SN
SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
SEPTEMBER 29, 2018

Social Science Do-Overs

Jupiter's Wacky Magnetism

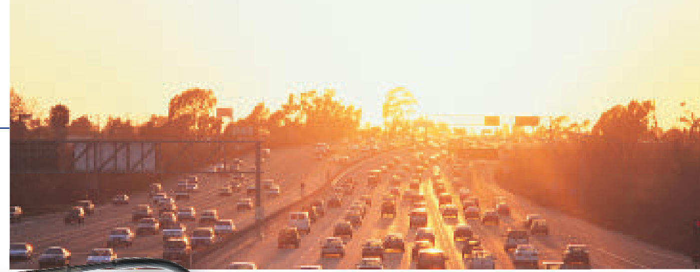
Crop Pests Like It Hot

Machines to Test the Standard Model

Building a Better Burger

Entrepreneurs aim to make meat without livestock

Urgent: Special Summer Driving Notice



To some, sunglasses are a fashion accessory…

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The sun rises and sets at peak travel periods, during the early morning and afternoon rush hours and many drivers find themselves temporarily blinded while driving directly into the glare of the sun. Deadly accidents are regularly caused by such blinding glare with danger arising from reflected light off another vehicle, the pavement, or even from waxed and oily windshields that can make matters worse. Early morning dew can exacerbate this situation. Yet, motorists struggle on despite being blinded by the sun's glare that can cause countless accidents every year.

Not all sunglasses are created equal. Protecting your eyes is serious business. With all the fancy fashion frames out there it can be easy to overlook what really matters—the lenses. So we did our research and looked to the very best in optic innovation and technology.

Sometimes it does take a rocket scientist. A NASA rocket scientist. Some ordinary sunglasses can obscure your vision by exposing your eyes to harmful UV rays, blue light, and reflective glare. They can also darken useful vision-enhancing light. But now, independent research conducted by scientists from NASA's Jet Propulsion Laboratory has brought forth ground-breaking technology to help protect human eyesight from the harmful effects of solar radiation light. This superior lens technology was first discovered when NASA scientists looked to nature for a means to superior eye protection—specifically, by studying the eyes of eagles, known for their extreme visual acuity. This discovery resulted in what is now known as Eagle Eyes®.

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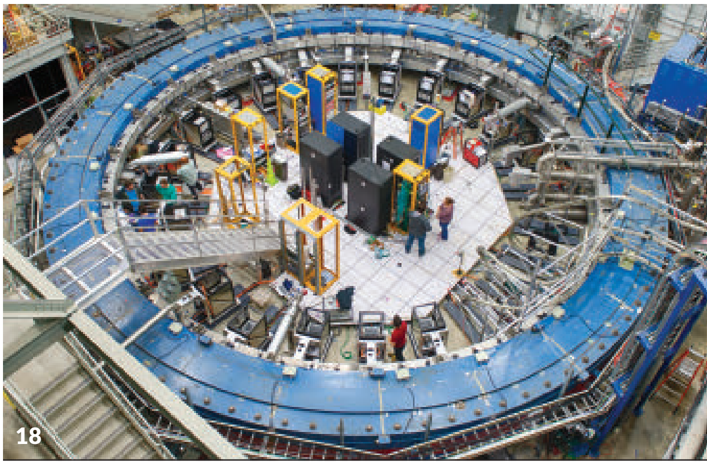

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Departments

COVER Beef burgers have a lot of fans, which means developers of lab-grown meat have their work cut out for them. *Magone/Alamy Stock Photo*

FROM TOP: FERMILAB; R. BLAŽEK; TANJA NIGGENDIJKER/WIKIMEDIA COMMONS (CC BY 2.0)

Building big experiments to study very little things

When I think of an experiment, I think of some flasks, a pipette, maybe an incubator. But to a particle physicist, an experiment can be a machine bigger than a house, designed to study subatomic particles.

There's a certain charm to the fact that such vast equipment has to be constructed to study the smallest known bits of matter. The tunnel of the Large Hadron Collider has a circumference of almost 27 kilometers. And KATRIN, an experiment in Karlsruhe, Germany, described by physics writer Emily Conover in this issue (see Page 18), requires a blimplike metal tank that's wider than some of the neighborhood streets.

Conover knows firsthand the exacting work of building a physics experiment. While a graduate student at the University of Chicago, Conover toiled away on Double Chooz. The experiment was designed to detect antineutrino oscillations, which occur when antineutrinos change from one type into another.

That endeavor required a source of antineutrinos. They're produced during certain nuclear reactions, so the experiment was located in a tunnel near a nuclear power plant in Chooz, France. It also required detectors to spot heavy relatives of electrons called muons, which constantly rain down on Earth and can cause reactions that mimic antineutrinos. The detectors, which included scintillators that would light up when a muon zipped through, made sure muons didn't get counted as antineutrinos by mistake.

Conover and her colleagues used an extruder to form hundreds of thin, 3-meter-long strips of plastic, then assembled them to make the detectors. "They were kind of floppy and covered with aluminum," Conover says of the detectors. "We were always terrified that we would break one."

The project involved taking several trips to France to install and test the detectors in the subterranean tunnel. All told, Conover worked on Double Chooz for six years. In the end, the experiment was a success: It was one of the first to measure a particular type of neutrino oscillation.

Scientists come in many flavors, and we're delighted to provide a behind-the-scenes look at their work across the disciplines. *—Nancy Shute, Editor in Chief*

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50 YEARS AGO

Girding against a new strain

Flu comes in many kinds, and the current vaccine ... has little effect against a newcomer that has afflicted at least 400,000 persons in Hong Kong. The Asian city was the source of the 1957 epidemic in the United States. Fears that it may provide a springboard for another one have caused the Public Health Service to ask eight pharmaceutical companies to begin production of a specialized vaccine.

UPDATE: The 1968 Hong Kong flu pandemic killed about a million people worldwide. A vaccine became available only after the pandemic had peaked. Even today, flu vaccine development is tricky because the three types of influenza virus that infect people are moving targets that change, or mutate, often. But scientists are getting closer to making universal flu vaccines that would protect against many flu strains over multiple seasons. Some candidates target parts of the influenza virus that are less prone to mutate. Others compile all seemingly possible mutations of a particular flu variety into one vaccine (*SN: 10/28/17, p. 18*).

Fireflies use their tail lights for mating. New evidence suggests that the flashing may also warn off nocturnal predators.

THE SCIENCE LIFE

There's method in a firefly's flashes

A firefly's blinking behind is more than just a pretty summer sight.

Fireflies flash to attract mates — but the twinkles may serve another purpose as well. Biologist Jesse Barber of Boise State University in Idaho had a hunch that the lights also warn off potential nighttime predators such as bats. He isn't the first person with this hypothesis. As far back as the mid-1880s, entomologist George Bowles wrote of fireflies: "May not the light then serve ... as a warning of their offensiveness to creatures that would devour them?" But the theory hadn't been tested, until now. "We always assumed that bats don't use vision for much," Barber says.

Many firefly species are "chemically protected," meaning they taste awful to predators, Barber says. Yet if an insect

THE –EST

This killifish can go from egg to sex in two weeks

A fish that lives in rain puddles has beaten its own record for the fastest known sexual maturity among vertebrates.

Turquoise killifish (*Nothobranchius furzeri*) that hatch after unpredictable rains in Mozambique can mature from hatchling to ready-to-breed adult in 14 days, researchers announced in the Aug. 6 *Current Biology*. Killifish in cushy lab conditions were already known to grow up faster than other vertebrates, developing fully in 18 days.

Some other vertebrates come close, but they take shortcuts, says study coauthor Martin Reichard, an evolutionary ecologist at the Czech Academy of Sciences in Brno. House mice, for instance, sometimes grow up in as few as 23 days. Yet they're born at a more advanced stage of development than the hatchling fish, Reichard says, and pups get a boost from mouse milk. There's also a kind of goby that matures in 23 days by just growing a gonad on a larval body.

But *N. furzeri* in its natural habitat manages a more impressive feat. Hatchlings can grow from just 5 millimeters up to 54 millimeters with functional gonads in just two weeks. When puddles dry, fertilized eggs can stay viable without hatching for months until it rains again. A rapidly vanishing puddle nursery dictates the need for speed and these fish waste no time. "Mating does not involve much elaborate courtship," Reichard says. A male briefly extends his fins, and if he's accepted, the female lays one egg before swimming off to find another mate. She manages 20 to 100 eggs a day, "typically before noon," he says. — *Susan Milius*

Turquoise killifish (a male shown) mature in the wild even faster than they do in the lab.

FROM TOP: DR. STEPHEN MARSHALL; R. BLAŽEK

Homing in Bats trying to catch darkened fireflies used a high-rate echolocation pattern (left) that is typical in hunting moving prey. But when fireflies were free to flash, the bats did not display this hunting echolocation behavior (right), suggesting they did not see the insects as prey.

doesn't offer a warning of its bad taste, it may get sampled anyway. Barber noticed that, unlike some moths, which signal their toxicity to bats with noises (*SN Online: 7/3/13*), fireflies don't make a peep. He wondered if the lightning bugs were warning bats of their foul taste with their blinking lights.

Barber and colleagues wanted to see if inexperienced bats took longer to learn to avoid fireflies when the flashings were masked. The team introduced fireflies to three bats that had never encountered the insects before. The bats learned to avoid the bright creatures "after just a few interactions," Barber says. Those early exchanges went something like this: catch, taste, drop. Soon, the bats avoided the fireflies completely.

Next came the tricky part. The team needed fireflies that wouldn't blink. Painstakingly, the researchers secured each firefly with a minuscule paper belt under a microscope, and, with a tiny brush, applied two coats of black paint to the flashing back end. Each rump — the team painted dozens — took about 45 minutes to cover. That's one of the reasons the experiment took three years, Barber jokes.

But the work paid off: When the researchers exposed a new set of bats to the darkened fireflies, the bats took about twice as long to learn that the insects had an awful taste.

The bats that learned to avoid the dark fireflies may have sensed the insects' distinctive flight pattern via echolocation, the researchers hypothesize in the Aug. 22 *Science Advances*. Bats may avoid fireflies through a combination of senses, echolocation to sense the insects' flight patterns and vision to glimpse those double-duty flashers. *— Leah Rosenbaum*

SCIENCE STATS

Atlantic hurricane predictions

In 2005, 28 named tropical cyclones, including Hurricane Katrina, churned across the Atlantic Ocean. That set a record likely to stand for a while. Under current climate conditions, there's only a 3.2 percent chance of more Atlantic storms in any one year, scientists report August 22 in *Science Advances.*

That makes 2005 a reasonable bench mark when it comes to risk management, at least for the near future, the researchers say. Study coauthor and climate scientist Sally Lavender of CSIRO in Aspendale, Australia, and colleagues examined thousands of years of climate simulations along with the statistical relationships between those climate conditions and tropical cyclone formation.

This study did not predict how Atlantic storm tallies might change in future years. The National Oceanic and Atmospheric Administration says that 2018 won't come anywhere near 2005's numbers. The Atlantic may spawn up to 16 named storms; as many as nine could become hurricanes. *— Carolyn Gramling*

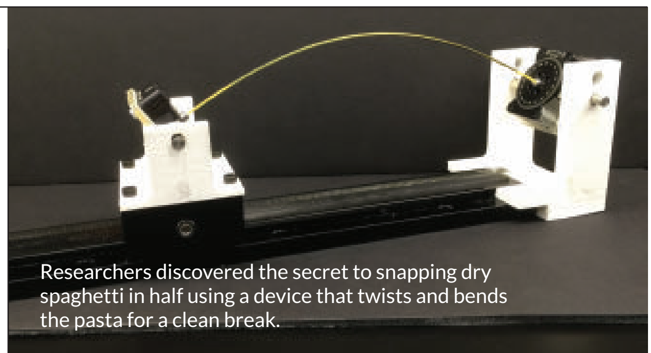
28

Total number of tropical cyclones in the Atlantic Ocean in 2005

3.2

percent

Chance that the Atlantic region could see more storms than it did in 2005, under current climate conditions



Researchers discovered the secret to snapping dry spaghetti in half using a device that twists and bends the pasta for a clean break.

MYSTERY SOLVED

How not to shatter spaghetti

For people who like their spaghetti short and neat, there's now a cleaner way to break the long sticks. Simply bending dry spaghetti in half typically shatters it into three or more fragments, because vibrations wracking the broken halves cause smaller pieces to splinter off (*SN: 11/12/05, p. 315*).

The answer is to twist then bend, researchers report August 28 in the *Proceedings of the National Academy of Sciences*. Mathematician Vishal Patil of MIT and colleagues broke hundreds of pasta rods with a custom-made spaghetti-snapping device. When spaghetti is twisted, they found, it doesn't bend as far before breaking, so the vibrations that rattle the broken halves aren't strong enough to spur further fractures. Twisting and snapping spaghetti sticks one by one is tedious work, so the news may not be much practical help in the kitchen. *— Maria Temming*

FROM TOP: B.C. LEAVELL *ET AL*/*SCIENCE ADVANCES* 2018; RONALD HEISSER, V. PATIL

News

MATTER & ENERGY

D-Wave mimics strange physics

New large-scale quantum computations are a first

BY EMILY CONOVER

Scientists have used a quantum computer to conduct large-scale simulations of two types of quantum materials. These studies involved about 2,000 quantum bits, or qubits — many more than the tens of qubits available in most quantum computers.

The results, published in separate papers in *Science* and *Nature*, provide a new realization of the vision of physicist Richard Feynman, who hoped to use quantum computers — rather than computers based on standard, or classical, physics — to simulate quantum systems and study their behavior. "Nature isn't classical, dammit, and if you want to make a simulation of nature, you'd better make it quantum mechanical," he famously said in 1981.

Performed on a computer built by D-Wave Systems Inc. of Burnaby, Canada, the simulations provide a way to study phenomena that are very difficult to replicate with classical computers. "These are really rather beautiful pieces of science," says physicist Seth Lloyd of MIT. The researchers are "able to reproduce all kinds of predicted phenomena."

D-Wave's machines, however, have attracted skepticism, and some physicists are not convinced of the importance of the new results.

In a study published in the Aug. 23 *Nature*, D-Wave physicists describe simulating the physics of a two-dimensional magnetic material, identifying a transition in which whirlpool-like defects known as vortices pair up in the material when the temperature drops. The theoretical prediction of this phase transition won the 2016 Nobel Prize in physics, and the phenomenon is relevant to the physics of superconductors, materials that transmit electricity without resistance at low temperatures (*SN: 10/29/16, p. 6*). The simulation's results matched the output of simulations performed on classical computers.

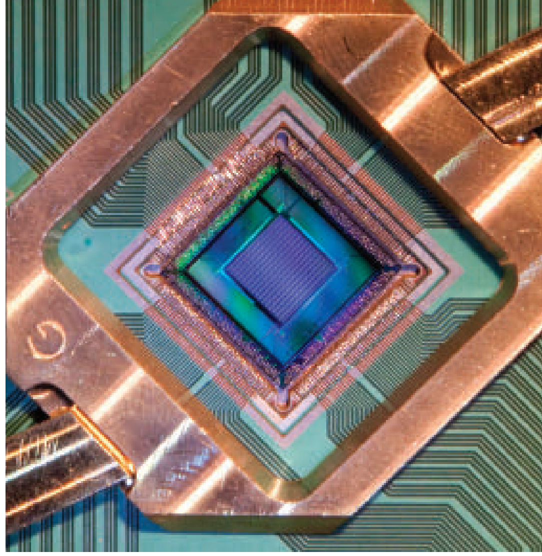
Another simulation, reported in the July 13 *Science*, replicated the behavior of a 3-D material that transitioned between different magnetic phases when the researchers changed variables such as an applied magnetic field. The observed phases included a disordered state known as a spin glass.

Other teams previously have performed simulations with quantum computers (*SN Online: 1/22/10*), but those simulations involved fewer qubits. "At this size, it's the first time that this type of computation is done," says D-Wave chief scientist Mohammad Amin, a coauthor of both studies. The more qubits, the more particles that physicists can simulate, allowing the computer to better mimic the physics that arises when many atoms get together in solid materials.

D-Wave's computers, available commercially since 2010, have stoked controversy. Scientists have debated whether the quantum machines really exhibit quantum behavior — such as the spooky linkages between distant particles known as entanglement — and whether the computers can work faster than classical computers (*SN: 7/26/14, p. 6*).

The new results give a boost to D-Wave's credibility by suggesting that quantum effects really are occurring inside the computer. "It does seem to be the case that they're using a quantum process to simulate another quantum process," says physicist Daniel Lidar of the University of Southern California in Los Angeles. Though the results did not provide direct evidence that the computer exhibits quantum effects, "it seems unlikely that ... this would have been successful had it been entirely classical."

Still, some skeptics are unmoved by the results. "They haven't addressed at all whether it's a quantum system they've got," says physicist Graeme Smith of the JILA research center in Boulder, Colo. And the new studies don't attempt to address the question of whether D-Wave performs more quickly than a classical computer.



A quantum computer built by the company D-Wave (quantum chip, shown) has replicated the behavior of two different materials, in the largest simulations of their kind yet.

D-WAVE

D-Wave's quantum computer is a specialized type, based on a process called quantum annealing. The quantum computers currently under development by Google, IBM, Intel and others are intended to be general purpose and could perform currently impossible feats like breaking data encryption schemes (*SN: 7/8/17, p. 28*). In contrast, quantum annealing computers are useful mainly for solving a certain type of problem called an optimization problem, in which the computer must choose the best option among many possibilities. D-Wave computers have been used for such problems already, including sifting through particle collider data, detecting trees in aerial images and picking the best route for cabs to travel around Beijing.

Using D-Wave to simulate quantum systems opens up new possibilities for the computer, says physicist Davide Venturelli of the Universities Space Research Association's Quantum Artificial Intelligence Lab at NASA's Ames Research Center at Moffett Field, Calif. The studies, he says, "will give a lot of ideas to people on what to do with the D-Wave machine." ■

GENES & CELLS

Some enteroviruses are so predictable

Outbreak patterns for hand, foot and mouth disease revealed

BY TINA HESMAN SAEY

Enteroviruses, including the ones that cause hand, foot and mouth disease, trigger outbreaks in predictable patterns.

Some of the viruses, which cause everything from fevers and rashes to meningitis, circulate every year or every two or three. How foreseeable those patterns are has been unclear. Now, using Japan's birthrate and infection rates, disease modelers have accurately predicted outbreaks of 18 of 20 enteroviruses, the team reports in the Aug. 24 *Science*.

Margarita Pons-Salort and Nicholas Grassly, both of Imperial College London, conducted the study with data from Japan because it keeps track of viruses spreading in the general population. Pons-Salort and Grassly examined health data collected from 2000 to 2016 to build and test their mathematical model.

Enteroviruses are similar to each other, and antibodies to one variety sometimes will attack another variety. Scientists thought this "cross-reactivity" could change how the viruses spread and make tracking individual varieties difficult, if not impossible.

But some of the viruses appear in regular cycles, so the researchers were hopeful they could track at least some, Pons-Salort says. She and Grassly started with a simple scenario: Catching an enterovirus would cause people to produce detectable antibodies that would make individuals immune to the virus for a long time, even for life. Birthrate would determine how long it would take for enough susceptible children to build up in the population to enable an outbreak. Japan's declining birthrate means that it should take longer than it used to for an outbreak to occur.

And in fact, one enterovirus called coxsackievirus A4, one of the hand, foot and mouth disease culprits, had switched from causing yearly outbreaks from 2000 to 2004 to causing outbreaks every two years. That pattern mirrored what happened with measles in Japan. Immunity and birthrate data help predict measles outbreaks. So using that same approach, Pons-Salort and Grassly detected disease patterns established in 2000 to 2014 that predicted how 18 of 20 enteroviruses behaved in 2015 and 2016.

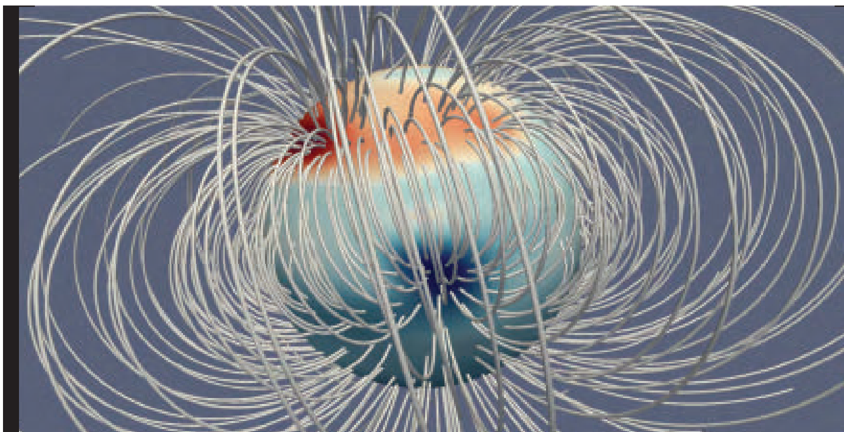
The two unpredictable viruses, coxsackievirus A6 and echovirus 18, initially behaved one way, but then their patterns changed. Altering variables in the model helped the researchers determine what probably happened.

Before 2009, coxsackievirus A6 caused herpangina, in which blisters form in the throat and roof of the mouth. Now, the virus is a leading cause of hand, foot and mouth disease worldwide. A change in 2010 that made the virus five times as virulent as its earlier form could account for the switch, the researchers calculated.

About 2006, something different happened to echovirus 18, which can cause meningitis in kids, Pons-Salort and Grassly found. Either a 9 percent increase in transmissibility or a change in a surface protein that influences how the immune system recognizes the virus may account for the virus's change in outbreak pattern.

Knowing when viruses will strike provides "opportunity to really plan ahead with the health care response," says infectious disease researcher Birgit Nikolay of the Pasteur Institute in Paris.

The model needs to be tested in other countries to see if other factors influence enterovirus spread, she says. But the study "is a really important first step in understanding the outbreak dynamics of enteroviruses." ■



K.M. MOORE *ET AL/NATURE* 2018

ATOM & COSMOS

Jupiter's magnetic field is surprisingly weird

If Earth's magnetic field resembles that of a bar magnet, Jupiter's looks like someone took a bar magnet, bent it in half and splayed it at both ends. The field emerges in a broad swath across Jupiter's northern hemisphere (red in the simulation) and re-enters the planet both around the south pole and in a concentrated spot (dark blue) just south of the equator, planetary scientist Kimberly Moore of Harvard University and colleagues report in the Sept. 6 *Nature*. This new look at the magnetic field comes courtesy of data from NASA's Juno spacecraft.

Jupiter's odd magnetic field is hard to explain. One possibility, the researchers say, is that the extreme temperature and pressure near Jupiter's core create a soup of rock and ice partly dissolved in liquid metallic hydrogen. The interplay of turbulent layers might generate a convoluted magnetic field. Or perhaps squalls of helium rain closer to the clouds stir up conductive layers below, contorting the field before it emerges from the clouds. *—Christopher Crockett*

EARTH & ENVIRONMENT

Global warming may rev up crop pests

Hungrier insects could do more damage to corn, wheat and rice

BY SUSAN MILIUS

With temperatures creeping up as the climate warms, those very hungry caterpillars could get even hungrier, and more abundant. Crop losses to pests may grow.

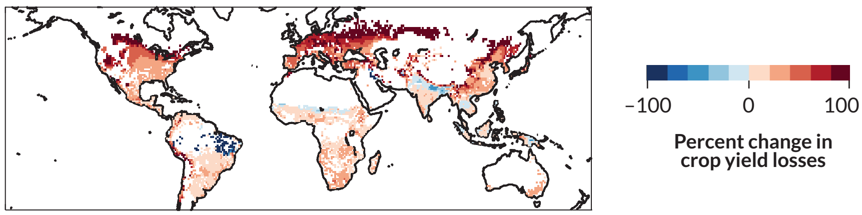
Insects will be "eating more of our lunch," says earth scientist Curtis Deutsch of the University of Washington in Seattle. Based on how heat speeds up insect metabolism and reproduction, he and colleagues estimate that each degree Celsius rise in temperature means an extra 10 to 25 percent of damage to wheat, maize and rice. The prediction appears in the Aug. 31 *Science*.

Insects already munch their way through 8 percent of the world's maize and wheat each year and damage 14 percent of rice, Deutsch says. If Earth's average global temperature rises just 2 degrees above preindustrial levels, annual crop losses could reach about 10 percent for maize, 12 percent for wheat and 17 percent for rice. That's a total loss of about 213 million metric tons for the three grains combined.

Unlike mammals and birds, insects heat up or chill as their environment does. As an insect warms, its metabolism speeds up, too. The faster it burns energy, the more ravenously the insect feeds and the sooner it reproduces. The speedup rates aren't hugely different across various kinds of insects, Deutsch says. So he and colleagues developed a mathematical simulation of how much insects as a whole would rev up, reproduce and ravage grains in warmer times.

Tropical insects are often already near the ceiling of their temperature tolerance, where an insect has to cope with so much heat damage that reproductive rates falter. In cooler temperate zones, where wheat grows, insects have more leeway to live faster. So future wheat is especially vulnerable, Deutsch says.

This is "an incredibly valuable first



Corn decline As Earth warms, the largest increases (red) in insect damage to maize by 2100 will show up in milder climates, a new analysis predicts.

MATTER & ENERGY

Physicists close in on the real Big G

Estimates for the strength of gravity are getting better

BY MARIA TEMMING

Physicists now have the most precise estimates yet for the strength of gravity.

Two experiments measuring the tiny gravitational attraction between objects in a lab have measured Newton's gravitational constant, also known as Big G, with an uncertainty of only about 0.00116 percent. Until now, the smallest margin of uncertainty for any G measurement has been 0.00137 percent.

The new set of G values, reported in the Aug. 30 *Nature*, is not the final word. The two values — 6.674184×10^{-11} and 6.674484×10^{-11} cubic meters per kilogram per second squared — disagree slightly, and they don't explain why previous experiments have produced such a wide spread of G estimates (*SN Online: 4/30/15*). Still, researchers may be able to use the new values, along with other estimates of G, to discover why measurements for this key fundamental constant are so finicky — and perhaps pin down the strength of gravity once and for all.

The exact value of G, which relates mass and distance to the force of gravity in Newton's law of universal gravitation, has eluded scientists for centuries. That's because the gravitational attraction between a pair of objects in a lab experiment is extremely small and susceptible to the gravitational influence of other nearby objects.

The currently accepted value for G, based on measurements from the last 40 years, is 6.67408×10^{-11} cubic meters per kilogram per second squared. That figure is saddled with an uncertainty of 0.0047 percent, making G thousands of times more imprecise than other fundamental constants — unchanging, universal values such as the speed of light (*SN: 11/12/16, p. 24*). The cloud of uncertainty surrounding G limits how well scientists can determine the masses of celestial objects and the values of other constants that are based on G.

0.00116 percent

Uncertainty for new measurements of Newton's gravitational constant

Shan-Qing Yang, a physicist at Huazhong University of Science and Technology in Wuhan, China, and colleagues measured G using two torsion pendulum instruments. Each device contains a metal-coated silica plate suspended by a thin wire and surrounded by steel spheres. The gravitational attraction between the plate and the spheres causes the plate to rotate on the wire toward the spheres.

But the two torsion pendulums had slightly different setups to accommodate two ways of measuring G. With one torsion pendulum, the researchers measured G by monitoring the twist of the wire as the plate angled itself toward the spheres. The other torsion pendulum was rigged so that the metal plate dangled from a turntable, which spun

C.A. DEUTSCH *ET AL/SCIENCE* 2018

step" toward predicting future losses, says Nathan Lemoine, a physiological ecologist at Colorado State University in Fort Collins. But, he notes, insect metabolism is just one of many factors that will affect future crop yields.

Even if farmers adopt new defenses, costs will probably rise, says plant pathologist Erich-Christian Oerke of the University of Bonn in Germany, who published data in 2006 that provided the starting point for the new study. Oerke was not involved in the new calculations.

Rising temperatures can encourage or discourage insects invading new territories. Temperatures may also affect the parasites that prey on crop pests. Both pests and plants may adapt and evolve. Predictions will have to evolve, too. "I don't want people to think this is a sky-is-falling story," Deutsch says. Hungrier insects will not wipe out these grains entirely. Yet any loss can be consequential to people who have gotten hungrier themselves in a more crowded world. ■

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to prevent the wire from twisting. The researchers measured G by tracking the turntable's rotation.

To make measurements as precise as possible, the researchers corrected for a long list of tiny disturbances, from slight variations in the density of materials used to make the torsion pendulums to seismic vibrations from earthquakes across the globe. "It's amazing how much work went into this," says physicist Stephan Schlamminger of the National Institute of Standards and Technology in Gaithersburg, Md. Conducting such a painstaking set of experiments "is like a piece of art," he says.

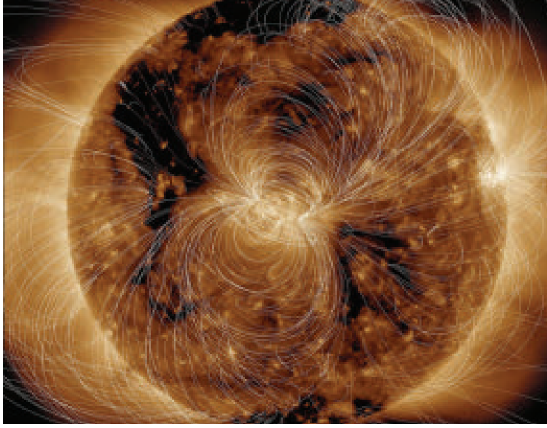
The record precision is "a fantastic accomplishment," says Clive Speake, a physicist at the University of Birmingham in England, but the true value of G "is still a mystery." Repeating these and other past experiments to identify previously unknown sources of uncertainty, or designing new G-measuring techniques may help reveal why estimates for this key fundamental constant continue to disagree, he says. ■

ATOM & COSMOS

Sun's gamma-ray output surprises

High-energy light could offer a way to probe magnetic fields

BY LISA GROSSMAN



SOLAR DYNAMICS OBSERVATORY/GSFC/NASA

The sun's magnetic fields, visualized as white lines, scramble cosmic rays and may cause them to shoot high-energy gamma rays toward Earth.

The lethargic sun turns out to be a factory of extremely energetic light.

Scientists have discovered that the sun puts out more high-energy gamma rays than predicted. But what's really weird is that the rays with the highest energies appear when the star is supposed to be at its most sluggish, researchers report in an upcoming study in *Physical Review Letters*. The research is the first to examine these gamma rays over most of the solar cycle, a roughly 11-year period of waxing and waning solar activity.

The changes in gamma rays are probably connected to the activity of the sun's magnetic fields. "The almost certain thing that's going on here is the magnetic fields are much more powerful, much more variable and much more weirdly shaped than we expect," says John Beacom, an astrophysicist at Ohio State University in Columbus.

The sun doesn't directly make high-energy gamma rays. Instead, cosmic rays — protons that zip through space with some of the highest energies known in nature — smack into solar protons, producing high-energy gamma rays in the process.

Those gamma rays would get lost inside the sun if not for the magnetic fields, which take charged particles like cosmic rays and spin them around like a house in a tornado. Theorists have predicted that cosmic rays whose paths have been scrambled by the sun's tangled magnetic fields should send high-energy gamma rays shooting back out of the sun, where astronomers can see them.

Beacom and colleagues, led by astrophysicist Tim Linden of Ohio State, sifted through data collected by NASA's Fermi Gamma-ray Space Telescope from August 2008 to November 2017. The observations spanned a period of low solar activity in 2008 and 2009, a period of higher activity in 2013 and then a decline in activity. The team tracked the number of solar gamma rays emitted per second as well as their energies and where on the sun the rays came from.

There were more high-energy gamma rays, above 50 billion electron volts, or GeV, than anyone predicted. Weirder still, rays with energies above 100 GeV appeared only during the solar minimum, when the sun's activity level was low.

Strangest of all, the sun emitted gamma rays from different parts of its surface at different times in its cycle. During the solar minimum, gamma rays came mainly from near the equator. During the solar maximum, when the sun's activity level was high, they clustered near the poles. The team couldn't connect the excess gamma rays to other solar behaviors that change with magnetic activity, like solar flares or sunspots.

"There really is something strange afoot," says Craig DeForest, a solar physicist at the Southwest Research Institute who is based in Boulder, Colo. "When there's some new discovery, scientists don't shout 'Eureka!' They go, 'Hmm, that's funny. That can't be right.' This is a classic case of that."

Beacom says the high-energy gamma rays may offer a new way to probe the magnetic fields in the uppermost layer of the solar surface. "You can't see [the magnetic fields] with a telescope," he says. "But these [cosmic rays] are journeying there, and the gamma rays they send back are messengers of the terrible conditions there." ■

HUMANS & SOCIETY

Replication crisis spurs reforms

Redo attempts highlight ways to improve social science

BY BRUCE BOWER

What started out a few years ago as a crisis of confidence in scientific results has evolved into an opportunity for improvement. Researchers are exposing how studies get done and encouraging independent redos of published reports. And there's nothing like a string of failed replications to spur improved practices.

That's the conclusion of a research team, led by Caltech economist Colin Camerer, that examined 21 social science papers published in *Nature* and *Science* from 2010 to 2015. Replication teams directed by Camerer's group successfully reproduced effects reported in 13 of those papers, the team reports August 27 in *Nature Human Behavior*.

The effort is an improvement over a previous attempt to replicate psychology findings (*SN: 4/2/16, p. 8*). But the results underscore the need to view any single study with caution. An opportunity now exists to create a culture of replication that provides a check on what ends up getting published and publicized, Camerer's team contends.

Still, the study reveals a troubling trend. For repeat studies that panned out, which included four to five times as many participants as originally studied, the statistical strength to detect actual effects was weaker than reported for the initial investigations. In other words, the best replications, which exceeded initial studies in their ability to detect actual effects, were only partially successful.

A new investigation of social science studies, including one that looked at how contemplation of The Thinker (shown) affects religious beliefs, finds that reproducibility is improving.

JOE DESOUSA/FLICKR (CC0 1.0)

One reason for replication difficulties is that journals have tended not to publish studies that disconfirm previous results, leaving initial findings unchallenged, says study coauthor and psychologist Brian Nosek of the University of Virginia in Charlottesville. Even the most prestigious journals have often published results that garner lots of attention but could easily have occurred randomly, he says.

On the plus side, such practices are changing. "The social and behavioral sciences are in the midst of a reformation in scientific practices," Nosek says.

> "The social and behavioral sciences are in the midst of a reformation in scientific practices."
> BRIAN NOSEK

In the last five years, for example, 19 of 33 journals in social and personality psychology have established policies requiring investigators to submit their research designs for peer review before submitting papers. Peer reviewers can check whether experimenters altered their procedures to tease out positive effects. These journals also collect researchers' experimental data so that replications can be done.

Intriguingly, when Camerer's group asked nearly 400 researchers, mostly psychologists and economists, to examine data from the 21 experiments and predict whether each could be reproduced, the scientists' forecasts were usually correct. Peer predictions may be one way to help bolster peer reviews and weed out weak studies, Nosek says.

Another positive sign is that scientists whose papers were rechecked generally cooperated with the effort, even if their findings weren't replicated. For instance, one replication failed to support a 2012 study in *Science* that reported that viewing pictures of Auguste Rodin's famous statue The Thinker reduced volunteers' self-reported religious beliefs. This finding was part of a project examining how mental reflection affects religious belief.

Will Gervais, a psychologist at the University of Kentucky in Lexington and a coauthor of the 2012 paper, welcomes the new evidence. "In hindsight, we oversold a study with an effect that was barely statistically significant," he says. Replication efforts represent "an opportunity to sharpen our scientific practices."

Yet, the problem with studies in the social sciences, as well as in neuroscience and medicine (*SN: 2/18/17, p. 10*), goes deeper than reproducibility, says Gerd Gigerenzer, a psychologist at the Max Planck Institute for Human Development in Berlin.

Researchers in these fields largely rely on a statistical technique that assesses whether a result — say, an apparent decline in religious belief after viewing The Thinker — would likely occur if there were no true difference. Scientists call that a null hypothesis. An arbitrary cutoff determines whether a reported difference from a null hypothesis is "statistically significant." But that doesn't establish the existence of a true effect, though it's often assumed to do just that. And typically, researchers don't test alternative predictions that try to explain how, for example, contemplation might affect spiritual conviction, Gigerenzer says.

What's worse, many researchers wrongly assume that achieving statistical significance makes replication unnecessary, Gigerenzer has found.

He contends that researchers usually resort to null hypothesis testing as a ritual for getting studies published, without having to develop actual theories. Psychology departments need to teach various statistical methods that can be used to test experimental predictions, he suggests. Journal editors should no longer accept studies based solely on statistical significance, he argues. "We need to blow up the current system and promote real statistical thinking and judgment." ■

BODY & BRAIN

Antibody attack muddles memory

In mice, rogue immune molecules target proteins on nerve cells

BY LAURA SANDERS

Antibodies in the brain can scramble nerve cell connections, leading to memory problems in mice.

In the last decade, brain-attacking antibodies have been identified as culprits in certain neurological diseases. The details of how antibodies pull off this neuronal hit job, described online August 23 in *Neuron*, may ultimately lead to better ways to stop the ensuing brain damage.

Research on antibodies that target the brain is a "biomedical frontier" that may have implications for a wide range of disorders, says Betty Diamond, an immunologist and rheumatologist at Northwell Health's Feinstein Institute for Medical Research in Manhasset, N.Y. "It's beyond the idea stage," she says. "It's into the 'It happens. Let's figure out the why and the when.' "

Antibodies that mistakenly target sites on the body's own tissues are called autoantibodies. One such autoantibody takes aim at part of the AMPA receptor, a protein that sits on the outside of nerve cells and detects incoming chemical messages. These autoantibodies interfere with the receptor's message-sensing job, neurologist Christian Geis of Jena University Hospital in Germany and colleagues found.

The team purified autoantibodies from patients suffering from autoimmune encephalitis, brain inflammation that causes confusion, seizures and memory trouble. When the researchers put these human autoantibodies into the brains of mice, the animals began showing memory problems, too. Mice injected with autoantibodies were worse at recognizing new objects than mice that didn't receive the autoantibodies.

Experiments on mice and human cells in lab dishes revealed the nature of the brain attack. The autoantibodies attached to particular bits of AMPA receptors and then forced those bits to move inside nerve cells where they were no longer effective. This shift left the nerve cells worse at sensing chemical signals from other nerve cells, a deficit that might have caused the mice's memory problems.

The details of this autoantibody brain attack might point out ways to help nerve cells under siege maintain communication, Geis says. Current treatments for autoimmune encephalitis are less specific, involving the removal of harmful antibodies from the blood or tamping down a person's overall immune response.

Autoantibodies have been linked to a variety of other illnesses, including lupus, autism and schizophrenia. But some of these results are difficult to interpret, Geis says, leaving questions about autoantibodies' roles in certain diseases. ■

MATH & TECHNOLOGY

Lithium-oxygen batteries get a boost

Redesign stores more energy, lasts longer than its predecessors

BY MARIA TEMMING

A new type of lithium-oxygen battery could pack more energy and last longer than its predecessors.

Lithium-oxygen batteries, which are more energy-dense and made of more sustainable materials than typical lithium-ion batteries, are promising candidates for the next generation of rechargeable batteries (*SN: 1/21/17, p. 22*). But lithium-oxygen batteries aren't widely used because they die quickly. By tweaking the building materials, researchers have constructed a lithium-oxygen battery that can release nearly 100 percent of its stored charge and be recharged at least 150 times. This battery, described in the Aug. 24 *Science*, could become a more reliable power source for electric cars or other electronics.

Lithium-oxygen cells are made of two electrodes, an anode and a cathode, separated by an electrolyte. When the battery is powering a device, oxygen molecules on the cathode combine with lithium ions from the electrolyte to form a solid compound called lithium peroxide. That chemical reaction releases energy. Recharging the battery breaks apart the lithium peroxide, returning oxygen and lithium to their starting positions.

But forging lithium peroxide generates unwanted chemical by-products, which wastes energy. As a result, the battery may be able to deliver only about 80 percent of its stored electric charge to the device it's powering. These pesky chemicals also damage the battery's electrolyte and cathode, so the battery often fails after only a few dozen recharges, says Larry Curtiss, a materials chemist at Argonne National Laboratory in Lemont, Ill.

To build a better lithium-oxygen battery, chemist Linda Nazar of the University of Waterloo in Canada and colleagues replaced the typical organic electrolyte for an inorganic molten salt, and the standard carbon-based cathode for a metal one.

50

percent

Increase in energy a new kind of lithium-oxygen battery could store compared with a typical one

In this battery, oxygen combines with lithium to create lithium oxide. This chemical reaction can store 50 percent more energy than the lithium peroxide reaction. And lithium oxide doesn't produce the chemical by-products that lithium peroxide does. That allows the new lithium-oxygen battery to release nearly all of its stored charge and recharge more times than lithium-oxygen cells that form lithium peroxide.

The new battery has to be heated to at least 150° Celsius to work. So there's still much work to be done before the battery is used in vehicles. Changing the substance used for the battery's electrolyte may bring down its operating temperature, says Yang Shao-Horn, an energy and materials researcher at MIT. ■

ATOM & COSMOS

Electrons hang 10 in new accelerator

In AWAKE experiment, the particles surf protons' waves

BY EMILY CONOVER

Particle accelerator technology has crested a new wave.

In a first, scientists have shown that electrons can gain energy by surfing waves kicked up by protons shot through plasma. The technique might someday help produce electron beams at higher energies than now possible, to investigate subatomic particles' inner workings.

Standard particle accelerators rely on radio frequency cavities, metallic chambers that create oscillating electromagnetic fields to push particles along. With the new demonstration, "we're trying to develop a new kind of accelerator technology," says Allen Caldwell of the Max Planck Institute for Physics in Munich. Caldwell is a spokesperson for the AWAKE collaboration, which reported the results online August 29 in *Nature*.

At the particle physics lab CERN near Geneva, the team sent beams of high-energy protons through plasma, a state of matter in which electrons and positively charged atoms called ions mingle. The protons set the plasma's electrons jiggling, creating waves that accelerated electrons that were injected into the plasma. Injected electrons reached energies of up to 2 billion electron volts.

Previously, scientists demonstrated the potential of plasma accelerators by speeding up electrons using waves set off by a laser or a beam of electrons. But proton beams can carry more energy, so electrons accelerated by protons' plasma waves may be able to reach higher energies in a single burst of acceleration.

The new result doesn't match the energies produced in previous plasma accelerators. The study is a proof of principle showing that proton beams can be used.

High-energy electrons are particularly useful for particle physics because they are elementary particles — they have no smaller constituents. Protons, however, are made up of a sea of quarks, resulting in messier collisions. And because each quark carries a small part of the proton's total energy, only a fraction of that energy goes into a collision. Electrons put all their oomph into each smashup.

But electrons are hard to accelerate: If put in an accelerator ring, they rapidly bleed off energy. So AWAKE uses accelerated protons to get electrons up to speed.

Some scientists had been skeptical that plasma could be controlled enough for an effort like AWAKE to work, says physicist Wim Leemans of Lawrence Berkeley National Laboratory in California. "This is very rewarding to see that, yes, the plasma technology has advanced." ■

BODY & BRAIN

IVF may raise kids' risk of hypertension

Environmental conditions at conception appear to affect health

BY AIMEE CUNNINGHAM

Assisted pregnancies give infertile couples the chance to have a child. But kids conceived with reproductive technologies, such as in vitro fertilization, are more likely to develop high blood pressure as adolescents than their naturally conceived counterparts, a study finds.

Of 52 teens conceived with technological help, eight had hypertension, defined as blood pressure greater than 130/80 millimeters of mercury. Only one teen of 43 conceived naturally had the same high blood pressure, researchers report in the Sept. 11 *Journal of the American College of Cardiology*. High blood pressure raises the risk of a future stroke or heart attack, among other health problems.

The estimated prevalence of hypertension among U.S. adolescents is about 3.5 percent, compared with 15 percent for the teens in the study born from assisted conceptions. "This is a small study, and this is not terrible blood pressure, but it's blood pressure that should alert somebody that we need to be checking it routinely," says cardiologist Larry Weinrauch of Harvard Medical School, who wrote an editorial accompanying the study.

As of 2014, more than 8 million babies worldwide have been born as a result of assisted pregnancies, according to preliminary data from the International Committee Monitoring Assisted Reproductive Technologies in Palo Alto, Calif.

The new work follows a 2012 study by the same researchers, looking at the same kids as preteens. Urs Scherrer, a specialist in internal medicine at the University of Bern in Switzerland, and colleagues found that the children from assisted conceptions had stiffer blood vessels than normal, and some vessels had thicker walls, features that contribute to a higher future risk of cardiovascular disease.

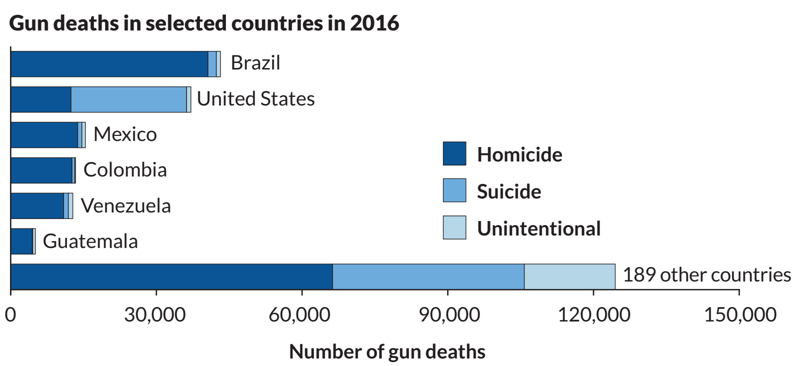
The blood vessel abnormalities and higher hypertension may be the result of changes involving epigenetic marks (*SN: 12/24/16, p. 12*). These chemical tags, added to DNA or to proteins called histones, are a way the body can ramp gene activity up or down. Environmental conditions — such as chemical exposures, diet and stress — can alter epigenetic marks and therefore gene regulation.

Assisted reproductive technologies put mature eggs and embryos in environmental conditions that differ from that of the womb. With IVF, for example, mature eggs collected from the ovaries are fertilized in a lab before being implanted into the uterus. In studies in mice, Scherrer and colleagues have shown that IVF can alter an epigenetic mark that changes the regulation of a gene that's active in the aorta, the body's main artery. Mice conceived by IVF also developed impaired blood vessels and hypertension.

More work is needed to uncover which epigenetic changes alter the development of the cardiovascular system. That information might improve assisted reproductive technologies and procedures by, for example, suggesting which environmental conditions outside the womb should be avoided because they may affect the chemical tags.

In the meantime, doctors should identify people conceived with assisted reproductive technology and monitor them, Scherrer says. "Every general practitioner should ask about your fetal and neonatal history." The use of these reproductive techniques "will have important effects on your future disease risk."

The first child born from IVF turned 40 in July. Because children conceived by these methods are still relatively young, it's not yet clear if there are other related health effects. More data are needed, Weinrauch says. "We have to start by making people aware of this and finding out if there is anything else going on." ■



HUMANS & SOCIETY

Gun violence around the world

A new survey reveals the hot spots for gun deaths that occur outside of war zones. In 2016, firearm-related homicides, suicides and accidental deaths were highly concentrated. For example, six countries — the United States, Brazil, Mexico, Colombia, Venezuela and Guatemala (shown above) — accounted for about half of the estimated gun deaths unrelated to armed conflict, even though the nations together contributed less than 10 percent of the world's population, researchers report in the Aug. 28 *JAMA*.

In Brazil and the other Latin American countries shown, most gun deaths were homicides. That high homicide rate is linked to drug and weapons trafficking, research has found. In the United States, suicide accounted for most gun deaths. Having guns in the house has been linked to higher use of the weapons to commit suicide and to more accidental gun deaths. *— Aimee Cunningham*

GRAPH: E. OTWELL; DATA: THE GLOBAL BURDEN OF DISEASE 2016 INJURY COLLABORATORS/JAMA 2018

EARTH & ENVIRONMENT

New tools aim to predict toxic tides

Better algal bloom forecasts can help protect human health

BY LEAH ROSENBAUM

The stench of thousands of dead, bloated fish hung over the beaches of western Florida this summer — casualties of an algal bloom that began last October. Such a bloom revisits the coastline almost every year, but this one is particularly intense — and toxic. Called red tides due to the water's often murky reddish tint, these blooms emit neurotoxins that can kill sea creatures, including dolphins and endangered sea turtles, and cause breathing problems for humans.

But the Florida red tide is not the only dangerous algal bloom that plagues U.S. waters. Throughout the country, a variety of toxic tides occur, and they're happening more frequently, in more places and lasting longer.

On the West Coast, "things have just gotten so much worse" in recent decades, says oceanographer Clarissa Anderson of the Scripps Institution of Oceanography in La Jolla, Calif. Freshwater bodies aren't immune, either. Lake Erie, for instance, has experienced increasingly large blooms, some even lasting into winter. All of these algal blooms can harm human and animal health and hurt industries like fishing that rely on water ecosystems.

The algal bloom problem is compounded by ongoing runoff from agricultural fields, filling freshwater and marine basins with nutrients that fuel algal growth. Higher carbon dioxide levels and the effects of climate change, including higher water temperatures and changes in salinity, could further prompt algal growth and worsen blooms, the U.S. Environmental Protection Agency warns.

Still, not all algae are bad. The term "algae" is a catchall used for a variety of organisms that photosynthesize and live in watery environments. They include bacteria, other single-celled organisms and larger "macroalgae" like kelp.

Harmful algal blooms, also known as HABs, are worrisome enough that scientists are developing forecasting tools to better predict when and where blooms might hit. Many of these forecast systems are still being tested, and most can predict blooms only three to seven days in advance.

Here's a look at some of the country's toxic tides and how scientists are trying to get ahead of them.

Breathing in Florida's red tides

Florida's red tides are caused by *Karenia brevis*, which releases neurotoxins called brevetoxins when the single-celled organism dies or is broken down by tumultuous waves.

During a red tide, toxins carried into the air mean that beachgoers "might cough or sneeze or have itchy eyes," says research scientist Tracy Fanara of Mote Marine Laboratory & Aquarium in Sarasota, Fla. For people already struggling with lung issues such as asthma, the effects can be even worse.

In September 2017, Mote began testing a program called HABScope, training 20 volunteers to sample water daily at various beaches during a red tide. Volunteers place three drops of seawater under a microscope and record a 30-second video of *K. brevis* swimming around on the slide. A computer program developed by the Gulf of Mexico Coastal Ocean Observing System uses image recognition to count the algal cells in each sample. That information, plus wind and water current conditions, goes into a model created by the National Oceanic and Atmospheric Administration that predicts breathing conditions at a particular beach for the next few days. The results are published online for the public.

In Maine, an algal bloom forecast gives predictions three to seven days in advance to help people avoid harvesting tainted shellfish.

ARTHUR VILLATOR/SHUTTERSTOCK

Across the Gulf of Mexico, the University of Texas Rio Grande Valley runs a similar program, the Red Tide Rangers.

While it used to take a scientist a day or more to count *K. brevis* cells in a sample, HABScope "allows a volunteer to do this within five minutes," Fanara says. "Hopefully with this real-time data that we're providing, we can get better and more accurate" forecast predictions.

HABScope also allows people to submit information about beaches in Florida that they visit via a crowdsourcing phone app. "Anybody can do it," Fanara says.

Seafood off the coast of Maine

The Gulf of Maine is home to an algal species that can contaminate shellfish, and if eaten, cause paralysis or even death. Blooms of single-celled *Alexandrium catenella* are "incredibly toxic," says NOAA oceanographer Richard Stumpf, who is based in Silver Spring, Md. Eight people in Maine were sickened with paralytic shellfish poisoning from recreational shellfish harvesting in closed areas from 2007 to 2009.

The emergence of a bloom leads fishery managers to temporarily close the region's multimillion dollar industry for harvesting clams, mussels, oysters, crabs and lobsters. Being able to forecast such blooms would help managers and fishermen plan for such closures in advance.

A. catenella flourishes in the warmer waters that circulate off Maine from July through September, consuming available nutrients until they run out. The algae then reproduce, with their offspring clumping together in cysts that sink to the seafloor until breaking open during the next warm season and sending cells to the surface. For about 12 years, scientists have been gathering sediment samples from about 50 seafloor sites in Maine each October and November and counting the number of cysts. That information, as well as projections for wind and sea temperatures, goes into a modeling system for predicting how big the

A toxic cyanobacteria bloom covers part of Lake Erie on August 14, 2017. Predicting the intensity of such blooms is important for water treatment before the lake water is sent to some 11 million people to drink.

ZACHARY HASLICK/AERIAL ASSOCIATES PHOTOGRAPHY INC./NOAA GREAT LAKES ENVIRONMENTAL RESEARCH LAB/FLICKR (CC BY 2.0)

next year's bloom might be, says Stumpf, who leads the project.

But that seasonal forecast can't predict exactly which areas will be most affected. For that, the team produces another, shorter-term forecast — which relies on data on wind conditions, water temperature, salinity and water currents — that can estimate local conditions three to seven days in advance.

Neither forecast can tell how toxic a particular bloom might be — a goal for Dennis McGillicuddy, an oceanographer at the Woods Hole Oceanographic Institution in Massachusetts. "Shellfish are basically little bioaccumulators of the toxin," he says. He and colleagues are working on a model to predict how many toxic algal cells shellfish would be exposed to in a season and how quickly the shellfish would be able to flush those toxins out, which can take months.

Lake Erie's blue-green blooms

Over the last several years, Lake Erie has been overtaken by a thick, slimy foe: cyanobacteria, or blue-green algae.

With cyanobacteria found in water bodies across all 50 states, scientists are working on how to predict blooms so that officials can make adequate plans for water treatment. Cyanobacteria produce toxins called microcystins that can cause skin rashes, vomiting and diarrhea.

The biggest cyanobacteria blooms in the United States occur during the warmest months in Lake Erie, a source of drinking water for about 11 million people. The water is treated, but sometimes not enough if a bloom's toxicity has been underestimated, leading to illness or temporary water shortages. In 2014, 110 people were sickened after drinking undertreated water, prompting the city of Toledo, Ohio, to warn 500,000 people against drinking tap water for two days.

The intensity of a bloom is directly related to how much of the nutrient phosphorus enters the lake via agricultural runoff (*SN: 3/17/18, p. 5*). A river-monitoring program run by Heidelberg University in Tiffin, Ohio, samples water flowing into Lake Erie several times a day to measure how much phosphorus enters the lake, Stumpf says, and researchers use the data to predict the seasonal bloom.

Stumpf and other researchers also release a shorter-term forecast — based on satellite images of the bright green blooms along with data on phosphorus content and wind conditions — to show where within the lake a bloom will appear within a few days. These forecasts then inform online advisories for the public.

Toxic acid in the Pacific

Off the West Coast, from California to Alaska, rod-shaped *Pseudo-nitzschia* typically proliferate during warmwater months. Some species secrete toxic domoic acid, which can cause short-term memory loss, brain damage or even death in people who eat contaminated shellfish. Marine mammals can also suffer this neurological harm.

"This is a really pivotal moment" for developing forecasting models, says Scripps oceanographer Anderson. She has spent the last decade developing a forecasting tool to predict the algae's domoic acid levels at locations up to 1,000 kilometers offshore from Oregon and California. The three-day public forecast, called C-HARM, relies on satellite photos that show chlorophyll patterns, sea temperature and salinity, and three computer simulations that integrate these inputs.

Anderson also puts out a monthly bulletin that estimates the probability of a bloom occurring at various locations.

In Washington, the threat of ingesting domoic acid is particularly concerning for Native Americans in the state who traditionally harvest razor clams.

To see where algae might spread, scientists first look at known spots where blooms often begin and then check sea temperature and salinity to track optimal conditions for algal growth. Building a forecast can take days or weeks, as scientists have to travel by boat to collect samples every other week. But this month, NOAA's Northwest Fisheries Science Center in Seattle is set to begin testing an underwater drone that can collect samples more frequently, even in rough conditions. "It's going to improve the accuracy of the forecast," says NOAA biologist Vera Trainer.

Health and wildlife authorities, as well as tribal representatives, rely on the forecasts to decide which beaches should be closed during clam season. "They're able to selectively open only those beaches that are safe," Trainer says. Researchers hope to make the forecast available to the public within a few years. ■

LIFE & EVOLUTION

Naked mole-rats eat their queen's poop and get parenting cues

Dealing with poop is an unavoidable hazard of raising children. For naked mole-rats, that's especially true.

During pregnancy, the scat of a naked mole-rat queen — the only female in the colony that reproduces — contains high levels of the sex hormone estradiol. The queen gives birth to a few dozen pups each year. When subordinate females eat that poop, the estradiol cues them to snap into parenting mode and care for the queen's offspring, researchers report online August 27 in the *Proceedings of the National Academy of Sciences.*

In colonies of naked mole-rats (*Heterocephalus glaber*), lower-ranking females don't have developed ovaries and don't experience the pregnancy-induced hormonal shifts that cue parenting behaviors, yet they still care for babies.

Experiments revealed poop's role in triggering parenting. Scientists in Japan gave poop pellets from nonpregnant queens to subordinates for nine days. One group got pellets with added estradiol to mimic pregnancy poop. Levels of estradiol increased in the dung of subordinate females that ate the hormone-packed pellets, suggesting that scat snacks could induce measurable hormonal changes. Those mole-rats were more responsive to the cries of pups than those that didn't get the hormone boost. *— Laurel Hamers*

GENES & CELLS

Genome tells story of poppy's transformation into a painkiller

A draft of the poppy's genome is providing clues to how the plant evolved to produce molecules such as morphine.

Scientists pieced together the genetic instruction book of the opium poppy (*Papaver somniferum*). They identified a cluster of 15 genes that help the plant synthesize a group of chemically related compounds that includes painkillers like morphine and other molecules with potential medicinal properties.

A group of genes that help poppy plants produce some of these molecules, known as benzylisoquinoline alkaloids, have been clustered together for tens of millions of years, an international research team reports online August 30 in *Science*. But the plant's morphine production evolved more recently. About 7.8 million years ago, the plant copied its entire genome. Some of the resulting surplus genes evolved new roles, helping poppies produce morphine.

It wasn't a one-step process, though. An even earlier gene duplication event caused two genes to fuse into one. That hybrid gene is responsible for a key shapeshift in alkaloid precursors, directing those molecules down the chemical pathway toward morphinelike compounds instead of other benzylisoquinoline alkaloids. *— Laurel Hamers*

The newly deciphered genome of the opium poppy is revealing how the plant evolved the ability to make painkilling molecules.

TANJA NIGGENDIJKER/WIKIMEDIA COMMONS (CC BY 2.0)

GENES & CELLS

CRISPR gene editing relieves dogs' muscular dystrophy symptoms

Gene editing can allay Duchenne muscular dystrophy in dogs. Using CRISPR/Cas9 in beagle puppies, scientists fixed a genetic mutation that causes muscle weakness and degeneration, researchers report online August 30 in *Science.*

Corrections to the gene responsible for muscular dystrophy had been made in human muscle cells in dishes and in mice, but never in a larger mammal. The new results bring scientists closer to making such treatments a reality for humans, says study coauthor Eric Olson, a molecular biologist at the University of Texas Southwestern Medical Center in Dallas.

People with Duchenne muscular dystrophy rarely live past their 20s, often dying of heart failure. The disease can be caused by mutations to the gene that encodes dystrophin, a protein essential for muscle structure and function. The mutations, often clustered in one region of the gene, usually stop dystrophin production.

Researchers injected two 1-month-old beagles that had a mutation in this genetic hot spot with different doses of a virus carrying the gene-editing machinery.

Eight weeks later, dystrophin levels increased in every muscle group examined, though the effect varied. Levels in the heart of the dog receiving the higher dose were 92 percent of what they were in pups without the mutation, but levels in the tongue were only 5 percent of normal.

Other work has found that bringing dystrophin levels up to just 15 percent of what they are in healthy people may be enough to relieve some muscular dystrophy symptoms. All of the muscles studied (except the tongue) showed at least that level of improvement in both dogs. *— Laurel Hamers*

BODY & BRAIN

Skull tunnels may speed immune cells' trek to brain injuries

Skulls seem solid, but the thick bones are actually riddled with tiny tunnels.

Microscopic channels cut through the skull bones of people and mice, scientists have found. In mice, inflammatory immune cells use these hidden channels to travel from the skull's bone marrow, where the cells are made, to the brain, the team reports in the September *Nature Neuroscience*. If immune cells travel such paths through people's skulls, the tunnels represent a newfound way for the cells to reach — and possibly inflame — the brain.

Researchers injected tracking dyes into bone marrow in the skull and other bones of mice, marking immune cells called neutrophils that originated in each locale. After a stroke, neutrophils flocked to the brain. Instead of coming equally from all sources of bone marrow, most of the cells came from skull marrow, Matthias Nahrendorf of Massachusetts General Hospital in Boston and colleagues found.

Microscopes revealed the presence of tiny rivulets in the skull bone that connect bone marrow inside the skull to the outer covering of the brain. In mice, neutrophils used these channels, which averaged about 22 micrometers across, as shortcuts to the brain.

Similar conduits turned up in bits of skull removed during three people's brain surgery. — *Laura Sanders*

HUMANS & SOCIETY

Skeletons hint that medieval warriors recruited from afar

Power systems transcended kinship in medieval Europe. A German burial site contains members of a powerful warrior family that journeyed widely to find recruits to join the household and support a post-Roman kingdom, a study suggests.

Thirteen individuals interred at Niederstotzingen about 1,400 years ago belonged to the Alemanni, a confederation of Germanic tribes that were conquered by and integrated into a neighboring kingdom of the Frankish people, researchers say.

DNA identified 11 skeletons as probably male, biomolecular archaeologist Niall O'Sullivan of Eurac Research's Institute for Mummy Studies in Bolzano, Italy, and colleagues report September 5 in *Science Advances*. Six had genetic ties to modern Northern, Eastern and Central Europeans. All but one were closely related. Tooth enamel analyses, which provide regional signals of early childhood diet, indicate the individuals grew up near Niederstotzingen.

Artifacts from three foreign cultures lay in the graves of several local males. Weapons typical of the Franks accompanied one man, who may have headed the power household, the team says.

Three individuals were unrelated to anyone else and had spent their youth in other regions, tooth data suggest. Two had DNA like that of Mediterranean people.

The new results lend support to suggestions that, after the Roman Empire's fall in the fifth century, the Frankish Empire maintained power for several centuries by establishing mobile warrior households, which enforced obedience to the ruler. — *Bruce Bower*

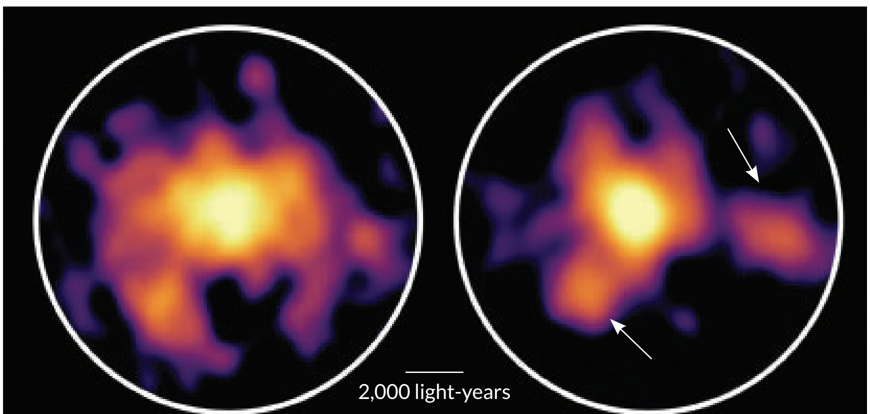
ATOM & COSMOS

How an ancient monster galaxy fueled furious star formation

New images of gas churning inside an ancient starburst galaxy help explain why this galactic firecracker underwent such frenzied star formation.

Using the Atacama Large Millimeter/submillimeter Array, or ALMA, in Chile, researchers took the most detailed views of the disk of star-forming gas that permeated the galaxy COSMOS-AzTEC-1, which dates to when the universe was less than 2 billion years old. The observations, reported in the Aug. 30 *Nature*, reveal a giant reservoir of gas that was susceptible to collapsing and forging new stars. COSMOS-AzTEC-1 and its starburst contemporaries are puzzling, because they cranked out new stars about 1,000 times as fast as the Milky Way does. According to standard cosmology theories, galaxies shouldn't have grown up fast enough to be such prolific star-formers so soon after the Big Bang.

Inside a normal galaxy, the outward pressure of radiation from stars helps counteract the inward pull of gas's gravity, which pumps the brakes on star formation. But in COSMOS-AzTEC-1, the gas's gravity was so intense that it overpowered the feeble radiation pressure from stars, leading to runaway star formation. The ALMA images unveil two especially large clouds of collapsing gas in the disk, which were both major hubs of star formation, astronomer Min Yun of the University of Massachusetts Amherst and colleagues report. The team doesn't know how the galaxy stocked up such a massive supply of star-forming material. — *Maria Temming*



Telescope images reveal the spread of molecular gas (left) and dust (right) inside the ancient starburst galaxy COSMOS-AzTEC-1. Arrows show two especially dense clouds, thousands of light-years from the galaxy's center, that were once hubs of star formation.

K. TADAKI *ET AL/NATURE* 2018, ALMA/ESO, NAOJ AND NRAO

MATH & TECHNOLOGY

Light gives new deicer an assist

A new material that converts light into heat could be laminated onto airplanes, wind turbines, rooftops and offshore oil platforms to help combat ice buildup.

This deicer, called a photothermal trap, has three layers: a top coating of a ceramic-metal mix that turns incoming light into thermal energy, a middle layer of aluminum that spreads this heat across the entire sheet (warming up even areas not bathed in light) and a foam insulation base. The photothermal trap, described August 31 in *Science Advances*, can be powered by sunshine and LEDs.

Engineer Susmita Dash of the Indian Institute of Science in Bangalore and colleagues laid a small sheet of the deicing material out in the sun on a day averaging about –3.5° Celsius, alongside a sheet of aluminum. Within four minutes, the photothermal trap heated to about 30° C, while the aluminum warmed to only about 6° C. After five minutes, snow on the photothermal trap had mostly melted, but snow remained on the aluminum.

Deicing often involves energy-intensive heating systems or environmentally unfriendly chemicals. By harnessing light, the photothermal trap may provide a more sustainable means of keeping surfaces ice-free. — *Maria Temming*

An inside look at three big efforts to study tiny particles

By Emily Conover

Diana Parno's head swam when she first stepped inside the enormous, metallic vessel of the experiment KATRIN. Within the house-sized, oblong structure, everything was symmetrical, clean and blindingly shiny, says Parno, a physicist at Carnegie Mellon University in Pittsburgh. "It was incredibly disorienting."

Now, electrons — thankfully immune to bouts of dizziness — traverse the inside of this zeppelin-shaped monstrosity located in Karlsruhe, Germany. Building the experiment took years and tens of millions of dollars. Why create such an extreme apparatus? It's all part of a bid to measure the mass of itty-bitty subatomic particles known as neutrinos.

KATRIN, which is short for Karlsruhe Tritium Neutrino Experiment, started test runs in May. The experiment is part of a multipronged approach to the study of particle physics, one of dozens of detectors built in an assortment of odd-looking shapes and sizes. Their mission: dive deep into the standard model, particle physicists' theory of the subatomic building blocks of matter — and maybe overthrow it.

Developed in the 1960s and '70s, the standard model has some sizable holes: It can't explain dark matter — an ethereal substance so far detected only by its gravitational effects — or dark energy, a mysterious oomph that causes the cosmos to expand at an increasing rate. The theory also can't explain why the universe is made mostly of matter, while antimatter is rare (*SN: 9/2/17, p. 15*). So physicists are on a quest to revamp particle physics by probing the standard model's weak points.

Major facilities like the Large Hadron Collider — the gargantuan accelerator located at CERN near Geneva — haven't yet found where the standard model goes wrong (*SN: 10/1/16, p. 12*). Instead, particle physics experiments have confirmed standard model predictions again and again. "In some sense we are victims of our own success," says Juan Rojo, a theoretical physicist at Vrije Universiteit Amsterdam. "We don't have hints about what is the next step."

New experiments like KATRIN might be able to ferret out answers. Also joining the ranks are Muon g-2 (pronounced "gee minus two") at Fermilab in Batavia, Ill., and Belle II in Tsukuba, Japan. A behind-the-scenes look at these experiments reveals the sweat, joy and sacrifice that goes into each of these difficult enterprises. These efforts involve hundreds of researchers, sport price tags in the tens of millions of dollars and require major technological undertakings: intricate electronics, powerful magnets and ultraclean conditions. Researchers have built complex apparatuses with their own hands, lugged tons of equipment across continents and cleaned the insides of detectors until they gleam.

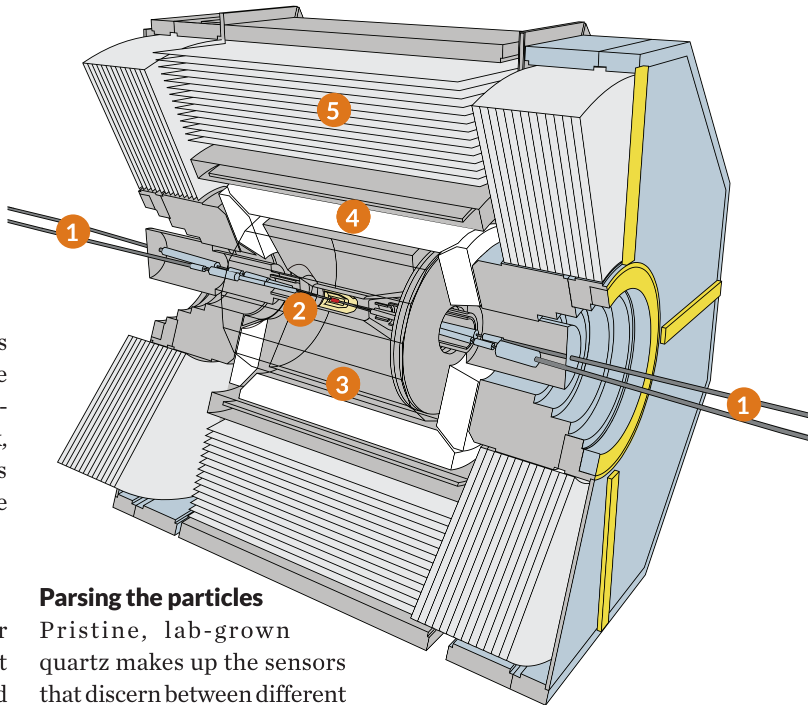
Here's a glimpse at three of the latest standard model challengers.

A researcher stands in the cavernous spectrometer of KATRIN, an experiment in Germany to measure the mass of particles called neutrinos.

MICHAEL ZACHER

Belle II

KEK High Energy Accelerator Research Organization
Tsukuba, Japan
Approximate cost: $50 million



How it works

Electrons and their antimatter partners, positrons, take laps around a 3-kilometer long, ring-shaped accelerator and collide at the center of the Belle II detector, producing a class of particles called B mesons. These particles contain a bottom quark, an exotic particle not found in run-of-the-mill matter. Scientists sift through the data produced when B mesons decay inside the 8-meter-tall detector to learn about the particles' weird ways.

OK, but why?

Certain B mesons seem to prefer to decay into electrons, rather than their heavier cousins, muons (*SN: 5/13/17, p. 16*). That goes against the standard model, which says electrons and muons should appear in equal amounts. If this unexpected behavior holds up to scrutiny, something big must be wrong with the theory. B mesons also partake in a process called CP violation, in which antimatter and matter don't behave like perfect mirror images. Studying CP violation might help scientists understand why the universe is composed of matter and not antimatter. In the Big Bang, matter and antimatter were produced in equal measure and should have annihilated into nothingness, but somehow matter gained an upper hand. It's "the most fundamental question human beings can ask ... 'Why are we here?' " says physics graduate student Robert Seddon.

Like an onion

Each layer of the detector has a different purpose. The innermost layers spot the tracks that particles take through the detector. Farther out, sensors tell one particle from another and measure particles' energies. The outermost section spots muons and other particles that can travel that far. When the accelerator is running, it creates a high-radiation environment in the lab that Seddon, of McGill University in Montreal, calls "completely off-limits. You go in there, you die."

Electrons collide with positrons at the center of Belle II, producing exotic particles called B mesons.

FROM TOP: T. TIBBITTS, HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION, INSTITUTE OF PARTICLE AND NUCLEAR STUDIES; BELLE II

Parsing the particles

Pristine, lab-grown quartz makes up the sensors that discern between different types of particles. Creating the sensors required gluing together bars of quartz over a meter long, precisely aligning them to within about 10 microns — close in size to a human red blood cell. Scratching or smudging the quartz damages it, so handling the bars took a soft touch. Physicists who had arrived recently from overseas were banned from the work, says physicist Saurabh Sandilya of the University of Cincinnati; there's no room for jet lag–induced clumsiness.

1. An accelerator sends electrons from one end and positrons from the other into Belle II.

2. Tracking detectors follow particles' paths after collision, pinpointing B mesons.

3. Quartz sensors distinguish between similar types of particles.

4. A calorimeter measures energies of particles.

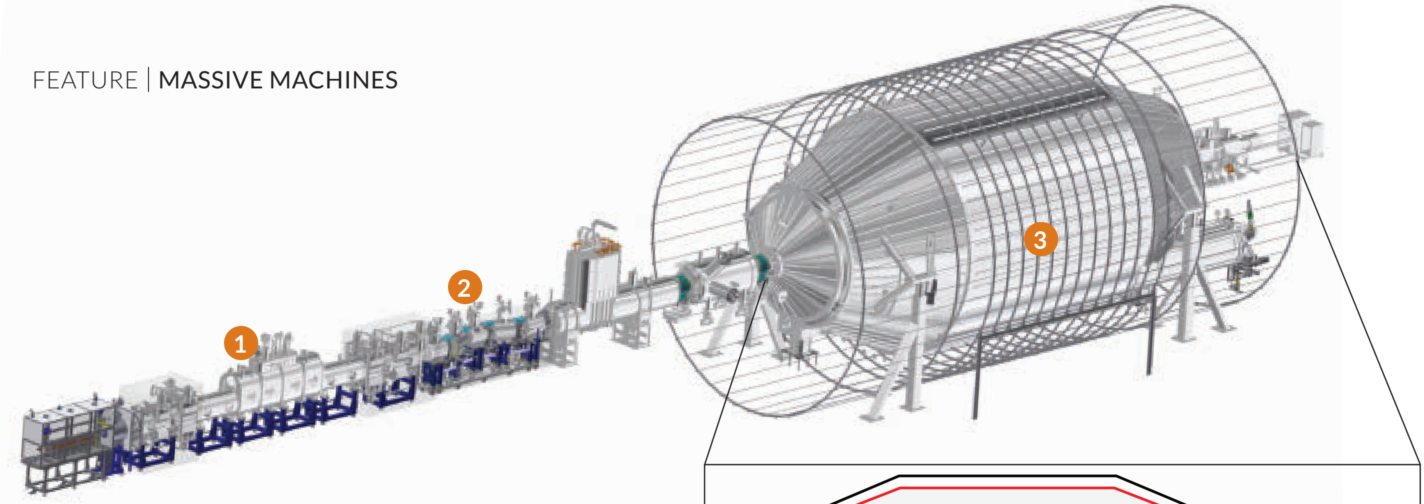
5. Outer layers spot particles that get past inner sections.

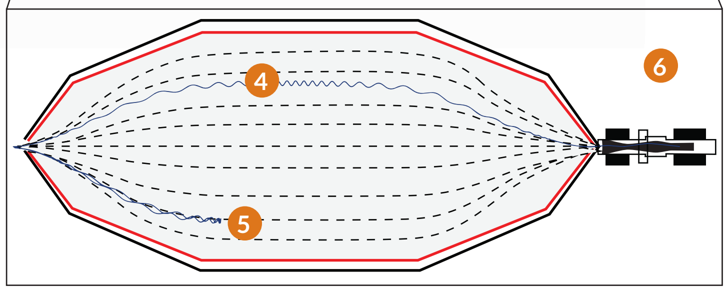
Let's get it started

On April 26, the first electrons and positrons collided in the new detector. Running the experiment was thrilling but tense. "Somebody brought me some whiskey because I was really scared," says physicist Tom Browder of the University of Hawaii at Manoa. He worried there might be a failure of a system called the trigger, which identifies interesting collisions from the deluge of boring events that the detector sees. After several hours, when the first events began rolling in around 1 a.m., the team finally took a breath.

Belle ringers

Like a baby, a new particle detector can interfere with its creators' sleep. The detectors run all night; if a malfunction occurs, experts might get an after-hours phone call. Physics graduate student Laura Zani of the University of Pisa in Italy certainly did. But the newborn detector, a piece of which she helped build, also inspired pride. When Zani saw the first particle tracks appear on computer screens, she thought, "We did it."





KATRIN

Karlsruhe Institute of Technology, Germany
Approximate cost: $70 million

1. Tritium decays, releasing electrons and antineutrinos, which escape.

2. Electrons travel along beamline to spectrometer.

3. The spectrometer sorts electrons by their energies.

4. A magnetic field (dotted lines) shepherds high-energy electrons to a detector at the other end.

5. An electric field turns low-energy electrons back.

6. Magnets focus electrons onto the detector.

How it works

Physicists aim to measure the mass of neutrinos, wily subatomic particles that are nearly impossible to detect. At one end of the 70-meter-long KATRIN, radioactive decays of tritium produce electrons and the antimatter twins of neutrinos. Those antineutrinos escape while the electrons cruise through KATRIN's blimp-shaped tank and are detected at the other end (*SN Online: 10/18/16*). The tank, a spectrometer, divvies up the particles according to their energies. Some energy from each tritium decay goes to generating the antineutrino's mass. That limits how much energy the electron gets. So measuring the electrons' energies can reveal the mass of neutrinos. KATRIN should officially start taking data next spring.

OK, but why?

A neutrino's mass is a tiny fraction of an electron's. "Why is it so light?" Parno asks. "That's mysterious." The standard model initially predicted that neutrinos have no mass at all. But measurements indicate that the particles must have mass, though how much is still a question. Neutrinos barely interact with matter and are incredibly numerous: Billions of neutrinos sail through your thumbnail each second. These particles are so quirky that scientists want to know more.

Radioactive rules

It all starts with tritium. This radioactive version of hydrogen, pumped through the experiment in a gaseous form, emits 100 billion antineutrino and electron pairs each second. In the tritium lab, special rules are in place because of the radioactivity — scientists enter via an air lock and must wash their hands when they leave. The place has a spaceship vibe, says

KATRIN's spectrometer was built off-site. Getting it into the lab in southwest Germany involved some tight squeezes along the way.

Larisa Thorne, a physics graduate student at Carnegie Mellon University. "I did feel quite like I was on *Star Trek*."

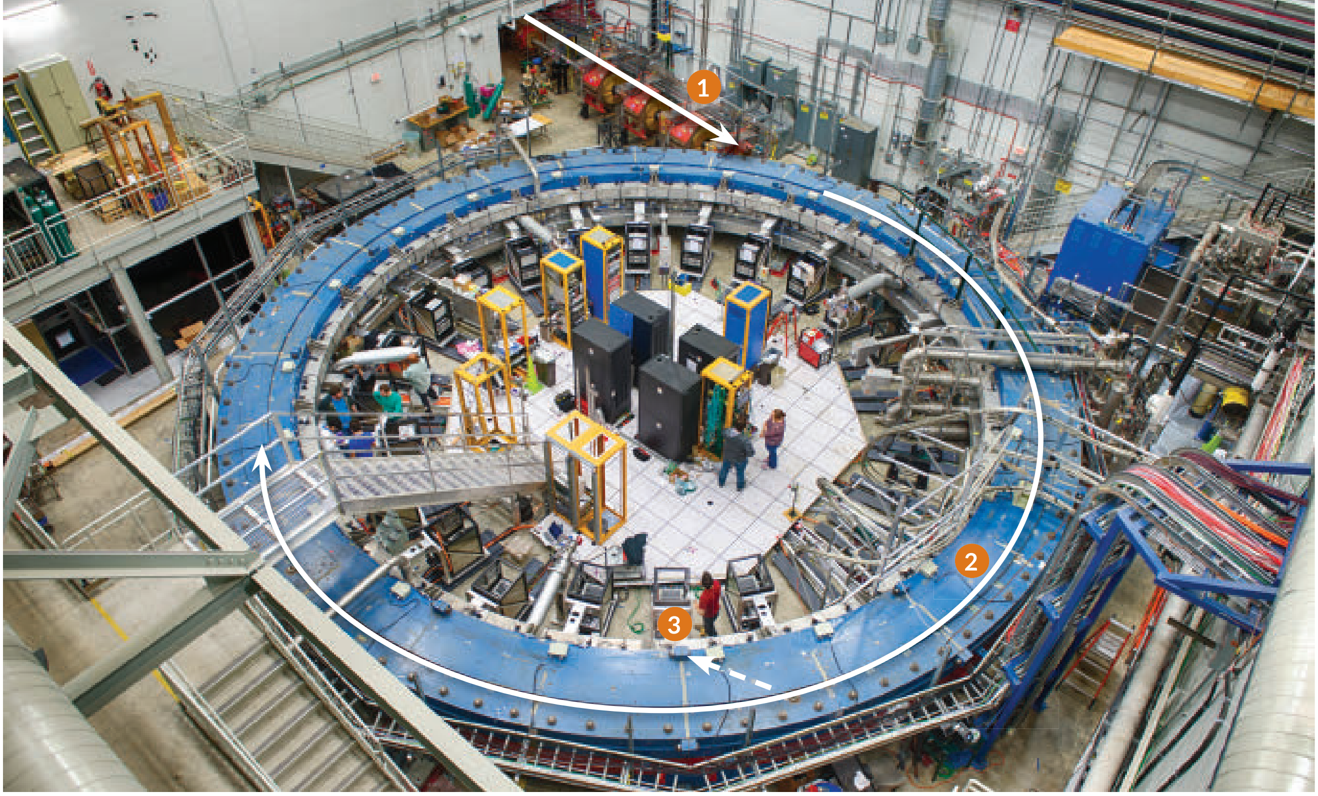
End of the line

At the opposite end from the tritium lab, powerful magnets focus high-energy electrons on a detector, which counts the electrons that arrive. Credit cards must be stashed in a locker or they'll be wiped by the magnetic field.

The big bake

The entire spectrometer is kept under ultrahigh vacuum, eliminating molecules of air or other substances that could interfere with the electrons' journeys. It's the largest ultrahigh vacuum vessel ever created. To get that extreme vacuum, the researchers temporarily heat the whole shebang to more than 200° Celsius, baking off water and other contaminants on the vessel's surface. Metal expands when heated, so the spectrometer bulges by about 12 centimeters during the process. "It's pretty strange to think that this large tank, which is filled with nothing … actually expands," Thorne says.

FROM TOP: KATRIN; T. TIBBITTS, M. ARENZ *ET AL*/*J. OF INSTRUMENTATION* 2016; KIT



FERMILAB

Muon g-2

Fermilab, Batavia, Ill.
Approximate cost: $46 million

1. Muons enter the magnet.
2. Muons circle in the same direction repeatedly.
3. Muons decay into positrons, which are picked up by detectors that measure energy and particle tracks.

How it works

Muons, heavier relatives of electrons, behave like tiny magnets with a north and south pole. Muon g-2, which started up in February, studies the properties of those minimagnets. Researchers beam thousands of muons into a doughnut-shaped electromagnet about as wide as the width of a basketball court. As muons circulate inside the electromagnet, their poles pivot like wobbling tops. Muons are unstable, so as they circulate, they decay into lighter particles known as positrons. The angles at which those positrons fly off can reveal the rate of the muons' magnetic gyrations and, therefore, the strength of the muons' magnets. The researchers will compare the measurement to predictions based on the standard model.

OK, but why?

Transient particles blip in and out of existence everywhere in space. Those particles tweak the rate at which the muons gyrate. If undetected particles are out there, Muon g-2's measurement might not square with predictions. A similar experiment performed at Brookhaven National Laboratory in Upton, N.Y., in the 1990s hinted at a mismatch (*SN: 2/17/01, p. 102*). Muon g-2 will make a more precise measurement to follow up on that lead.

One ring

Muon g-2's magnetic field is about 30,000 times as strong as Earth's magnetic field. Such strength is useful only if the magnetic field is ultrauniform. So physicists strategically placed thousands of tiny metal shims — many just a fraction of the thickness of notebook paper — to adjust the magnetic field. Hours of "shimming" left physicists' hands "covered in dirt and oil and grease," says physics graduate student Rachel Osofsky of the University of Washington in Seattle. The dirty job was worth it: The magnetic field is now uniform to within 0.0015 percent.

Long trek

The electromagnet, a hand-me-down from the Brookhaven Lab, had to be shipped from Upton to Fermilab in Illinois. But how to transport an enormous, fragile doughnut? In 2013, the magnet took a boat trip down the East Coast and cruised up the Mississippi and other rivers to Lemont, Ill. A truck carried the cargo the rest of the way, going about 8 kilometers per hour on closed-off highways in the middle of the night. The magnet barely squeaked through the tight passages of electronic tolling arches. No word on whether the magnet had to pay.

Tiny tubes

Building a particle detector takes lots of painstaking work, much of it done by graduate students. For Muon g-2, building the tracking detectors, which observe the trajectories of the emitted positrons, required threading wires 25 microns thick through 100-micron-wide holes. Imagine trying to stick a piece of spaghetti through a straw, both small enough for a Lego figurine to use. "That was like a year of our lives just getting wires down tiny holes," says Saskia Charity, a physics graduate student at the University of Liverpool in England. ■

Explore more

- Fermilab Muon g-2 Experiment: muon-g-2.fnal.gov

Dreaming Up Tomorrow's Burger

IMPOSSIBLE FOODS INC.

Two groups of scientists, for similar reasons, are exploring opposite ways of changing how meat is made. One approach grows just the edible parts of the animal; the other tries to simulate meat with plants (meatless Impossible Burger, shown).

Can science make meat without the moo?

By Susan Milius

This isn't as extreme as if the federal government had decided to regulate time travel. But it's almost as surprising. The U.S. Food and Drug Administration is taking the first step toward rules for growing nutritious, delicious, juicy meat in labs, not farms.

The notion of growing, say, just the beef instead of the whole cow has been floating around since at least the 1890s. This sci-fi fantasy got a bit more real at a 2013 televised tasting of a lab-grown hamburger, though the patty cost about as much as a Rolls-Royce.

In July, the movement passed a new milestone: In a packed auditorium in suburban Maryland, the FDA convened the first public hearing (the U.S. Department of Agriculture is jumping in too) to discuss federal regulation of food grown from cells — no hooves or fins or feathers in sight.

What to call such fare is a point of contention. Enthusiasts suggest "clean meat" or "cultured meat." But calling this stuff "meat" doesn't sit well with traditional farmers. "They're hijacking our brand," Montana rancher Maggie Nutter testified on behalf of the United States Cattlemen's Association. Meat is harvested from a real animal. Period. (Yet the cells to start a meat-growing culture come from a real animal too.)

Whatever it's called, cultured meat is one of two high-science endeavors to get animals, at least in the traditional sense, out of agriculture.

The other camp wants to take every bit of the animal out of agriculture and make "meat" from plants. These dreamers, including Patrick O. Brown of Impossible Foods in Redwood City, Calif., do not want to make another veggie burger. (Brown goes icy at the v-b label.) Instead they want to focus the full glory of molecular biology on identifying the proteins or other molecules that give meats their seductive flavors and textures. Then, sourcing each vital component from some nonanimal origin, these pioneers want to build plant "meat" so delicious that die-hard carnivores will sigh happily and take another bite.

"Animals happened to be the technology that was available 10,000 years ago" for making meat, Brown says. "We stuck with that same technology, and it's incredibly inefficient by any measure — and destructive."

Brown is convinced that science can come up with something better, for the sake of the environment, food security and animal welfare. He's going the plant path, but says if the clean meat scientists can make their dream financially viable, "I'll be their biggest fan." The looming questions for both of these approaches, however, may arise from the not-so-scientific swerves of human desire.

76 percent

Projected rise in worldwide demand for meat by 2050

NIKOS ALEXANDRATOS AND JELLE BRUINSMA/FAO 2012

Brave new meat

Many people like meat the way it is. Yet they may not always grasp what technological change could look like, says Bruce Friedrich, executive director of the Good Food Institute based in Washington, D.C. In another sign that the alternate-meat movement may be gaining traction, he and Brown were on a panel in June explaining their visions of future meat to a meeting of international economists at the headquarters of the World Bank.

On the panel, Friedrich conjures another weighty gathering. "It's 1898. The world's first-ever urban planning conference is convening." The focus: "175,000 horses on the streets of New York ... laying down 50,000 tons of horse excrement every month." Failing to come up with a solution, the planners "go home despondent," Friedrich says. "Ten years later Henry Ford introduces the Model T."

Cars and other horseless vehicles caught on quickly, and within a decade, horse-drawn carriages were clop-clopping their way to the shrunken status of tourist attraction. What most people had really loved about equine transportation was not the workhorse itself so much as its speed, convenience and capacity. People still raise horses for pleasure, but when cars offered speed without manure, horse transport was history.

Likewise, most people don't love modern industrial animal agriculture itself, Friedrich contends, with its high-density animal facilities and its greenhouse gases (*SN: 7/7/18, p. 10*) and other environmental consequences (*SN: 11/28/15, p. 22*). What people do love is the beef, pork, chicken and eggs that make current agriculture seem inevitable. Change, he argues, will take the Model T of meat.

Call it a Model M

That Model M will have to be affordable, but maybe more importantly, it has to deliver on flavor, a formidable challenge.

Meat scientist Hannah Laird runs a sensory evaluation lab at Texas A&M University in College Station. She recruits beef lovers to spend six months to a year learning to pick out and score some 40 flavors and aromas that can show up in ground beef. For two hours a day, trained panelists sniff, taste and rate beef samples against reference foods on characteristics such as "brown/roasted" (beef suet ranks an 8) and "metallic" (Dole canned pineapple juice, 6).

Raw beef is bland, Laird says. It provides mainly an aroma and flavor known as "bloody/serumy" with a few other components such as "overall sweet." Cook it though, and oh my. Brown/roasted! Fatlike! Umami! Maybe smoky-charcoal (or, perhaps, smoky-wood), cocoa, salty, buttery, cumin, floral. For a less-than-perfect patty, testers could report "barnyard."

The sensory experience of cooked ground beef is so embedded in American culture and so singular that one flavor is called "beef identity." Cooked beef exerts such pull on its devotees in large part because of its sheer beefiness.

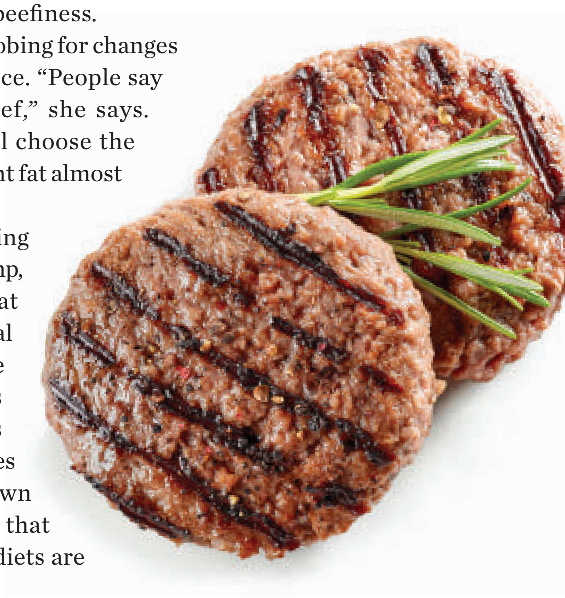
Laird is finishing a project probing for changes in this intense culinary romance. "People say they want low-fat ground beef," she says. But in blind taste tests, they'll choose the 20 percent fat over the 10 percent fat almost every time.

Taste preferences start forming in the womb, says Gary Beauchamp, who studies food preferences at Philadelphia's Monell Chemical Senses Center. Tests there have detected an influence of mom's diet during pregnancy on baby's food preferences. But preferences can change. In Beauchamp's own work on salty flavors, he finds that people who switch to low-salt diets are

What sells a burger?

Flavors
Distinctly beefy, umami, brown/roasted, salty, a bit of fat

Texture
Juicy, springy, well-defined and cohesive particles



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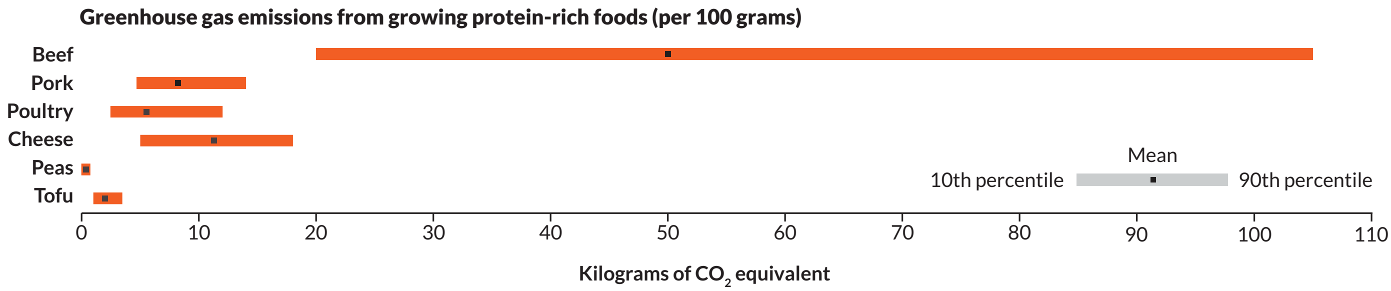


Farm to table
The amount of greenhouse gases released from farming, processing and transporting meats and other proteins varies between the most efficient producers (left side of bars) and the least efficient (right sides). Beef is the top emitter overall.
SOURCE: J. POORE AND T. NEMECEK/*SCIENCE* 2018

often miserable at first, but months later, these dieters rate a taste of their once-beloved foods as too salty. It would be daunting to predict what might happen with meat preferences, he says. "The complexity of something like a hamburger is astounding."

Why try?

To displace that juicy cultural icon under the lettuce, tomato and special sauce will take some doing, but a range of thinkers argue that it's important to try.

"Meat production is one of the most important ways in which humanity affects the environment," population biologist Charles Godfray and colleagues wrote in the July 20 *Science*. By a variety of measures, animal agriculture leaves big environmental hoofprints, the University of Oxford researchers noted.

Greenhouse gases emitted during animal agriculture account for about 14.5 percent of humankind's total, according to a 2013 report from the U.N. Food and Agriculture Organization.

Judging the hypothetical environmental footprint of cultured meat is tricky at this stage. A 2015 estimate in *Environmental Science & Technology* suggests that cultured meat could be less of a contributor to climate change than normal beef and require nowhere near as much land. Yet the lab processes might demand even more energy than conventional beef. The researchers are careful to call their results "possible future scenarios rather than predictions."

Worries about the environment, however, don't inspire people to change their diets as effectively as concerns about personal health, several surveys show. The health consequences of eating a lot of meat need a long and thoughtful story of their own. U.S. residents consume an astounding amount of beef, chicken and pork, according to the Paris-based Organisation for Economic Co-operation and Development: 79 grams (retail weight) per day. That's triple the worldwide average. Many people are miles away from what the American Heart Association recommends: limiting meat to four or five 6-ounce (170 grams) servings of lean beef, skinless chicken or seafood per week.

The health consequences of eating cultured meat aren't clear, since there are no products on the market to test. Plant-based foods can avoid many of the saturated fat problems of meats as long as people don't doll them up with saucy, cheesy extravagance. Yet the Impossible Burger and the Beyond Burger, a meat-mimicking competitor, are not low fat.

Beyond art

For Friedrich, a big reason to move away from meat made from whole animals is waste. "Throwing food away is a horrible idea," he says. "But that's basically the relationship all of us enter into every time we choose to eat meat." To get one calorie of meat from a chicken means putting in nine calories of feed. And chicken is one of the more efficient meats. Why not create just the pieces of an animal that people could eat?

Scientists have already proved that this is, sort of, possible. The first lab-cultured burger publicly unveiled, in 2013, required hand assembly of some 20,000 individual muscle cells at Maastricht University in the Netherlands. Producing and testing cost donor and Google cofounder Sergey Brin 250,000 euros.

The flavor was "surprisingly close" to regular ground beef, says the first person to taste cultured beef in public, food trend researcher Hanni Rützler of Vienna. It might have tasted more burgerlike,


Possibly the world's most famous lab-grown hamburger patty (left), unveiled in 2013, was hand-assembled from thousands of individual cow muscle cells. Pinked up with a touch of beet juice, the burger was served well-done.

GRAPH: C. CHANG; BURGERS: DAVID PARRY/PA WIRE she says, if its scientist-creators had allowed the chef to mix in some onions and discernible seasoning. Beet juice was permitted for pinkness (that early burger hadn't grown enough of the protein myoglobin, which gives meat its color).

That televised tasting, however, represented a leap forward from an earlier public tasting of lab-grown meat, in this case, frog legs. At the 2003 closing of an art installation in Nantes, France, a dinner party of tasters picked up their forks before an audience to try frog leg muscle fibers that artists Oron Catts and Ionat Zurr of the art group SymbioticA had been culturing on display.

Three tasters spit it out. The flavor was fine — lemon butter and garlic from a very good sauce, Catts says. The muscle fibers, however, hadn't been exercised as they grew on their mesh support, nor did the mesh have time to soften during the relatively brief gallery show. Thus the meat's texture was disconcertingly like "jelly on fabric," he says. As its cocreator, he felt an obligation: "I swallowed it."

Custom-making bits of living animal tissue for biology has been flourishing for decades. Medical teams have implanted lab-cultured bladders in people, and experimental lung tissue has survived several weeks in pigs (*SN: 9/15/18, p. 8*). These approaches, however, are very different from churning out gastronomically pleasing hamburger meat by the pound. Changing science experiments into food production takes so much more than just nicking a tiny pip of cells from a cow's muscle and dropping them into a sciencey soup.

A muscle fiber cell that has matured into its full elongated glory can't divide into two fibers. To grow muscles, researchers need to start with cells that still retain a lot of flexibility. There are trade-offs among the options. What are called pluripotent stem cells can turn into anything and divide many times, yet they can be trickier to control than cells already on their way to becoming a muscle. These cells, called myoblasts, naturally appear in animal muscles ready to repair damage. Collecting them could make for easier control, but they don't divide as many times as stem cells. So meat growers may have to go to their cell banks more often.

A tasty morsel of meat contains more than muscle fiber cells. Connective tissue holds those fibers in place, and fat cells, a big component of flavor, power the fibers' exertions. One of the big challenges for tissue culture, edible or simply research-based, has been trying to get blood vessels to reach into meat. Without vessels to supply oxygen and food to inner cells, a scrap of muscle cells can't develop much thickness. Thus, clean meat projects so far tend to produce ground beef instead of a porterhouse.

Lowering the bar from steak to ground meat and growing jumbles of cells is still complex. "We know that many of these cells don't really like … to be isolated," says cell biologist Chris Dammann, cofounder of cellular aquaculture start-up BlueNalu in San Diego. As normal tissue forms, cells communicate with their neighbors and "know exactly where they are," he says. When a scientist pulls out cells for culture, the cells "get a little bit confused," he says. Without orienting inputs, an isolated cell can devolve into its built-in suicide program.

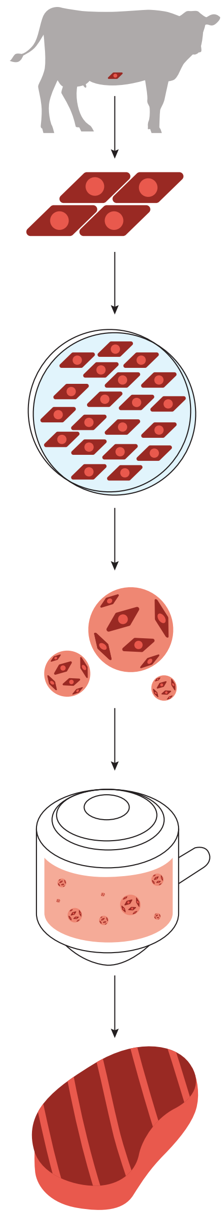
To coax disoriented cells into growing neighborhoods, researchers are exploring various scaffolds. On this and other details, however, start-ups are not willing to share.

Andrew Pelling, a biophysicist at the University of Ottawa, will talk. He turned to the produce aisle for scaffold inspiration. His lab stripped the living innards of cells out of apple segments. On the remaining fine mesh of cellulose, he grew human cells (not for food). The nonprofit New Harvest foundation in New York City has provided money for similar scaffold experiments planned for Asian pears, carrots, rose petals, asparagus and mushrooms.

Cells also need nutrients and compounds that give them the normal body signals that regulate growth. Biomedical lab scientists often enrich their nutrient culture medium with what's called fetal bovine serum, plasma collected from calf fetuses. A liter can cost hundreds of dollars, which is a serious drawback for the clean meat industry, cautions Jean-François Hocquette. (Alternatives exist for medical tissue, but suitable edible options have been a long-standing challenge.)

Hocquette is a Paris-based researcher with the French National Institute for Agricultural Research who starts a Skype call with a cheerful smile and a warning: He doesn't see how the cultured meat industry is going to become financially viable, and not just because of the serum.

There's the scaling up of the bioreactor, the chamber where the cells grow, which needs to mimic an animal body in temperature and in making sure cells get the nutrients and signals they need. Erin Kim, New Harvest's former communications director, says that the foundation funded the development of a bioreactor prototype, about the size of a portable space heater. It was "a short, little project," she says. However,



No bones about it
The basic idea for culturing meat in the lab starts with cells collected from an animal. The early stage flexible cells within muscles can grow on beads or other scaffolds. Put into a bioreactor, the cells are coddled into multiplying into something delicious.
SOURCE: NEW HARVEST

C. CHANG

Crowded field

At least 20 start-ups are cooking up ways to use lab-culture techniques, still to be perfected, to make foods and other products. Several are being hush-hush, says Liz Specht, but here are a few.

Beef
Memphis Meats, Mosa Meat

Pork
Higher-Steaks

Seafood
Blue Nalu, Finless Foods

Chicken
SuperMeat, Memphis Meats

Egg whites
Clara Foods

Milk
Perfect Day

Fois gras
Integriculture

Pet food
Wild Earth, Bond Pet Foods

Leather
Modern Meadow

it created a much bigger sensation in the field than she would have expected for a problem that every company must have been working to solve. "We were bombarded by people wanting to pick our brains." Her conclusion: Bioreactor design may not be that far along.

Regardless of the uncertainties, the push to grow meat or other animal products without whole animals is growing, says food scientist Liz Specht of the Good Food Institute. In 2016 she knew of six companies chasing this dream. Just two years later, she knows of at least 20. Even established giants of food production, such as Tyson Foods and Cargill, are investing.

Plans for cultured products include beef, pork, seafood, poultry, egg whites without eggs, milk without cows, fois gras and pet food. Beyond food, there's leather and spider silk.

The plant path

Meanwhile, Impossible Foods' Brown and some like-minded pioneers are taking a leap of faith in the opposite direction: trying to re-create genuinely meaty eating from plant ingredients.

"When I go to meetings that are basically nothing but ardent environmentalists, they're pretty much all having meat for dinner, and they know very well what the issue is. It's not that they're bad people," he says. "It's just that it's very difficult for people to change their diets."

Brown is trying anyway. The molecular biologist, an award-winning developer of the ubiquitous lab tool called a DNA microarray and a member of the National Academy of Sciences, ditched a wunderkind science life at Stanford University to — of all the job swerves in the world — start a burger business.

"I loved what I was doing," Brown says of his academic days. Yet he realized "the most important scientific problem in the world was figuring out what makes meat delicious — and how to make that same experience sustainably from plant ingredients. I'm not kidding."

To woo the true carnivores in ways that current veggie burgers don't, Brown has assembled a research team to search for underappreciated molecules that give meat its allure. "There's a lot of interesting stuff there," he says.

He launched Impossible Foods in 2011 and is convinced that he's found "the magic ingredient that makes meat taste unlike anything else on Earth." It's the structure called heme, he says, basically a molecular cage of nitrogen surrounding an iron atom. Heme is a powerful catalyst forming the business end of human blood hemoglobin as well as plenty of other compounds. It often plays a role in extracting energy from food, a major part of animal life.

Therefore, heme as part of the distinctive meat taste makes sense to Brown, and he's found a plant version, leghemoglobin, in soybean roots. Instead of harvesting roots, though, the burger makers put leghemoglobin genes into yeast and brew the magic ingredient much the way insulin and rennet (for making cheese) are grown: in vats.

An early attempt at a plant-based burger tasted like "rancid polenta," one taster reported, but Brown's project has made much progress since then, he says. The team is still tinkering with the flavor and the process of their plant-based technology for making burgers, but Brown doesn't seem disturbed.

> "The most important scientific problem in the world was figuring out what makes meat delicious."
>
> PATRICK O. BROWN

"However good it is today, the next day it will be better," he says. "The cow is not improving at all."

Historian Gabriella Petrick in Boston has not yet tried one of Brown's burgers, or one from competitor Beyond Meat. She studies technology and food systems, and she points out that the world-changing Model T was far from the first horseless carriage. (Nicolas-Joseph Cugnot, a French military officer, demonstrated his three-wheeled, steam-powered vehicle, getting it up to 4.8 kilometers an hour briefly in 1771, though it proved impractical for towing artillery and was sidelined.) Ford's car was more practical and, a vital point, affordable.

Likewise, some of the big innovations in food, such as canning or freezing, took at least a generation to catch on, Petrick says.

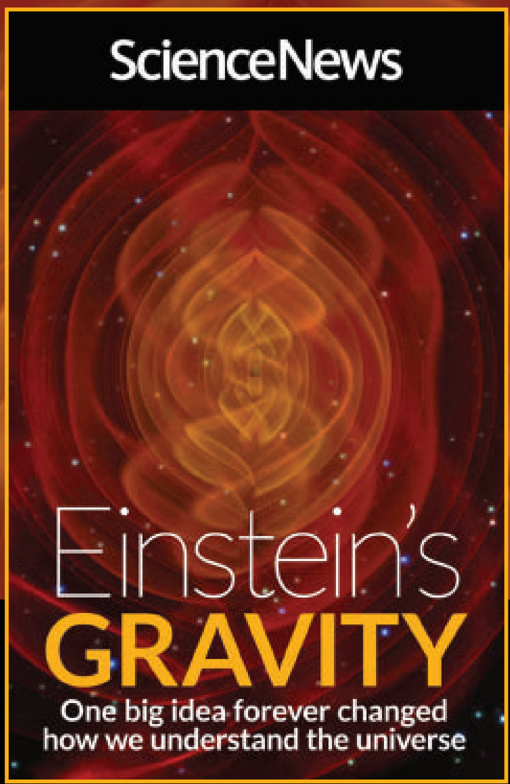
She can, however, think of one encouraging counterexample in which all the supporting pieces for change, such as consumer demand, shipping infrastructure and refrigeration technology, lined up. It wasn't long before 1930s Northeasterners moping for fresh greens in winter embraced a funny-looking oddity recently available from California's Salinas Valley: the now-ubiquitous iceberg lettuce. Just maybe, the next iceberg will be the burger itself. ■

Explore more

- Paul Shapiro. *Clean Meat*. Gallery Books, 2018.

C. CHANG

Einstein's BIG IDEA



Albert Einstein reinvented gravity.
Gravity has reinvented the cosmos.

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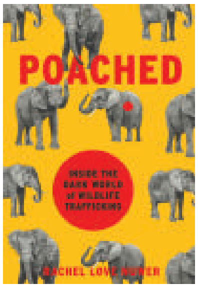


Poached
Rachel Love Nuwer
DA CAPO PRESS, $28

BOOKSHELF

Journalist offers a deep, disturbing look into the illegal wildlife trade

Perhaps the most unsettling scene in *Poached,* by science journalist Rachel Love Nuwer, comes early in the book, in a fancy restaurant in Ho Chi Minh City, Vietnam. The author and two friends sit down and are handed leather-bound menus offering roasted civet, fried tortoise, stewed pangolin and other delicacies made from rare or endangered species. The trio makes an abrupt exit, but only after seeing a live cobra gutted at one table and a still-living civet brought out to feed another group of diners.

Statistics on the illegal wildlife trade can be mind-numbing. Rhinos have dwindled to just 30,000 animals globally and tigers to fewer than 4,000. Over a million pangolins — scaly anteaters found in Africa and Asia — have been killed in the last 10 years. Just last month came a report from the Humane Society of the United States and the Humane Society International that the United States imported some 40,000 giraffe parts, from about 4,000 animals, between 2006 and 2015.

But in *Poached,* Nuwer gives readers a firsthand view of what the illegal wildlife trade is like on the ground and what, if anything, can be done to stop it. She accompanies a poacher into the U Minh forest of Vietnam in search of water monitors, cobras and civets. (Thankfully, they don't find any.) She has dinner with a man who keeps a rhino horn in an Oreo tin. She visits a zoo in Japan that may have helped popularize trade in the rare earless monitor lizard. And she attends numerous meetings of wildlife officials and conservationists as they attempt to fight back against the illegal trade.

Poached isn't all gloom and doom; there are a few success stories. Nuwer, for instance, visits Zakouma National Park in Chad where managers have halted the slaughter of elephants. This hard-won accomplishment exemplifies the book's underlying message: There are no easy solutions to stopping wildlife trafficking. The effort in Zakouma required a lot of money and training for its rangers, which is not available in most places.

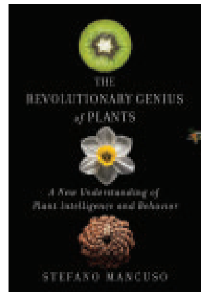
What's most needed, Nuwer argues, is changing how we think about wildlife crime. Many people view poaching as belonging to a special category of illegal activity. But it's not; it's just crime. Those involved are often also dealing in drugs or conflict diamonds or human trafficking. A change in mind-set could help overcome a major conservation obstacle, Nuwer notes. Rather than detectives and the courts being tasked with handling this sort of crime, the job has been left to rangers, wildlife managers and conservationists. "As some have put it," she writes, "it is like asking botanists to stop the cocaine trade." The world's wildlife deserves better than that. *— Sarah Zielinski*

Poaching of pangolins and other protected wildlife should be treated like any other crime, a new book argues.

DARRENBRADLEYPHOTOGRAPHY/ISTOCKPHOTO

BOOKSHELF

Smart plants can teach humans a thing or two



The Revolutionary Genius of Plants
Stefano Mancuso
ATRIA BOOKS, $30

More than 200 years ago, French botanist René Desfontaines instructed a student to monitor the behavior of *Mimosa pudica* plants as he drove them around Paris in a carriage. *Mimosa pudica* quickly closes its leaves when touched — presumably as a defense mechanism. Desfontaines was interested in the plants' response to the continuous vibrations of the ride. Initially, the leaves closed, but after a time, they reopened, despite the shaking. "The plants are getting used to it," the student wrote in his notebook.

Stefano Mancuso recounts this tale in *The Revolutionary Genius of Plants* and reports on a modern follow-up: a repeat of the experiment (without the carriage) demonstrating that plants can indeed learn that an external provocation is harmless and remember what they've learned for weeks.

Learning is impossible without memory, and both are hallmarks of intelligence, argues Mancuso, who leads the International Laboratory of Plant Neurobiology at the University of Florence in Italy. But our animal-centric view of neuroscience makes us loathe to employ terms like "memory" and "intelligence" when talking about organisms without a brain. With infectious passion, Mancuso sets out to convince us that the plant way of doing things not only deserves our respect, but also may help us solve greater societal woes.

The *M. pudica* story sets the stage for an eye-opening philosophical argument that makes the book worth a close read — you will never look at plants, or animals, the same way again. To overcome the human bias toward brain-centered intelligence, Mancuso writes, one must consider that, unlike animals, plants can't move.

Being anchored in one spot required

that plants evolve entirely different solutions to short- and long-term threats like predators, fire and drought. (Animals do not solve problems, notes Mancuso, they avoid them.) The plant solution is decentralization: Rather than having a brain, kidneys or other organs that would be points of vulnerability, plants are modular. Functions that would be carried out by organs in an animal are instead distributed throughout the organism. A plant evaluates its environment with its whole body and responds appropriately.

Mimosa pudica, a plant that closes its leaves when touched, can learn that certain experiences are harmless.

Most people use words like "acclimate" or "harden" to describe this botanical evaluation and response. At the book's outset, Mancuso makes a compelling and enthusiastic case that these terms throw shade, so to speak, on plants' unappreciated smarts. Yet he soon veers into a discussion of plants' remarkable adaptations. Natural selection favors such traits and tricks — a seed that propels itself into the ground, for example, or a succulent that avoids predation by disguising itself as a pebble — when they provide an evolutionary advantage, but require no intelligence to evolve.

Nonetheless, *The Revolutionary Genius of Plants* is a delightful read, and the examples of plant resourcefulness dazzle. Not only is the book rich in botany, Mancuso also includes historical anecdotes and contemporary examples of how taking a page from the plant approach has provided solutions to human problems. A chapter on the distributed intelligence of plant roots — akin to that of insect colonies and nerve cells in an animal brain — touches on democracy, Wikipedia and crowd-sourced quantum physics. His stories have something for everyone: hot pepper aficionados, space enthusiasts and architecture buffs. There's so much good stuff that you can almost forgive the book for not living up to the title's promise. — *Rachel Ehrenberg*

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Science News IN HIGH SCHOOLS

AJAYTVM/SHUTTERSTOCK

Society for Science & the Public is excited to announce this year's 24 recipients of STEM Research Grants

Middle school science teachers across the United States and its territories received grants of up to $5,000 from the Society to spend on scientific research equipment, such as Raspberry Pi computers, water and soil testing kits and computer software for data analysis. To date, the Society has provided $220,000 in grants to science, technology, engineering and mathematics teachers through this program.

Congratulations to all!

Devin Berge
La Plata Middle School
Silver City, N.M. | $5,000

Elizabeth Clark
Manchester Middle School
Richmond, Va. | $3,000

Fernando Cleves
Joyce Kilmer Upper School
West Roxbury, Mass. | $3,000

Melanie Corell
Guinyard-Butler Middle School
Barnwell, S.C. | $5,000

Mary Crowley
Murray Middle School
St. Paul, Minn. | $5,000

Anthony Duncan
John S. Gillett Intermediate School
Kingsville, Texas | $2,000

Kate Elliott
Foothills Elementary School
Salem, Utah | $3,000

Kimberly Gasaway
Okaloosa STEMM Academy
Valparaiso, Fla. | $5,000

Megan Heitkamp
Salk Middle School
Elk River, Minn. | $3,000

Beth Kenna
Cedarbrook Middle School
Wyncote, Pa. | $5,000

Joseph King
Challenge School
Denver, Colo. | $5,000

Deborah Kletch
Fishers Junior High School
Fishers, Ind. | $5,000

Denise Kratz
Explorers Homeschool Association
Ann Arbor, Mich. | $4,000

Christal Long
From the Heart Christian School
Suitland, Md. | $5,000

Carole McKee
Northern Lights ABC
Anchorage, Alaska | $5,000

Patricia Mosey
Eagle Ridge Middle School
Savage, Minn. | $1,000

Lucia Perez
Jose Marti MAST 6–12 Academy
Hialeah, Fla. | $5,000

Megan Sabin
Algona Middle School
Algona, Iowa | $3,000

Jonathan Sailer
Elroy Schroeder Middle School
Grand Forks, N.D. | $5,000

Ebubekir Sen
Sonoran Science Academy
Tucson, Ariz. | $5,000

Melissa Sleeper
Gifford Middle School
Vero Beach, Fla. | $5,000

Setefano Umaga
Afonotele Elementary School
Pago Pago, American Samoa | $4,000

Laura Wilbanks
Southcrest Christian School
Lubbock, Texas | $4,000

Tammy Will
Morrison Public School
Morrison, Okla. | $5,000

$220,000
Total amount given to teachers through the STEM Research Grant Program

$100,000
Total given to teachers in 2018

24
Number of teachers receiving grants in 2018

AUGUST 4, 2018

Science Mews

Reader **David Roy** shared his August 4 issue of *Science News* with a family member. **Roy** wrote: "One of our cats, a 5-month-old ... named Z, has a head for science — *Science News*, actually."

DAVID E. ROY

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Fighting fake news

Computer programmers are building deception-detecting algorithms to fight the onslaught of fake news, ***Maria Temming*** *reported in "Detecting fake news"* (SN: 8/4/18, p. 22*).*

Reader **Lou Floyd** found the story compelling and troubling. "It points [to] a major problem facing us all today that affects the very foundation of our government and society," he wrote. Automated tools to detect fake news and track how it spreads are intriguing, **Floyd** wrote, but he was concerned about how often such systems might mislabel true news as false.

Scientists are still getting a sense of which factors might indicate an article's truthfulness, **Temming** says. "Before deploying any computer program to flag false news, researchers should closely examine how frequently that program throws the baby out with the bathwater."

Computer programs that err on the side of caution, mislabeling more true news as false, may pose less of a problem if the programs funnel suspicious stories to human fact-checkers, she adds. "This is how many programmers currently envision their algorithms being used," **Temming** says.

Floyd also wondered how fake news–detecting technology could keep up with fake news peddlers' ever-changing methods to avoid detection.

This is a common question, says computer scientist **Benjamin Horne** of Rensselaer Polytechnic Institute in Troy, N.Y., who develops fake news–finding systems. It's possible that fake news and fake news–detecting technologies could end up in an arms race. "But there are also features that likely can't be gamed," he says. For instance, many people produce fake news because fictitious, sensational headlines attract clicks that generate ad revenue. If fake news–finding algorithms are trained to look for sensational language, fake news producers could try to change their tone, but they probably wouldn't make as much money, **Horne** says.

Clinical clarity

A test for human papillomavirus, or HPV, infection caught precancerous cervical cells better than the standard Pap test in a clinical trial, ***Aimee Cunningham*** *reported in "HPV tests could replace Pap smears"* (SN: 8/4/18, p. 9*).*

Some readers were confused by the trial's result: After four years, researchers found 5.5 new cases of precancerous cells per 1,000 women who had gotten Pap tests, compared with 2.3 cases per 1,000 women who had gotten HPV tests. "That's reversed," reader **Lydia Collins** wrote. "The whole point of the article is that HPV tests are better than Paps."

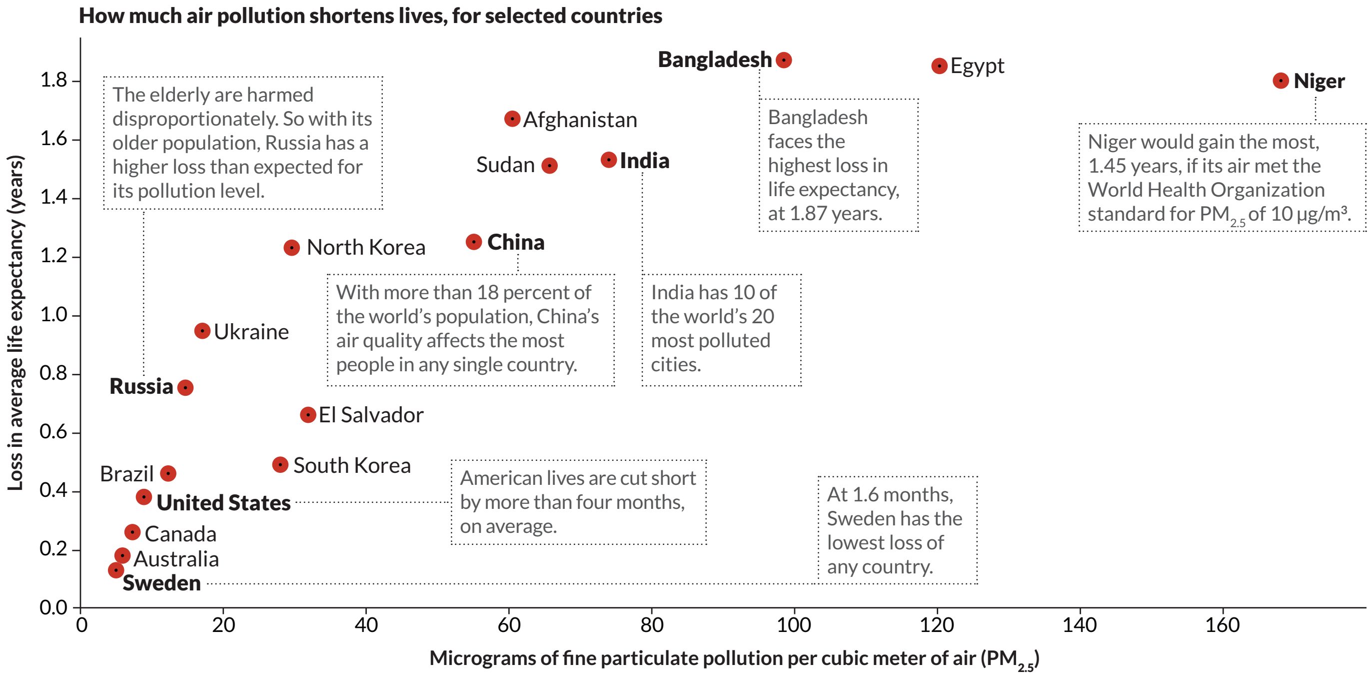
The statistics are accurate, but the key point is "four years later," **Cunningham** says. HPV testing caught cases earlier, so in later tests, there were fewer cases to detect in that group than in the Pap test group, where warning signs of abnormal cell growth were more often missed.

Blazing particles

Light detected by sensors embedded in Antarctic ice helped scientists trace a single high-energy particle, called a neutrino, to a flaring galaxy 4 billion light-years away, ***Emily Conover*** *reported in "Elusive neutrino's homeland found"* (SN: 8/4/18, p. 6*).*

Reddit user **tanner6232** wondered how neutrinos, which are nearly massless and have neutral charge, can interact with ice to produce light.

Neutrinos interact via what's called the weak interaction. "As the name implies, it's really weak, which is why neutrinos very rarely smack into stuff," **Conover** says. When the neutrino hit the ice, the particle interacted with the nucleus of an atom in the ice to produce another charged particle: a heavier cousin of an electron called a muon. "This particle is what actually produced light in the ice," **Conover** says. That muon traveled faster than the speed of light in ice (which is slower than light's speed in a vacuum), generating bluish light called Cherenkov light that scientists detected. "It's analogous to the sonic boom created by a jet moving faster than the speed of sound," she says.



Air pollution is shortening lives worldwide

Air is free. But breathing dirty air has a price. Specifically, it can cost a person months, or even more than a year, of life.

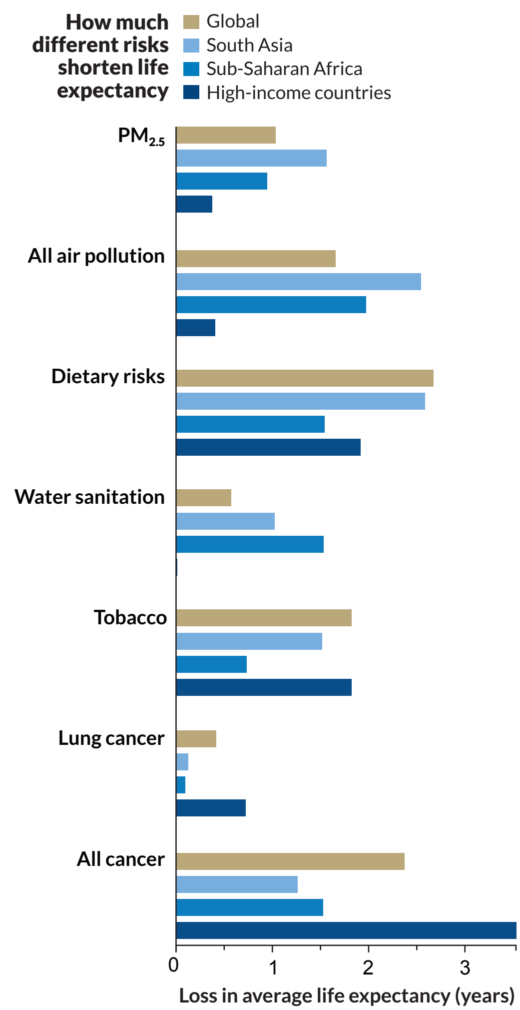
Using 2016 data from the Global Burden of Disease project, a new study estimates how much air pollution shaves off of life expectancies in nations globally (selected countries shown above). The research is the first major look at country-specific life expectancy impacts of fine particulate matter called $PM_{2.5}$ that consists of particles and droplets smaller than 2.5 micrometers. An average human hair, for comparison, is 30 times as wide.

In 42 countries, mostly in Africa and Asia, life expectancy drops by at least a year, on average, thanks to air pollution. Even in high-income countries with relatively clean air, such as the United States and Australia, the little bit of $PM_{2.5}$ pollution that does exist costs people a few months of life.

Most other studies present air pollution effects in terms of death or disease rates. The new approach, published online August 22 in *Environmental Science & Technology Letters*, is meant to make the risk more relatable, says study coauthor Joshua Apte, an environmental scientist at the University of Texas at Austin. "Talking about mortality figures and large body counts, you see people's eyes glaze over," he says. "People care not just about whether you die — we all die — but also how much younger are you going to be."

The team also compared how different risks, such as air pollution, tobacco use or cancer, shorten average life expectancy for various regions and for high-income countries (graphs at right). Overall, the results show that improving the air can boost life spans in some areas more than other health priorities, including improving water sanitation or preventing lung cancer.

In South Asia, for example, $PM_{2.5}$ pollution had a bigger effect on life expectancy than all cancers combined. But in high-income countries, the trend was reversed. That insight "can help people, or policy makers, decide where to spend their money," says Kirk Smith, a global environmental health expert at the University of California, Berkeley. "It's another bit of analysis that shows air pollution is a major risk factor globally." — *Katy Daigle*



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The Baltic region is home to the largest known deposit of amber, dating from 44 million years ago (during the Eocene epoch). Amber is a unique gem; not only is it simply beautiful, but also equips mankind with valuable data through its capacity to show us the past. It has the ability to preserve organic tissues of life forms, something both valued by scientists and gem collectors alike. **THE BEAUTY OF AMBER,** comes from the fossilized resin of trees. 40 million years ago, this resin was exuded by trees to heal damage to a branch or trunk. Embedded with the ability to produce negative ions, amber has been made into a variety of decorative objects; used in jewelry and as a healing agent in traditional folk medicine. B**altic Amber** from around the Baltic Sea contains a higher percentage (8%) of succinite, which acts as an anti-inflammatory and an analgesic when worn against the skin.

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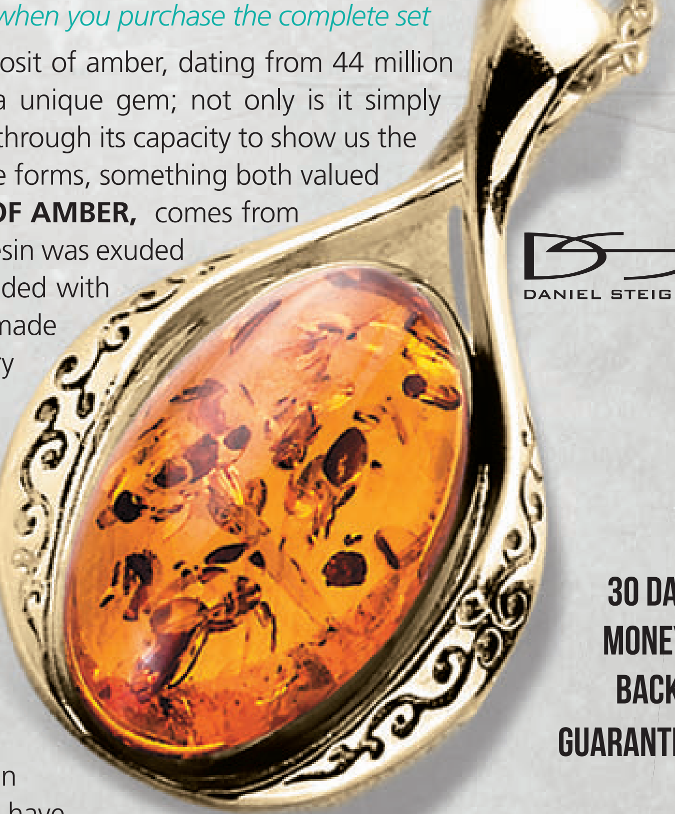

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