving the public good — while also doing extraordinary science. Garwin really, truly, is a genius. — *Tom Siegfried*

Congratulations to Regeneron Science Talent Search Top 40 Finalists

The Regeneron Science Talent Search (Regeneron STS) is the nation's most prestigious science competition for high school seniors. Science Talent Search alumni have made extraordinary contributions to science and together hold more than 100 of the world's most coveted science and math honors, including the Nobel Prize and the National Medal of Science.

Finalists compete for more than $1.8 million in awards — the top 10 awards range from $40,000 to $250,000 for the first-place winner. Another $1.2 million was awarded to Regeneron STS top scholars and their schools earlier in the competition.

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JANUARY 21, 2017

Saved by the Bell

*Physicists used light from stars to perform a cosmic Bell test, which verified that quantum particles were indeed "spooky," **Emily Conover** reported in "Quantum effect passes space test"* (SN: 1/21/17, p. 12).

Reader **George Mitchell** took issue with **Conover's** description of entangled photons before they are measured as having multiple polarizations at once. "We don't know the direction of their polarization," **Mitchell** wrote. "It is undefined."

"Multiple polarizations" in this context is meant to indicate that there are multiple possible outcomes of a polarization measurement; the particle does not have a definite polarization that is simply unknown. "Bell tests like the one in the article confirm this interpretation," **Conover** says (*SN Online: 1/27/16*).

It's similar to how Schrödinger's cat can be in a "superposition" of both alive and dead at the same time (*SN: 11/20/10, p. 15*). "It's not that we don't know whether the cat is alive or dead; it's both," she says. "This is hard to wrap one's head around." In any case, it is effectively impossible to put a real cat in a superposition, because it is too large to display the strange properties of quantum mechanics. "But for particles," she says, "this is acceptable behavior."

Land ho

*From Nuna to Pangaea, shifting landmasses have repeatedly reshaped Earth's surface. Researchers are now picturing a future supercontinent dubbed Amasia, due in 250 million years, **Alexandra Witze** reported in "Supercontinent superpuzzle"* (SN: 1/21/17, p. 18).

Reader **Pierre Grillet** wondered how subduction — the process by which a tectonic plate is pushed beneath another tectonic plate — could pull continents apart. "I would suggest that a different mechanism is also at work here. Rising material must balance crust material being subducted into the mantle," he wrote. "It would make sense that this rise should occur in the center of the plate, where the mantle is hotter. Rising material would then spread sideways, pushing the sides of the plate over the oceanic crust and pulling the plate apart."

The process **Grillet** describes is a theory proposed by some researchers. Other researchers have doubts (*SN: 4/4/15, p. 13*). "Plumes of hot material rising from the mantle could rip continents apart, but the plumes would have to rise up at weak points along continental boundaries, which seems unlikely," says **Thomas Sumner**, *Science News*' earth sciences writer. A competing theory covered in the story suggests that subduction tears continental plates apart by pulling at their edges.

Power up

*A variety of next-generation batteries promise to store energy more efficiently, providing power for longer periods, **Susan Gaidos** reported in "Charging the future"* (SN: 1/21/17, p. 22).

Reader **Tom Wicker** was disappointed that the beginning of the story equated power and energy. "Everybody wants more power from their batteries," **Gaidos** wrote, citing smartphone, laptop and electric-car batteries as examples.

"Laptop batteries can supply more than enough power. You need to charge them frequently because of the limited amount of energy they store," **Wicker** wrote. "It is of course correct that drawing more power, more energy per unit time, from a battery will drain it faster. But that is true even though the battery may have no problem supplying the required amount of power. It just can't do that for as long as required due to insufficient energy storage."

Wicker's distinction between energy and power is correct, **Gaidos** says. "When talking about batteries, the term 'portable power' is frequently used, when what is really meant is portable energy. The research under way, as described in the story, aims to create batteries with high power that can maintain that power through a large number of recharge cycles," she says.

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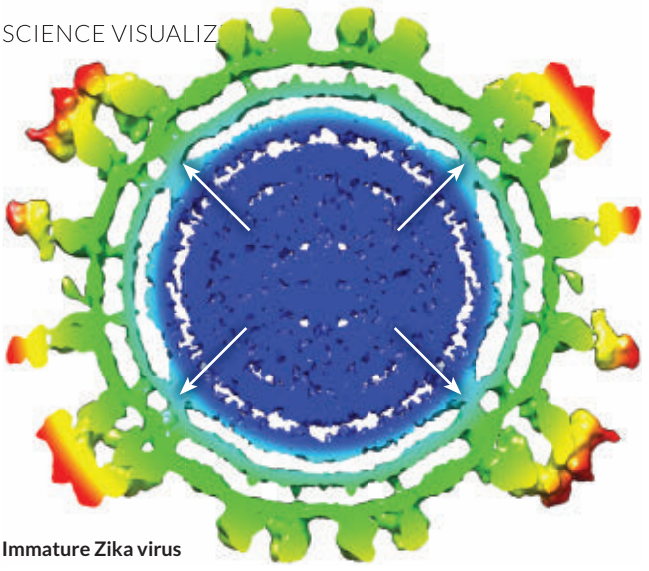
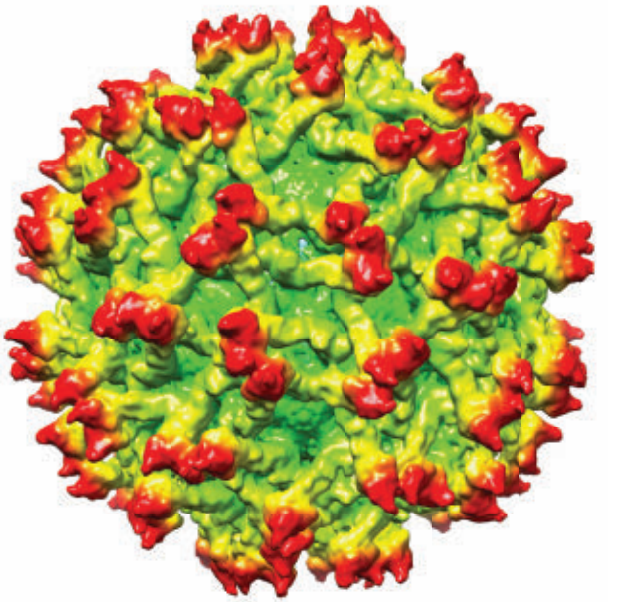


Immature Zika virus



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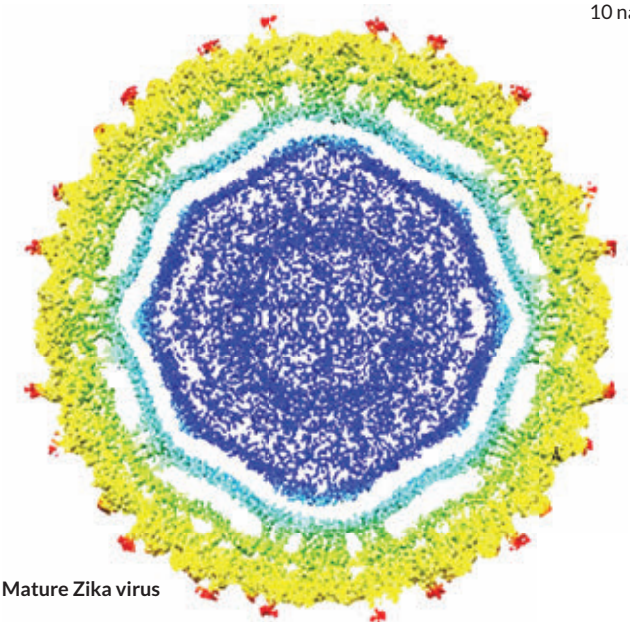
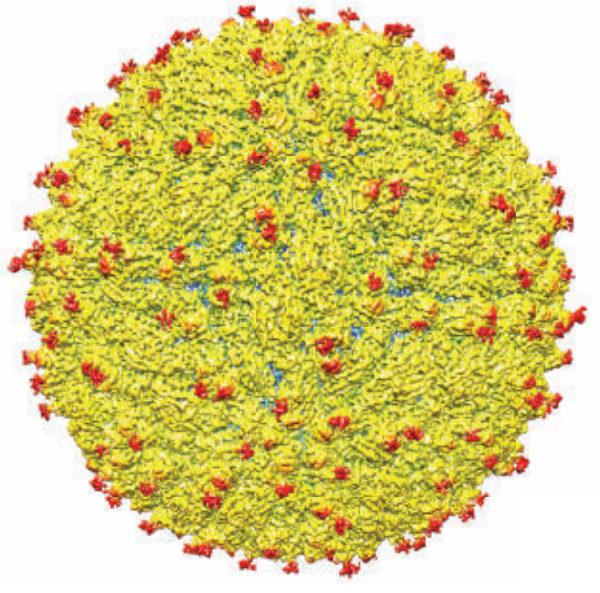


Mature Zika virus



Zika's baby photo snapped

Before an immature Zika virus becomes infectious, it does some major remodeling.

In a fledgling virus particle, the inner protein and RNA core (shown in dark blue above) forms bridges (arrows) to the surrounding membrane layer. As the virus matures, the core shuffles around and the bridges melt away.

It's the first time scientists have seen such rearrangement in the core of a flavivirus, the group that also includes the viruses that cause dengue, West Nile and yellow fever, says virologist Richard Kuhn of Purdue University in West Lafayette, Ind.

Scientists don't know why the immature Zika virus reshuffles its insides — perhaps it helps the maturing virus become infectious. That's the next big question to answer, Kuhn says.

If blocking the reorganization made mature viruses harmless, scientists would have a new clue about preventing Zika infection. The map of the immature virus' structure, published online January 9 in *Nature Structural & Molecular Biology*, could offer other hints for thwarting Zika, too.

With a technique called cryo-electron microscopy, Kuhn and colleagues could see three-headed protein spikes (red) studding the immature virus' surface like some kind of medieval weapon, and could even distinguish the separate layers of the membrane (aqua) that encloses the core. (The maps are radially colored; colors change as distance from the core increases.) Outside the membrane lie surface proteins called envelope, or E, proteins (green and yellow) that help the virus sneak into cells.

Last year, Kuhn's team reported the structure of the mature Zika virus (*SN: 4/30/16, p. 10*). The new work offers another illuminating peek at Zika — a baby picture, of sorts. — *Meghan Rosen*

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