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ScienceNews



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COVER Research on gun control is inconclusive except for one strong link: Lots of guns means more suicides by gun. *Sascha Burkard/Alamy Stock Photo*



Scientific evidence should inform politicized debates

Over the years, readers have on occasion written to me to point out what they see as an increasing politicization of *Science News*. These are not accolades — more than one of those readers has contemplated ending their subscription. Some of those critics deny climate change, some oppose

GMOs, others view any policy discussion in our coverage as worrisome. So, are we actually getting involved in politics?

My short answer is no. But there are many areas in which science has important things to say to citizens and policy makers. And reporting on the body of evidence that relates to societal issues falls fully within our mission, even for scientific questions with political ramifications. It's well worth the ink to inform people about pressing problems or provide factual information in what have become hotly contested and polarizing debates.

Science can help establish what's known, what's not known and how scientists might find answers. That's what *Science News* reports on, with the aim of giving readers not a political argument but a clear idea of where the evidence currently stands and what questions remain. Facts based on sound science can perhaps even provide a common ground for people of differing opinions to speak to each other rationally.

In the case of what researchers can say with respect to the efficacy of gun laws, it turns out that there are more questions than answers. The numbers on U.S. gun violence are clear: In 2013, the United States had many more gun-related deaths than other nations with similar standards of living. But as Meghan Rosen investigated the state of the knowledge (see Page 16), it became evident that now, in the United States, it's hard to even do the science. Researchers told her that they just don't have the data needed to answer questions about the impacts of different gun control laws.

"I thought the evidence behind well-known gun control policies would be more clear-cut," Rosen says. But studies of background checks, waiting periods and a 1994 assault weapons ban don't necessarily show a corresponding reduction in gun violence. Maybe such laws don't do what lawmakers intended, but there are also confounding factors that may dilute any conclusions, Rosen reports. The 1994 ban on assault weapons, for example, stopped only sales of new weapons and didn't apply to those already in circulation. Most disturbing to Rosen was the blocking of scientific research by Congress, which has maneuvered to stop the Centers for Disease Control and Prevention and the National Institutes of Health from doing or funding work that might advocate or promote gun control laws. That has effectively reduced research into the best ways to prevent gun violence.

The science that has been done on whether U.S. gun control laws reduce gun violence has been mixed. There aren't a lot of straightforward answers to guide policy. But in this case, science has not had a fair chance to build the foundation for an evidence-based conversation. Without facts, it really is all political. Our aim is to find and report on those facts (or the lack of them), so that they can become part of the conversation. *— Eva Emerson, Editor in Chief*

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NOTEBOOK



Excerpt from the May 14, 1966 issue of *Science News*

50 YEARS AGO

Danger in 'swimming hole'

As warm weather approaches, the old swimming hole will again beckon boys and girls in farm areas. But disease germs lurk in waters exposed to cattle and other animals One "swimming hole disease" called leptospirosis is caused by water-borne Leptospira pomona.... Warm summer temperatures are ideal for maintaining leptospiral organisms in water, and heavy rains may transport the organisms downstream.

UPDATE: An estimated 100 to 200 people get leptospirosis annually in the United States. The disease, which can cause fever, headache and vomiting, is most common in tropical and rural regions worldwide. Summertime swimming is also haunted by another single-celled terror that thrives in warm freshwater: the so-called "brain-eating" amoeba, Naegleria fowleri. The amoeba caused 35 reported infections in the United States from 2005 to 2014. If N. fowleri enters a person's nose, it can travel to the brain, where swelling triggered by the immune system kills most victims (SN: 8/22/15, p. 14).

THE SCIENCE LIFE

Say cheese

Rachel Dutton's research is cheesy, by design. The microbiologist at the University of California, San Diego uses cheese rinds to study how microbes form communities.

Dutton, who has a long-standing interest in how bacteria and other microbes interact, got the inspiration for her studies several years ago while visiting the Marine Biological Laboratory in Woods Hole, Mass. In the salt marshes there, multiple species of bacteria, archaea and other microbes were growing in thick, manylayered mats. They would have been perfect for studying microbes in groups. Except for one thing: Many organisms that thrive in those mats won't grow in captivity. Dutton needed a microbe community that she could pick apart, manipulate and reconstruct in the lab.

The solution came with a round of cheese from France. Sliced open, its rind reminded Dutton of the microbial mats on the coastal salt marshes. "I took a piece of cheese into the lab and put it under the microscope," she says. "Everything I was looking for in a microbial community was present."

Dutton and colleagues did genetic analyses of 137 cheeses from 10 countries and identified 24 genera of bacteria and fungi that are common in cheeses and will grow in the lab, the team reported in 2014 in the journal *Cell*.

By sampling a Vermont cheese as it aged over 63 days, the group also discovered that rind communities don't form instantly. At the beginning, community members included Proteobacteria and *Leuconostoc* bacteria, plus candida yeast commonly found in raw milk. Within a week, *Staphylococcus* had overwhelmed the Proteobacteria. As the cheese ripened, *Brevibacterium* and *Brachybacterium* plus *Penicillium* and *Scopulariopsis* fungi

Fungi and bacteria shape the distinctive characters of a wide range of cheeses.



Bacteria and fungi, like the *Penicillium camemberti* shown here (top), work together to give cheeses their texture and flavor. Microbiologist Rachel Dutton got the inspiration to study cheese when she realized that cheese rinds (left, a rind from a washed rind cheese) resemble microbial mats (right) from salt marshes and other locations.

became prominent inhabitants of the rind. That pattern held whenever those organisms congregated in a cheese in the lab.

Cheesemakers from Vermont taught Dutton how to ferment cheese curds and create her own lab version of a dry-aged cheddar. Although cheeses can have complex combinations of microbes — stinky cheeses have the most diverse mixes — Dutton's lab crafts a more simplified rind using three types of fungi and four bacteria. The researchers grow the microbes in pairwise combinations to learn how they interact.

Studying cheeses and other fermented foods could teach scientists how microbial communities evolved in different places and lead to the creation of new, tastier and safer foods, Dutton and Benjamin Wolfe of Tufts University wrote last year in *Cell*.

There's one drawback to the cheesy research: The lab has a ripe odor, Dutton says. "We look like a normal microbiology lab, but we don't smell like one." — *Tina Hesman Saey*

– Tina Hesman Saey

SCIENCE STATS

Global obesity rates continue to climb

Despite massive public health campaigns, the rise in worldwide obesity rates continues to hurtle along like a freight train on greased tracks.

In 2014, more than 640 million men and women were obese (measured as a body mass index of 30 or higher). That's up from 105 million in 1975, researchers estimate in the April 2 *Lancet*. The researchers analyzed four decades of height and weight data for more than 19 million adults, and then calculated global rates based on population data. On average, people worldwide are gaining about 1.5 kilograms per decade — roughly the weight of a half-gallon of ice cream.

But the road isn't entirely rocky. During the same time period, average life expectancy also jumped: from less than 59 years to more than 71 years, George Davey Smith points out in a comment accompanying the new study. Smith, an epidemiologist at the University of Bristol in England, boils the data down to a single, seemingly paradoxical sentence: "The world is at once fatter and healthier." — *Meghan Rosen*





The -est This eclipse goes on and on

Once every 69 years, a nearby star dramatically dims for about 3 1/2 years during the longest known stellar eclipse in our galaxy.

The star, called TYC 2505-672-1, is a red giant, about 10,000 light-years away in the constellation Leo Minor. The star is orbited by a dim, hot companion star that appears to be enveloped by a thick cloud of dust roughly one to three times as wide as Earth's orbit. The cloud, reported in an upcoming *Astronomical Journal*, blocks much of the red star's light from reaching Earth for a good long time.

Researchers already knew that TYC 2505-672-1 had drastically faded recently. But astronomer Joseph Rodriguez of Vanderbilt University in Nashville and colleagues scoured data from many telescopes — including images from a Harvard University photograph archive dating back to 1890 — and found that the starlight dipped and rebounded not only between 2011 and 2015 but also in the 1940s. The previous eclipse record holder was Epsilon Aurigae, a star roughly 2,000 light-years away that dims for about 24 months every 27 years. — *Christopher Crockett*

INTRODUCING

Tiny beetle preserved in amber

An amber collector in Germany has spotted the ancient remains of a beetle never before seen in the fossil record.

Two itty-bitty specimens, entombed in amber since the middle Eocene epoch some 54.5 million to 37 million years ago, represent a new species of Jacobson's beetle, researchers report online March 28 in the *Journal of Paleontology*. The beetles (*Derolathrus groehni*) are, like their modern relatives, about as long as a grain of rice is wide.

MicroCT scans and other images revealed narrow bodies, a shiny brown exterior and two wispy featherlike wings protruding from the hindquarters, angled like the blades of a helicopter. The fossils look just like today's Jacobson's beetles, says study coauthor Chenyang Cai of the Chinese Academy of Sciences.

Fringed, eyelashlike wings may have helped the beetles ride the wind, eventually spreading to far-flung regions of the world — from western Russia (a big source of Baltic amber) to distant habitats in Fiji, Sri Lanka and even Alabama, where Jacobson's beetles have been spotted recently. — Meghan Rosen



Feathery wings on the posterior of this tiny ancient beetle (in amber), the first of its kind to be discovered, may have helped it drift on the wind millions of years ago.

BY THOMAS SUMNER

The U.S. Environmental Protection Agency has a methane problem — and it could misinform the country's carboncutting plans. Recent studies suggest that the agency's reports fail to capture the full scope of U.S. methane emissions, including "super emitters" that contribute a disproportionate share of methane release. Those EPA reports influence the country's actions to combat climate change and the regulation of methaneproducing industries such as agriculture and natural gas production.

EPA's newest methane report, released April 15, shows that the agency has taken steps to fix the methane mismatch. The report boosts the agency's estimate of total annual U.S. methane emissions by 13 percent. That's an increase of more than 3.4 million metric tons of the greenhouse gas, and it has the same 100-year global warming impact as a year's worth of emissions from about 20 million cars.

The new calculation revises the agency's U.S. methane emissions estimates for 2013 to 28.859 million tons, up from EPA's previous estimate of 25.453 million. Two-thirds of that increase comes from the natural gas and petroleum sectors,

Mounting methane U.S. atmospheric methane concentrations rose from 2010 through 2014, satellite data show. Dots mark regions that had a statistically significant change in methane levels. Changes are relative to those observed over the North Pacific Ocean, a stand-in for the global background concentration of methane.

Change in U.S. atmospheric methane levels 2010-2014



EARTH & ENVIRONMENT

EPA underestimates methane releases

Rising amounts of greenhouse gas missed by agency's methods

with much of the rest coming from landfills. The report also provides the first estimate of methane emissions for 2014, a slight increase to 29.233 million tons.

While the new methane estimates are a "step in the right direction," EPA still has a ways to go, says David Lyon, an environmental scientist at the Environmental Defense Fund. Even with the higher methane estimates, the agency is still undercounting U.S. emissions by about 20 to 60 percent, Lyon says.

As additional information on methane sources becomes available, "EPA will continue to refine its estimates in the annual inventory," says EPA spokesperson Enesta Jones.

Methane, which makes up the bulk of natural gas, originates from natural sources, such as wetlands, as well as from human activities such as landfills, cattle ranches (*SN: 11/28/15, p. 22*) and the oil and gas industry. Globally, human activities emit about 60 percent of the 600 million tons of methane released annually. Once in the air, methane prevents some of Earth's heat from escaping into space, causing warming. Methane emissions currently account for about

a quarter of human-caused global warming.

The EPA's underestimation of U.S. methane emissions comes down to accounting. EPA samples emissions from known methane sources, such as cows or natural gas pipelines, and works out an average. That average is then multiplied by the nation's number of cows, lengths of pipe and other methane sources. Results from this method disagree with satellite and land-based observations that measure changes in the total amount of methane in the air. A 2013 report in the Proceedings of the National Academy of Sciences found that U.S. methane emissions based on atmospheric measurements are about 50 percent larger than EPA estimates (SN Online: 11/25/13).

EPA doesn't just misjudge the scale of emissions, it also misses the long-term trend. EPA reported that U.S. methane emissions remained largely unchanged from 2002 to 2014. But researchers examining surface and satellite data reported March 2 in Geophysical Research Letters that emissions of the greenhouse gas rose more than 30 percent over that period. The United States could be responsible for as much as 30 to 60 percent of the global increase in methane emissions over the last decade, the researchers conclude. "We're definitely not a small piece of that pie," says study coauthor Alex Turner, an atmospheric scientist at Harvard University.

Correctly tracking methane is important, Turner says, because over a 100-year period, the warming impact of methane is more than 25 times that of the same amount of CO_2 . Methane levels have also risen faster: Since the start of the industrial revolution, methane concentrations have more than doubled while CO_2 has risen by about 40 percent.

While methane is more potent than CO_2 , atmospheric methane levels are about one two-hundredths that of CO_2 . Methane also stays in the atmosphere for only around 12 years before being absorbed by soil or breaking apart in chemical reactions. "If we reduce methane emissions, the climate responds very quickly and global warming would slow down almost immediately," says Cornell University earth systems scientist Robert Howarth. " CO_2 , on the other hand, has an influence that will go hundreds to even thousands of years into the future."

Turner and colleagues tracked methane across the continental United States using land stations that measure methane in the air and satellite observations that record dips in the infrared radiation frequencies absorbed and reemitted by methane. The team compared its measurements with those taken over Bermuda and the North Pacific Ocean - places far from major methane sources.

From 2002 through 2014, methane concentrations over the continental United States grew faster than those over the oceans, the researchers found. The difference was most pronounced over the central United States, where methane concentrations rose nearly twice as fast as in other parts of the country. Natural gas drilling and production boomed in the central United States during the period studied, though the researchers could not precisely trace the source of the additional methane.

Turner and colleagues say they're working with EPA to further reconcile methane estimates. EPA will provide small-scale estimates of methane emissions down to 10-kilometer-wide squares. By combining that grid with space and land observations, scientists should be able to isolate where methane mismatches are the most pronounced.

While Turner's research can't pinpoint the exact origins of the additional methane, other studies point to the oil and gas industry. The numbers that the EPA uses to tabulate methane emissions assume that equipment is functioning as intended, says Stanford University sustainability engineer Adam Brandt. Malfunctioning equipment can spew huge amounts of methane. That became clear last October when the largest U.S. methane leak in history began in an underground natural gas storage facility near Los Angeles. The leak released 97,100 tons of methane, equivalent to

the annual greenhouse gas emissions of 572,000 cars, before being permanently sealed in February, researchers estimated in the March 18 Science.

Super methane emitters are a problem elsewhere, too, albeit typically much smaller than the California leak, researchers report in the June 2016 Environmental Pollution. Surveying emissions from 100 natural gas leaks around Boston, the researchers found that 7 percent of leaks contributed half of the total methane released. In 2014, a different research team reported in Environmental Science & Technology that 19 percent of pneumatic controllers used at U.S. natural gas production sites accounted for 95 percent of all controller emissions.

Monitoring and quick repairs can stamp out rogue methane sources quickly, Brandt says. Super emitters, he adds, are easier to fix than to quantify.

MATTER & ENERGY

Gamers rise to physics challenge

In quantum task, humans find strategies computers miss

BY EMILY CONOVER

Human intuition might seem useless in the weird world of quantum mechanics. It's a peculiar realm in which particles can be in multiple places at once and can tunnel through barriers that should be impenetrable. But in a quantuminspired game, humans bested computers, scientists report in the April 14 Nature.

"To me it is more than surprising – it is really mind-blowing," says physicist Tommaso Calarco of Ulm University in Germany, who was not involved in the study.

The researchers, led by physicist Jacob Sherson of Aarhus University in Denmark, based their game on a quantum computer made of atoms trapped in a grid pattern and enticed gamers into finding the optimal way to shuttle atoms back and forth. In this type of quantum

Human intuition has spawned new strategies for quantum computation, thanks to a video game.



computer, scientists must move the atoms quickly and precisely to make calculations. What the gamers may not have realized is that they were helping researchers edge closer to the "quantum speed limit" set by the laws of physics at the smallest scales, which caps the speed of such calculations.

In the game, known as Quantum Moves, atoms are represented by colored liquid contained in a well. The player controls another well, using it to collect and move the liquid. But this is no normal fluid: Make a wrong move and it spreads out into a sloshing quantum mess.

The players outperformed the scientists' computer algorithm, coming up

with strategies the computer missed. The researchers then fed the human strategies back into the original algorithm to improve the results, thereby drawing closer to the quantum speed limit.

Sherson was surprised by the players' success. "Maybe we have a tendency to make it too academic and too scary, this world of quantumness," he says. "What our games do is they sort of force you to form a quantum intuition."

Sherson now hopes to recruit more Quantum Moves players to help him better understand how humans form their strategies. Computer and mobile versions of the game are available online at scienceathome.org.

GENES & CELLS **'Dirty' mice make better human mimics** Sterile lab rodents' immune systems don't behave like people's

BY TINA HESMAN SAEY

Don't blame lab mice for shortfalls in their ability to mimic human immune systems — blame their upbringing.

Mice with more experience fighting pathogens have immune system reactions more like humans', conclude two studies published online April 20. "Dirty" mice from pet stores or the wild have more humanlike immune systems than clean lab mice do, researchers report in *Nature*. And in *Cell Host & Microbe*, scientists find that infecting lab mice with a series of viruses and parasites alters their immune responses to be similar to those of dirty mice and humans.

In recent years, scientists have debated whether mice are adequate stand-ins for humans in medical research. Some say mice are poor substitutes and that money should instead be spent on bolstering human studies (*SN: 3/23/13, p. 10*). Others look at the same data and conclude that mice do a pretty good job of representing humans (*SN: 9/20/14, p. 14*). Plus, many important studies could not be done with humans, so animals are a necessity.

But even mouse fans recognize there is room for improvement. "All science is an approximation of the real situation," says Andrew Macpherson, an immunologist at the University Hospital of Bern in Switzerland who relies on mice models. "I don't think anybody doubts that the models don't always accurately recapitulate what is happening in humans." The new papers show where mice fall short and suggest ways to improve their ability to mimic people, he says.

Lab mice's immune system responses "really do look different" from that of humans', says immunologist David Masopust, coauthor of both studies. Masopust, of the University of Minnesota in Minneapolis, and colleagues wondered whether those dissimilarities are due to irreconcilable differences in the genetic makeup of mice and humans or if the environment plays a role.

His group counted immune cells in blood from adult lab mice, adult humans and human umbilical cords. Of special interest were memory CD8+ T cells, which cull body cells that are infected with viruses or bacteria, or that are cancerous. Lab mice and human infants have few of these memory cells; adult humans have a plethora. That indicates that lab mice have inexperienced immune systems, much like human babies.

The finding "is one of those things that once you know it, it's incredibly obvious," says E. John Wherry, an immunologist at the University of Pennsylvania. "Mice are like humans raised in a bubble."

Masopust agrees. "They live a preposterously hygienic existence." Even mice with severe immune deficiencies can thrive in immaculately clean labs.



Unlike lab mice kept in sterile environments (right), wild mice (one shown, left) have dealt with infections that train their immune systems to react similarly to an adult human's. The immune systems of lab mice react more like a newborn baby's.

Ultraclean lab mice can't emulate the sort of history most human immune systems experience, says Tiffany Reese, a viral immunologist at the University of Texas Southwestern Medical Center in Dallas. Adults carry an average of eight to 12 chronic viruses, such as Epstein-Barr (the cause of mononucleosis). Worm parasites infect about 2 billion people worldwide. And by adulthood, people have usually fought off multiple colds, flus and other infections.

Masopust's team found that the memory T cell profiles of wild and pet store mice more closely resembled that of adult humans than lab mice's did. Housing lab mice next to pet store mice for a month caused the immune systems of lab mice to change, making them resemble the dirty mice, the researchers reported in *Nature*. In discrepancies between studies of lab mice and humans, "the mouse may not be at fault," Masopust says. "It's the way that they are cared for."

An experienced immune system not only looks different, it also works differently from an inexperienced one, Reese and colleagues report in *Cell Host & Microbe*. Reese infected lab mice with two types of herpesviruses, gave them the flu and inoculated them with an intestinal parasite. She then compared how uninfected mice reacted to a yellow fever vaccine with how chronically infected mice reacted. Uninfected mice made more antibodies against the vaccine. The result might help explain why some vaccines that look promising in animal studies don't pan out in human trials.

Controlled infections may increase understanding of how pathogens interact with each other, with friendly microbes that live in the body and with the host's immune system, says Reese's coauthor Herbert Virgin, a viral immunologist at Washington University School of Medicine in St. Louis.

Some researchers have a bias that mice are not humans, Virgin says. "But I think that's too simplistic a view. We shouldn't be asking whether the mouse is a perfect model for humans, but whether we can make the mouse emulate more closely the basic nature of human physiology."

ATOM & COSMOS

How to make black holes 'sing'

Certain mergers would create odd gravitational wave signals

BY EMILY CONOVER

When black holes collide, astronomers expect to record a gravitational wave "chirp." But rapidly spinning black holes, like the one featured in the 2014 film *Interstellar*, might prefer to sing.

According to the calculations of Caltech physicist Kip Thorne, who served as a consultant for *Interstellar*, the movie's black hole, known as Gargantua, must have had a mass 100 million times that of the sun and whirled about its own axis at breakneck speeds.

If such a rapidly spinning black hole merges with a companion, it would produce a unique signal — one that gravitational wave detectors might be able to observe, MIT physicist Niels Warburton reported April 18. "There is a completely different gravitational wave signature," said Warburton, who coauthored a related paper posted online March 3 at arXiv.org.

The standard signal of merging black holes is a chirp, named for the increase in frequency and amplitude of the gravitational waves produced as the black holes spiral inward. When converted into sound waves, this pattern sounds like a bird's chirp. Warburton and colleagues performed calculations to determine the gravitational wave signature from a merger with a black hole spinning at nearly full tilt. Instead of a chirp, the gravitational waves would maintain a constant pitch but slowly fade away.

"It was certainly very unexpected to see something that didn't chirp," said MIT physicist Jolyon Bloomfield, who was not involved with the research.

If such black hole mergers occur in nature, next-generation gravitational wave observatories like the Evolved Laser Interferometer Space Antenna might provide proof of their existence. Plans call for eLISA to measure gravitational waves from space beginning in 2034.

The Advanced Laser Interferometer Gravitational-Wave Observatory, which made the first detection of gravitational waves (*SN: 3/5/16, p. 6*), might be able to observe such mergers if the conditions were just right. Although LIGO can't observe mergers of black holes as massive as Gargantua, smaller spinning black holes would produce a similar effect.

Spinning black holes are "really interesting from a fundamental physics point of view," said Samuel Gralla of the University of Arizona in Tucson, a coauthor on the new paper.

Black holes can spin faster and faster as they suck in matter, but there may be

MEETING NOTES

Ancient dwarf galaxy was heavy-element factory

In the primeval universe, a violent event roiled a dwarf galaxy, leaving an indelible mark on the stars that formed there. Scientists reached that conclusion after finding traces of heavy elements produced by the cataclysm in the ancient dwarf galaxy Reticulum II.

Many of the universe's heaviest elements form primarily through the r-process, a chain of reactions through which atomic nuclei climb the periodic table, swallowing up neutrons and decaying radioactively. But scientists don't agree on where the seeds of these heavy elements are sown, except that it must be an environment rich in neutrons.

Alexander Ji of MIT and collaborators used the Magellan telescopes in Chile to catalog chemical elements in nine of Reticulum II's stars. Seven contained heavy elements in the proportions produced by the r-process.

Since most similar dwarf galaxies show no conclusive evidence of r-process elements, the scientists deduced that the event must be rare. The progenitor was probably a collision of two neutron stars, or an unusual type of stellar explosion that spews jets of material, Ji said April 19. – *Emily Conover*

Map charts previously unknown gamma-ray sources

A new map of the sky charts the origins of some of the highest-energy photons ever detected. Researchers from the High-Altitude Water Cherenkov Observatory in Mexico released an analysis of their first year of observations of gamma rays, ultrahigh-energy light particles blasted in our direction from some of the most extreme environments in the universe.

The team found 40 gamma-ray sources, about a quarter of which hadn't previously been identified. The map is "revealing new information about nature's particle accelerators," Brenda Dingus, a leader of the HAWC collaboration, said April 18. These accelerators include supernova remnants and active galaxies known as blazars that shoot out blasts of particles.

The team found new sources in areas that had already been searched by other high-energy gamma-ray telescopes. "That's a little perplexing," Dingus said. The discrepancy could be due to the fact that HAWC observes higher-energy gamma rays, or that the sources are too spread out for the other telescopes to find. – *Emily Conover*

a limit to how fast they can go. At a black hole's center is a singularity, or region of infinite density, which is hidden by an event horizon — the surface inside of which nothing can escape the black hole's pull. But if the black hole twirls too fast, the singularity becomes exposed. Such a "naked singularity" is thought to be impossible to reach, because the known laws of physics would break down.

According to the scientists' calculations, black hole mergers sing when the larger black hole is rotating just below the limit, at 99.99 percent of its maximum speed. This makes singing black holes an enticing prospect for understanding physics at its extremes.

BODY & BRAIN

A sugar can melt away cholesterol

Molecule removed plaques from mice's hardened arteries

BY TINA HESMAN SAEY

A sugar that freshens air in rooms may also clean cholesterol out of hardened arteries.

The sugar 2-hydroxypropyl-betacyclodextrin, or cyclodextrin, removed cholesterol that had built up in the arteries of mice fed a high-fat diet, researchers report in the April 6 Science Translational Medicine. The sugar enhances a natural cholesterol-removal process and persuades immune cells to soothe inflam-

A sugar called cyclodextrin stopped cholesterol crystals (white) from building up in the arteries of mice fed a high-fat diet. Mice that had fewer cholesterol crystals also had fewer inflammation-causing immune cells called macrophages (red).



No cyclodextrin treatment

500 µm Cyclodextrin treatment

mation instead of provoking it, say immunologist Eicke Latz and colleagues.

Cyclodextrin is the active ingredient in the air freshener Febreze. It is also used in a wide variety of drugs: it helps make hormones, antifungal chemicals, steroids and other compounds soluble. If the new results hold up in human studies, the sugar may also one day be used to liquefy cholesterol that clogs arteries.

Other researchers say the approach is promising but must be tested in clinical trials. The sugar is generally considered safe, but injecting it may raise the risk of liver damage or hearing loss, says Elena Aikawa, a vascular biologist at Brigham and Women's Hospital in Boston.

Previous work has indicated that the sugar may damage hearing in mice and cats. The molecule shunts cholesterol

> through the liver, so large cholesterol influxes might cause fat to build up in the liver, impairing its function. But mice taking cyclodextrin in the study did not exhibit side effects from the treatment

Cyclodextrin works by flipping a master switch, a gene called LXR, Latz and colleagues found. LXR's protein

turns on other genes involved in processing cholesterol and ushering it out of the body. The sugar also activated LXR genes in human arteries examined in the lab and turned on inflammation-calming processes, Latz's team discovered.

Latz, of the University Hospital Bonn in Germany, credits Nevada businesswoman Chris Hempel with the idea to use cyclodextrin to treat atherosclerosis. In people with the condition, cholesterol, calcium, immune cells and other substances form plaques inside arteries, hardening them. Plaques block blood flow and can break away and cause heart attacks and strokes (SN: 2/20/16, p. 32).

Hempel has twin daughters with a rare genetic disease called Niemann-Pick Type C, in which cholesterol crystals clog organs. In 2009, the girls got permission from the U.S. Food and Drug Administration to receive infusions of cyclodextrin. Previous work in animals suggested it could dissolve cholesterol.

Hempel later read a paper by Latz and colleagues that described how cholesterol crystals irritate macrophages and provoke them to cause inflammation and heart disease. Macrophages normally patrol the body and help kill invading pathogens. The immune cells also gobble up cholesterol and deliver it

LIFE & EVOLUTION Corals could soon reach heat limit

More warming may curb ability to adjust to temperature spikes

BY SARAH SCHWARTZ

Corals are in hot water and may soon lose their ability to handle the heat.

In Australia's Great Barrier Reef, most past bouts of warming allowed many corals to adjust their physiology and avoid serious damage. But as waters warm even more, corals may run out of wiggle room, researchers report in the April 15 Science.

"One of the things that we have been striving for is trying to figure out the rate and limit of ... physiological adjustments that corals have," says marine biologist Stephen Palumbi of Stanford University, who was not involved with the study. The

findings indicate corals may be unable to cope with much more warming, he says.

If water temperatures surge quickly, corals may bleach, losing the photosynthetic, symbiotic bacteria that provide them with nutrients and oxygen. But if waters warm slightly - less than the heat spike where bleaching begins, roughly 2 degrees Celsius above average - and then cool for a brief time before heating up to a greater extent, corals are better prepared to survive. In the lab, corals exposed to this two-step warming process experienced less bleaching and cell death than corals suffering a high initial heat

wave, the researchers find.

"We liken it to the idea of training for a marathon," says study coauthor Scott Heron, a physical oceanographer at the National Oceanic and Atmospheric Administration's Coral Reef Watch in College Park, Md. "If they have a little bit of exposure, and then the recovery period after that ... they're better prepared for the race when it comes."

From 1985 to 2011, some 75 percent of warming events in Great Barrier Reef sites occurred in this stepwise fashion. But with climate models predicting a 2-degree increase in sea temperatures by the end of the century, warming events might push corals past their bleaching point with no chance to prepare.

Computer simulations predict that as waters grow warmer, reef heat waves

to the liver where it can be made into bile and escorted out of the body in feces.

Hempel e-mailed Latz and suggested that cyclodextrin might melt the cholesterol crystals in arteries. Latz and colleagues tested the idea by feeding mice genetically prone to atherosclerosis a high-fat diet and giving them regular injections of cyclodextrin under the skin. The sugar kept cholesterol plaques from building up in the mice's arteries. The scientists also found that cyclodextrin reduced already established plaques by about 45 percent, even though mice were still eating a high-fat diet.

Cyclodextrin could be used in combination with other drugs, such as statins, says Eran Elinav, an immunologist at the Weizmann Institute of Science in Rehovot, Israel. Statins inhibit cholesterol production. "Potentially, combining cholesterol lowering with dissolution of preformed cholesterol in plaques could be additive," he says.

Although cyclodextrin is already approved by the FDA for use in people, it may be years before it's known whether injecting the sugar will soften people's hardened arteries. No pharmaceutical companies have come forward to sponsor expensive clinical trials needed to get approval for this specific use, Latz says.

will increase overall. And the fraction of such events that could condition corals to withstand bleaching will fall from 75 to 22 percent, the team reports. The team predicts most reefs that have experienced preconditioning in the past will lose the ability to prepare when average water temperatures increase by 0.5 degrees. Warming trends suggest that the added half degree should appear within 40 years. "If that protective mechanism does get lost going into the future, then what we've seen so far as being bad impacts could become worse," Heron says.

For now, preparation may help some corals survive in warming seas, but reduced carbon emissions will be required to sustain coral cover throughout the century, the team's data suggest.

Story of dinos' die-off not a simple tale

Dinosaurs' numbers were already dwindling before asteroid hit

BY MEGHAN ROSEN

Neither a giant asteroid nor a gradual die-out can take full blame for dinosaurs' demise. Rather, the culprit may be both, two new studies suggest.

Tens of millions of years before the asteroid delivered its killer blow some 66 million years ago, the number of dinosaur species had already begun to drop, researchers report online April 18 in the *Proceedings of the National Academy of Sciences.* But not all dino groups were in decline, other researchers suggest online April 21 in *Current Biology*.

At first glance, the two studies seem to conflict, but "they can coexist," says paleontologist Michael Benton, who coauthored the *PNAS* paper. Both add to what has become an increasingly intricate picture of dinosaurs' final days.

In the 1960s and '70s, scientists generally believed that dinosaurs petered out after a long, gradual decline. That view took a U-turn in 1980, when researchers proposed that, instead, an asteroid impact suddenly triggered the extinction.

What actually happened is probably more nuanced, says Benton, of the University of Bristol in England. He and colleagues analyzed the number of



Dinosaurs called toothed maniraptorans (one in flight) thrived until their sudden extinction 66 million years ago. Modern birds' ancestors (one in log) may have survived by eating seeds.

dinosaur species emerging and going extinct in a roughly 175-million-year fossil record. Up to 50 million years before the mass extinction, dinosaurs started losing species faster than they gained new ones. This loss in diversity may have made it harder to bounce back from the asteroid's impact.

"This doesn't in any way attack the importance of the impact," Benton says. But in most dinosaur groups, species numbers were already dwindling.

According to the analysis in *Current Biology*, toothed maniraptorans (small birdlike relatives of velociraptors) were an exception. An analysis of over 3,000 of these dinosaurs' fossilized teeth suggests that these dinos' ecosystem was stable up until the extinction, says study coauthor Derek Larson of the Philip J. Currie Dinosaur Museum in Wembley, Canada.

Larson and colleagues looked for variations in the teeth's dimensions and in serration size. Big changes in variation over time could be a hint that the dinos were on the decline, Larson says. But "things basically stayed the same through the last 18 million years of the Cretaceous."

Toothed maniraptorans "seemed to be doing just fine right up until the extinction," says University of Oxford paleobiologist Roger Benson.

Larson's team suspects that diet may explain why toothed, meat-eating maniraptorans went extinct after the impact while some of their relatives — the beaked ancestors of birds — didn't. In analyzing modern birds' diets, the team determined that ancestral birds probably ate seeds, Larson says, a hardy food source that could have lasted for decades or longer.

Seeds might have sustained ancestral birds through the nuclear winter that could have followed the asteroid impact. When hoards of plants and animals died out, and dinos ran out of food, Larson says, "the only resource that would have been reliable and available would have been seeds." HUMANS & SOCIETY

Debate over Homo naledi continues

Fossils' age and arrival in cave remain mysterious

BY BRUCE BOWER

Homo naledi, a rock star among fossil species in the human genus, has made an encore. Its return highlights debate over whether this hominid was a distinct *Homo* species that purposefully disposed of at least some of its dead.

H. naledi made worldwide headlines last year when researchers announced the discovery of an unusually large collection of odd-looking *Homo* fossils in the bowels of a South African cave system. Presentations on April 16 underscored key uncertainties about the hominid.

One of the biggest mysteries: *H. naledi*'s age. Efforts are under way to date the fossils and sediment from which they were excavated with a variety of techniques, said paleoanthropologist John Hawks of the University of Wisconsin-Madison. An initial age estimate may come later this year if different dating techniques converge on a consistent figure. A solid date for the fossils is essential for deciphering their place in *Homo* evolution and how the bones came to rest in a nearly inaccessible cave.

Some presenters reasserted that *H. naledi* intentionally dropped dead comrades into an underground chamber, where their bones were later found by cave explorers and then scientists. But others raised questions. Even team leader Lee Berger, a paleoanthropologist at the University of the Witwatersrand in Johannesburg, hedged his bets.

"It's way too early to tell how *H. naledi* bodies got in the chamber," Berger said.

Berger's group recovered 1,550 *H. naledi* fossils from a minimum of 15 individuals of all age groups (*SN:* 10/3/15, p. 6). Slender researchers wended through narrow passageways in South Africa's Rising Star cave system and squeezed down a vertical chute



to reach pitch-dark Dinaledi Chamber. There, they found hominid fossils scattered on the floor and up to 20 centimeters beneath the surface.

Berger's team assigned the bones to a new species called *H. naledi* based on an unexpected mix of humanlike features and traits typical of *Australopithecus* species from more than 3 million years ago.

Fossil analyses presented at the meeting challenged a suggestion by some researchers, both before and during the meeting, that *H. naledi* actually represents a variant of *Homo erectus*, a species known to have existed by 1.8 million years ago (*SN: 11/16/13, p. 6*).

H. naledi possessed a shoulder unlike those of other *Homo* species, said team member Elen Feuerriegel of the Australian National University in Canberra. *H. naledi*'s collarbone and upper arm bone resemble corresponding *Australopithecus* bones, she reported. *H. naledi*'s shoulder blades must have been positioned low and behind the chest, an arrangement more conducive to climbing trees than running long distances.

H. naledi's hand was built both for climbing and gripping stone implements, said Tracy Kivell of the University of Kent in England. Her analysis of 150 hand bones, including a nearly complete hand, showed a humanlike wrist and thumb combined with *Australopithecus*-like curved fingers.

H. naledi's curved toes and flaring pelvis also recall *Australopithecus*. Still, a preliminary lower-body reconstruction — incorporating fossil evidence of humanlike legs, knees and feet — suggests *H. naledi* walked almost as well as modern humans do, said Zach Throckmorton of Lincoln Memorial University in Harrogate, Tenn. *H. naledi* and West Asian *H. erectus* share several tooth features as well as relatively small braincases and similar statures. "That complicates matters," said Christopher Walker of Duke University. Upper-body features that Berger's team considers characteristic of *H. naledi*, such as the upper arm's shape, possibly occurred in West Asian *H. erectus* as well, added Tea Jashashvili of Witwatersrand, who has studied those finds.

Explaining how *H. naledi* bones ended up in Dinaledi Chamber is also complicated. Ongoing studies of sediment and rock indicate that there was never a direct opening to the underground fossil site from above, said Marina Elliott of Witwatersrand.

Bones from some body parts, including five feet, three hands and part of a backbone, were found aligned as they would have been in living individuals, indicating at least some bodies reached the chamber intact, Hawks said. Curiously, some sets of aligned bones were found beneath scattered bones from diverse individuals.

If the dead were dropped down a vertical chute into Dinaledi Chamber, bodies on top would have been least damaged and most likely to retain aligned bones. Along with that mystery, some sets of aligned bones somehow ended up far from the chute's opening, Berger said.

An alternative entrance to Dinaledi Chamber possibly existed in the past, Aurore Val, of Witwatersrand, asserted online March 31 in the *Journal of Human Evolution*. Beetles or snails that damaged some *H. naledi* bones don't inhabit dark, underground caves, Val argued. Such damage probably occurred on the surface or in a nearby, once-accessible part of the cave system, she proposed.

The surfaces of many *H. naledi* fossils had been worn down enough to have possibly erased predators' tooth marks and signs of animal trampling, which would be additional signs that another entrance to the chamber once existed, Val said.

Given the large number of isolated and broken *H. naledi* fossils, bodies or body parts may have entered the chamber long after death, in Val's view. Perhaps water from another part of the cave system carried bodies into Dinaledi Chamber, she speculated.

Geologic studies show that water occasionally reached the chamber and mildly eroded sediment there, Berger said. But he doubts water washed bones into Dinaledi Chamber. "Even if there was another entrance to the chamber, it still allowed access only to *Homo naledi,*" Berger argued. No remains of any other animals have been found in association with *H. naledi* bones.

Like any rock star of lasting impact, the South African hominid may soon wow fans with new material. "Thousands of *Homo naledi* fossils are almost certainly left in the underground chamber," Berger said.

MEETING NOTES

Viking-era 'woman in blue' provides clues to Iceland's earliest settlers

The partial skeleton of a young woman found in Iceland in 1938 in a grave with Viking-era objects belonged to a child of some of the island's earliest settlers, researchers reported April 14. Tooth development and wear suggest that the individual, known as the "woman in blue," was between 17 and 25 years old when she died.

It's not known if the woman was a Viking or if she came from another northern European population, said bioarchaeologist Tina Jakob of Durham University in England. A chemical analysis of one of the woman's teeth indicates that, between ages 5 and 10, she started eating a lot of fish and other seafood for the first time after having previously consumed mainly plants and land animals, a team led by Jakob and Joe Walser III of the University of Iceland in Reykjavik found.

"The woman in blue was not Icelandic," Jakob said. "She came from southern Scandinavia or the British Isles."

A blue-dyed apron she wore — from which she got her nickname — and a strap from some type of garment display weaving techniques from ninth to 10th century Norway and Britain's Celtic society, Jakob said. The apron's plantbased blue dye was typical of female Viking clothing, she added. Fiber and chemical studies show that Icelandic sheep provided wool used for these garments.

Radiocarbon dating of the apron, strap and one of the woman's teeth indicate she was born around 900, the scientists conclude. Evidence of Iceland's initial settlement dates to between around 871 and 930, Jakob said.

While the woman lay in her grave, a Scandinavian copper brooch came in contact with her face, helping to

A young woman now determined to have been one of Iceland's earliest settlers was found in 1938 in a grave with various Vikingera objects, including this pair of brooches.



preserve skin fibers. DNA from the woman is now being studied. – *Bruce Bower*

Belize cave was site of Maya child sacrifice

Grim discoveries in Belize's aptly named Midnight Terror Cave shed light on a long tradition of child sacrifices in ancient Maya society.

A large portion of 9,566 human bones, bone fragments and teeth found on the cave floor from 2008 to 2010 belonged to individuals no older than 14 years, bioarchaeologist Michael Prout of California State University, Los Angeles reported April 15. Many of the human remains came from 4- to 10-year-olds. Because these bones are so fragmented, it's difficult to estimate precisely how many individuals were placed in the cave.

Prout and colleagues suspect these children were sacrificed to a rain, water and lightning god that the ancient Maya called Chaac.

Radiocarbon dating of the bones indicates that the Maya deposited one or a few bodies at a time in the cave over about a 1,500-year-period, starting at the dawn of Maya civilization around 3,000 years ago, Prout said. At least 114 bodies were dropped in the deepest, darkest part of the cave, near an underground stream. Youngsters up to age 14 accounted for a minimum of 60 of those bodies. Ancient Maya considered inner cave areas with water sources to be sacred spaces, suggesting bodies were placed there intentionally as offerings to Chaac.

Until now, an underground cave at Chichén Itzá in southern Mexico contained the only known instance of large-scale child sacrifices by the ancient Maya, Prout said. Other researchers have estimated that 51 of at least 101 individuals whose bones were found scattered in Chichén Itzá's "sacred well" were children or teens.

Researchers have often emphasized that human sacrifices in ancient Central American and Mexican civilizations targeted adults. "Taken together, however, finds at Chichén Itzá and Midnight Terror Cave suggest that about half of all Maya sacrificial victims were children," Prout said. — Bruce Bower

Genetic escape artists resist disease

13 people found with harmful mutations but no symptoms

BY TINA HESMAN SAEY

Some people can evade diseases even though they carry genetic mutations that cause serious problems for others.

Researchers found 13 of these genetic escape artists after examining DNA from nearly 600,000 people, the scientists report online April 11 in *Nature Biotechnology*. Learning how such people, if they truly exist, dodge genetic bullets may help move inherited-disease research from diagnosis to prevention.

Hundreds of mutations that lead to genetic diseases have been uncovered since the discovery of a disease-causing flaw in the "cystic fibrosis gene" in 1989. But, says study coauthor Stephen Friend, "finding the gene that causes the disease is not the same as finding a way to prevent the symptoms or manifestations of that disease."

Clues to preventing genetic diseases could come from studying people who should have gotten sick but didn't, suggest Friend, of the Icahn School of Medicine at Mount Sinai in New York City, and colleagues. Finding people like that is a challenge, though, because they don't have symptoms.

To identify such people, the team assembled existing genetic data from 589,306 adults who had their DNA tested as part of 12 ongoing or past studies. The researchers then searched for mutations known to cause genetic diseases in childhood. Since study participants were adults, they should already have developed symptoms.

Initially, the researchers found more than 15,000 potential escape artists. Further analysis whittled the field to 42. Of those, medical records indicated that 14 did have symptoms of their genetic disease after all. Another 15 were ruled out because a closer examination found that only one copy in a pair of diseaseassociated genes was mutated. The other copy was normal, so it could compensate for the debilitated copy. The remaining 13 people carried dual mutations associated with one of eight different diseases but somehow had not developed symptoms. The study suggests that it is possible to find people who are resistant to getting genetic diseases.

But some resilient people may have been missed because the study included only a fraction of known disease-causing mutations, says Daniel MacArthur, a geneticist at Massachusetts General Hospital in Boston. More troubling is that the researchers could not confirm that resistant people were disease-free or verify that all really have mutations. That's because consent forms signed when participants agreed to share their genetic information did not contain provisions for researchers to contact

Disease	Mutated gene	Number of resistant people
Cystic fibrosis (lung disease)	CFTR	3
Smith-Lemli-Opitz syndrome (developmental disorder)	DHCR7	2
Familial dysautonomia (neurological disease)	IKBKAP	1
Epidermolysis bullosa simplex (skin condition)	KRT14	1
Pfeiffer syndrome (bone disorder)	FGFR1	1
APECED (autoimmune disease)	AIRE	1
Acampomelic campomelic dysplasia (bone disorder)	SOX9	1
Atelosteogenesis (bone disorder)	SLC26A2	3

Genetic resistance In a study of nearly 600,000 people's genetic and medical records, scientists found 13 people who carry disease-related mutations yet appear not to have the disease. SOURCE: R. CHEN ET AL/NATURE BIOTECHNOLOGY 2016

participants later for retesting. "Some of their resilient cases may be mirages," MacArthur wrote in a commentary, also in *Nature Biotechnology*.

Garry Cutting, a medical geneticist at Johns Hopkins School of Medicine, is also concerned that some of the lucky 13 may not be true escape artists. Cutting studies genes and environmental factors that determine the severity of cystic fibrosis, a disease in which thick mucus builds up in the lungs, pancreas and other organs. People develop the disease when they inherit two defective copies of the *CFTR* gene. More than 1,800 different mutations in that gene can cause the disease if inherited in double copies or in combinations of mutations.

Of the 13 resilient people in the study, three carry dual copies of a very rare mutation in the *CFTR* gene but don't have cystic fibrosis.

Only one person in a separate database of 88,000 cystic fibrosis patients carries two copies of the rare mutation. So finding three people with double copies of the mutation is extraordinary, Cutting says. "It's so exceptional that I believe it requires more extensive verification."

He says he would be delighted if the people really turn out to be resistant to getting cystic fibrosis, but he's puzzled why that mutation alone allows escape. It could be that a variant in another gene counteracts that specific mutation in the *CFTR* gene. Or a second mutation in the mutant *CFTR* gene may reverse the effect of the disease-causing one. However, it is also possible that the three people avoided cystic fibrosis because they have only one copy of the mutated gene and one healthy copy that the researchers missed with the methods they used, Cutting says.

MacArthur points out another potential drawback to the study: Even if the researchers expand the study to 1 million or more people, they may not discover enough "genetic superheroes" to create a sample size large enough to detect protective genes. Such an effort may require participation from hundreds of millions of people and researchers willing to share data on a global scale.



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MSERES in the Gun Control Debate

Researchers face roadblocks and a dearth of informative data **By Meghan Rosen**

> uying a handgun in Connecticut means waiting – lots of waiting. First comes an eight-hour safety course. Then picking up an application at a local police department. Review of the application (which includes a background check and fingerprinting) can take up to eight weeks. If approved, the state issues a temporary permit, which the buyer trades in at state police headquarters for a permanent one. Then it's back to the store for the gun.

Head west to Missouri, though, and buying a

handgun is practically a cakewalk. Customers at Osage County Guns in Belle, Mo., for example, can walk into the store and walk out with a gun if they pass the FBI's instant background check, says John Dawson, the store's chief technical officer.

"If a person knew exactly what they wanted," he says, the store could, "in theory, complete the transaction in about 15 minutes."

Missouri and Connecticut have staked out opposite ends of the gun law spectrum. Connecticut didn't require handgun buyers to get a permit until 1995. Missouri had a tough law on the books, but repealed it in 2007. The states' laws have flip-flopped, making for a fascinating natural experiment on gun laws' effects on gun violence.

The states "had mirror image policy changes, and mirror image results," says Daniel Webster, a health policy researcher at Johns Hopkins University.

Flipping the laws was associated with 15 percent fewer gun suicides in Connecticut and 16 percent more in Missouri, a statistical analysis by Webster and colleagues, published last year in *Preventive Medicine*, estimated. Similar analyses by Webster



in 2014 and 2015 indicated a 40 percent reduction in Connecticut gun homicide numbers, and an 18 percent rise in Missouri.

The evidence is very suggestive, says Harvard University researcher David Hemenway. But it's not extensive enough to persuade everyone – or to move national policy.

In fact, questions loom about the impact of all sorts of policies, from background checks to assault weapons bans to gun buybacks. That's partly because gun research faces roadblocks at every turn: Scientists have to deal with data shutouts, slashed funding and, occasionally, harassment.

For a few questions, however, researchers have come up with solid answers: There's a convinc-

ing link between gun availability and gun suicide, for one. And studies from the United States and abroad suggest that some gun laws do rein in gun violence. To make firm conclusions, though, scientists are desperate for more data.

But the U.S. Centers for Disease

Control and Prevention can't collect gun data like it used to, and information about guns used in individual crimes is locked up tight. Under current federal laws, Hemenway says, "It's almost impossible for researchers to get even the data that are available."

Locked up

In a squat brick building tucked in the hills of Martinsburg, W.Va., gun data are overflowing.

Thousands of cardboard boxes, stacked high in tidy columns, line the hallways of the federal government's National Tracing Center. In the parking lot, steel shipping containers hold even more boxes. Each box contains about 2,000 pages of gun purchase records. To trace a gun, the center's employees often search through these records by hand.

That's their job: tracking when and where guns used in crimes were originally purchased, and by whom. It's a huge undertaking: In 2015, the center, part of the Bureau of Alcohol, Tobacco, Firearms and Explosives, or ATF, received more than 373,000 gun trace requests from law enforcement.

Such a mass of data is a researcher's dream. But current laws keep gun traces secret. The agency shares traces only with law enforcement. The public can see just summaries or aggregate data.

Webster has used this data to paint a rough picture of how Missouri's repeal affected the flow of guns to criminals. In 2006, when buying a handgun required a permit, 56.4 percent of guns recovered by police had been originally sold by a Missouri gun dealer. In 2012, five years after the state nixed the permit requirement, the number rose to 71.8 percent, Webster and colleagues reported in the *Journal of Urban Health* in 2014.

The findings suggest that it's easier now for criminals in Missouri to get their hands on legally purchased guns. But Webster can't say for certain whether more guns are moving to criminals — or whether legal gun owners are committing more crimes. For that, he'd need to see the individual gun traces.

About a decade ago, researchers who wanted such detailed data could get it. "We'd just hand them a DVD," says ATF information specialist

Neil Troppman. "Those days are long over."

A handful of laws snarl the process, from how a gun trace begins to who can see the data.

One big hitch in the system: Police officers who find a gun at a crime scene can't always look up the

owner's name on a computer. That's because there is no national registry — no searchable database of guns and their owners. To set one up would be illegal. So police have to submit a request to the tracing center, which tracks the gun's movement from manufacturer or importer to dealer. Then the ATF can ask the dealer who bought the gun. If the dealer has gone out of business, ATF employees dig for the answer themselves, in old gun purchase records stockpiled at the tracing center. The process takes an average of five days. And after law enforcement gets the data, federal law makes sure no one else can see it.

Federal constraints

In 2003, Congress unleashed a beast of a bill with an amendment that effectively tore out the ATF's tongue. The Tiahrt amendment was the first in a series of provisions that drastically limited the agency's ability to share its crime gun data — no giving it to researchers, no making it public, no handing it over under Freedom of Information Act requests (the public's channel for tapping into information from the federal government).

Funding for gun control research had dried up a few years earlier. There's no outright ban, but a 1996 amendment had nearly the same effect. It's known as the Dickey amendment, and it barred the CDC from using funds to "advocate or promote gun control." According to a 2013 commentary in *JAMA*, that meant almost any research on guns.



U.S. gun injuries and deaths, 2013



Stark reality In 2013, 33,636 people died from gun injuries in the United States (top pie chart). Suicides outnumbered homicides almost 2-to-1 (middle). Males made up the bulk of gun deaths. SOURCE: CDC





Rate of suicides by gun in states with high versus low levels of gun ownership





If the 1996 law's language was vague, Congress made the message clear by cutting the CDC's budget by \$2.6 million — exactly the same amount the agency had spent the previous year on gun violence research. The funds were later reinstated, but earmarked for other things. So the CDC largely backed off, except for some basic tallying, says spokesperson Courtney Lenard, because of the funding cuts and because Congress "threatened to impose further cuts if that research continued."

In 2011, Congress hit the National Institutes of Health with similar restrictions. About a year later, President Obama tried to ease the choke hold: He ordered the CDC to research the causes and prevention of gun violence, and called on Congress to provide \$10 million in funding. Finally, 17 years after the CDC cuts, news reports proclaimed that the ban had been lifted and research could resume. But Congress never authorized the money, and the CDC remained on the sidelines. This April, nearly 150 health and science organizations, universities and other groups signed a letter urging Congress to restore the CDC's funding.

Meanwhile, research on gun violence and gun control trudges forward: Researchers can sometimes convince law enforcement agencies to share data on guns linked to crimes, and grants can come from private foundations. Yet even with limits on research, the science in some cases is solid: A gun in the home, for example, increases the odds a person will commit suicide by about 3-to-1. Here, Hemenway says, "The weight of the evidence is overwhelming."

But how to use laws to reduce gun violence remains hotly contested, and opinions among the public, and even scientists, are polarized.

Critics of gun control laws think the matter is clear: Again and again studies show that gun control policies just don't work, says economist John Lott, who has written extensively on the subject. Take background checks, he says, "Given that these laws are costly, you'd like to believe there's some evidence that they produce a benefit."

Webster acknowledges the divisive split in opinions. "The vast majority of people are on one side of the fence or the other," he says. "They'll point to a study that is convenient to their political arguments and call it a day."

Bad for your health

For researchers who manage to navigate the legal tangles and funding troubles of gun research, actually doing the research itself isn't easy.

Unlike clinical trials in medicine, where scientists can give, for example, a cholesterol drug to half a study's participants and then compare the effects between users and nonusers, scientists studying gun violence can't dole out new handguns

to one group and none to another and see what happens.

Instead, researchers turn to observational studies. That means looking at how — and if — suicides track with gun ownership in different groups of people and over time, for example. Finding a link between two observations doesn't necessarily mean they're connected. (People have linked the yearly number of Nicolas Cage movies to swimming pool drownings, after all.) But finding a lot of links can be telling.



Roughly 10,000 boxes full of gun purchase records line the halls and walls of the federal government's National Tracing Center in Martinsburg, W.Va.

For suicides, the link to gun access holds strong – among old people, young people, women, adolescents, "you name it," Hemenway says. Lots of guns means lots of suicides by gun, he says.

In 2007, Hemenway and colleagues examined gun ownership rates and statewide suicide data from 2000 to 2002. People in states with a high percentage of gun owners (including Wyoming, South Dakota and Alaska) were almost four times as likely to kill themselves with guns as people living in states with relatively few gun owners (such as Hawaii, Massachusetts and Rhode Island), the researchers reported in the *Journal of Trauma Injury, Infection and Critical Care.*

More recently, a 2013 study in Switzerland compared suicide rates before and after an army reform that cut the number of Swiss soldiers by

half. After the reform, fewer people had access to armyissued guns — and the suicide rate dipped down by about two per 100,000 men age 18–43. That's about 30 men each year who didn't die from suicide, the study's authors estimated in the *American Journal of Psychiatry*.

A 2014 review of 16 such studies, published in the *Annals of Internal Medicine*, came to the same conclusion, again: Access to guns meant higher risk of suicide.

"The evidence is unassailable," says Stanford University criminologist John Donohue. "It's as strong as you can get."

Mental illness factors into suicide too, says Jeffrey Swanson, a medical sociologist at Duke University. (Some 21 to 44 percent of suicides reported to the CDC are committed by people with mental health problems.) And federal laws aren't particularly good at keeping guns away from mentally ill people. A 1968 law prohibits gun sales to a narrow slice of people with a history of mental illness, but it's easy for others to slip through the cracks. Even people the law does target can end up with guns — because states don't have to report mental health records to the FBI's national background-check system.

"You've got tons of records that would disqualify people from buying guns," Swanson says, but they don't necessarily make it into the system.

Even if the United States had a perfect mental health care system and cured schizophrenia and bipolar disorder and depression, he says, the overall problem of gun violence would still exist. Mentally ill people just aren't that violent toward others, Swanson noted in the *Annals of Epidemiology* in 2015. In fact, people with mental illness committed fewer than 5 percent of U.S. gun killings between 2001 and 2010, according to the CDC.

"People think that in order to fix gun violence, we need to fix the mental health care system," Swanson says. That's wrong, he argues. "It's a diversion from talking about guns."

Weak laws

After Sandy Hook, San Bernardino and other high-profile mass shootings, people have been talking about what gun control laws, if any, actually work.

Unfortunately, there's just not enough evidence to make strong conclusions about most

People with mental illness committed fewer than 5 percent of U.S. gun killings between 2001 and 2010. laws, Hemenway says. In 2005, for example, a federal task force reviewed 51 studies of gun laws, mostly in the United States, and came up empty-handed. The task force couldn't say whether any one of the laws made much of a difference. The efficacy of U.S. gun laws is hard to pin down

for two main reasons, Hemenway says: Gun laws aren't typically very strong, and studies tend to look at overall effects on violence.

One major study published in *JAMA* in 2000 analyzed suicide and homicide data from 1985 to 1997 to evaluate the impact of the Brady Act, a 1994 federal law that requires background checks for people buying guns.

Eighteen states and the District of Columbia already followed the law. So researchers compared



Standing out In 2013, the United States led 22 countries in deaths from gun homicides (red). The rates of other homicides (gray) were closer to rates in other countries. Source: *GLOBAL BURDEN OF DISEASES, INJURIES AND RISK FACTORS,* INST. HEALTH METRICS AND EVAL.

FEATURE | MISFIRES IN THE GUN CONTROL DEBATE



Making connections Gun laws vary dramatically across the United States. Public health researchers have linked states' gun laws to levels of gun violence. Louisiana and Alaska, for example, led the country in the number of gun deaths per 100,000 people in 2014. These states also have weaker gun laws (darker colors) than states such as California and New York (lighter colors). SOURCES: CDC, LAW CENTER TO PREVENT GUN VIOLENCE

suicide and homicide rates with those in the 32 states new to the law. If Brady curbed gun violence, those 32 states should see dips in deaths.

That didn't happen (with one exception: Gun suicides in those states dropped in people age 55 and older — by about 1 per 100,000 people).

"I don't think anybody was really shocked," Webster says. After all, Brady had a gaping hole: It didn't require background checks for guns bought from private sellers (including those at gun shows). The loophole neutered Brady: People who didn't want a background check could simply find a willing private seller. That's just too easy, Webster says: It's like letting people decide whether they want to go through the metal detector at the airport.

Like the Brady Act, the 1994 Federal Assault Weapons Ban didn't seem to do much to prevent violence, criminologist Christopher Koper and colleagues concluded in a 2004 report to the U.S. Department of Justice. The law, which expired in 2004, imposed a 10-year ban on sales of military-style semiautomatic guns. These weapons fire one bullet per trigger squeeze and have features like threaded barrels (which can be used for screwing on silencers) or barrel mounts (for attaching bayonets). The 1994 law also banned most large-capacity magazines (storage devices that feed guns more than 10 rounds of ammo).

But like Brady, the ban came with a catch: It didn't apply to weapons and magazines made before September 13, 1994. That's a lot of exemptions. At the time, the United States had more than 1.5 million assault weapons and nearly 25 million guns with large-capacity magazines, reported Koper, of George Mason University in Fairfax, Va.

"The more complete the bans are, the better the effects seem to be," Donohue says. Take Australia: In 1996, the country enacted strict laws and a gun buyback program after a mass shooting killed 35 people in Tasmania. The ban made certain longbarreled guns illegal (including semiautomatic rifles and pump-action shotguns — weapons that let people fire lots of rounds quickly), and the country bought back and destroyed more than 650,000 guns.

With the law, Donohue says, "Australia effectively ended the problem of mass shootings."

And as economists Christine Neill and Andrew

Leigh found, the law drastically cut down the number of gun suicides, too.

Tough laws

Eleven years after Australia launched its tough gun control legislation, Neill, of Wilfrid Laurier University in Canada, and Leigh, then at Australian National University in Canberra, announced that the law might actually be saving lives.

Critics attacked. One petitioned Neill's university to reprimand her. Then they came for Leigh's e-mails. He had to hand over any that mentioned firearms or guns. Had there been anything improper — any whiff that the researchers were biased — Neill believes gun advocates would have pounced.

Neill and Leigh, now an Australian politician, had uncovered telling changes in different regions' suicide rates between 1990–1995 and 1998–2003. "Firearms suicides fell most in Tasmania, by a long shot," Neill says, almost 70 percent, the team later reported in 2010 in the *American Law and Economics Review*.

Australia's law, called the National Firearms Agreement, or NFA, applied to all of the country's states and territories, but some had more guns than others. Tasmania, for example, had the most guns bought back, Neill says: 7,302 guns per 100,000 people. More guns bought back meant bigger drops in suicide rates, she says.

It's a stark result, and suggests that tough laws can have big impacts. Australia "did an outright ban and something akin to a confiscation of guns," Webster says. "That's never going to happen in the United States."

Instead, the United States goes for smaller laws, fashioned mostly state-by-state. Still, some may be effective. Blocking domestic violence offenders' access to guns seems to cut down on homicides, for example. From 1982 to 2002, states with restraining order laws that bar offenders from buying guns had rates of intimate partner homicide that were 10 percent lower than in states lacking the laws, researchers reported in 2006 in *Evaluation Review*.

In 2010, Webster and colleagues reported similar results at the city level. He and colleagues tracked intimate partner homicides from 1979 to 2003 in 46 U.S. cities. Those that made it hard for people with domestic violence restraining orders to get guns had 19 percent fewer intimate partner homicides compared with cities with less stringent laws, the team reported in *Injury Prevention*.

"These are pretty consistent findings," Webster says. Those state policies seem to be working. **Big picture only** Gun trace data are available to researchers only in aggregate. Researchers can look at the total number and the types of guns traced in a state. But they can't learn the where and when of a gun linked to a specific crime.

Can researchers get these answers?

Types of guns traced, 2014

Pistol

53.4%

-	
What gun shop sold the gun?	No
Who bought the gun?	No
When was the gun traced?	No
How long before the gun ended up in a crime?	No

Conclusions about other, more well-known laws, such as "right-to-carry," are less convincing. Such laws, which allow people to carry concealed handguns in public, could offer people a means of defense. Or they could make it easier for people in an argument to whip out a gun.

"The findings are all over the map," Hemenway says. A report from the National Research Council in 2005 found no causal link between rightto-carry laws and crime. It also concluded that people do use guns to protect themselves (say, by threatening or shooting an attacker) but how often is hard to say. Estimates vary from 100,000 to 2.5 million times per year in the United States.

Economist Mark Gius of Quinnipiac University in Hamden, Conn., estimated that restricting people's right to carry boosts a state's murder rate by 10 percent, he reported in 2014 in *Applied Economics Letters*.

Donohue's 2014 results lean a different way. The Stanford researcher updated the NRC analysis with more than a decade of new data and found that laws letting people carry concealed weapons boost violent crime — a bit. Based on data from 1979 to 2012, his statistical modeling showed that a state with a right-to-carry law would experience 8 percent more aggravated assaults than a state without such a law, for example.

"More and more evidence is amassing that these laws are harmful," Donohue says, but he concedes that there's still uncertainty. "I'm not quite ready to say that we've nailed it down."

Less uncertainty would require more analyses and more data. But in this field, even that doesn't guarantee consensus.

"The problem is that there are many ways to slice the data," Donohue says. "Almost nothing is as clear as the advocates make it — on both sides."

Explore more

 Garen J. Wintemute. "The epidemiology of firearm violence in the twenty-first century United States." Annual Review of Public Health. March 2015.



Pistols were more than half of the 246,087 guns the Bureau of Alcohol, Tobacco, Firearms and Explosives traced for involvement in a crime in the United States and its territories in 2014. Revolvers and rifles were a distant second and third. Other firearms traced included machine guns, tear gas launchers and flare guns. SOURCE: ATF



Laser technology reveals surprising sprawl around Angkor Wat By Bruce Bower

Smartphone-toting pilgrims regularly stream into northern Cambodia from all over the world. Their destination: Angkor Wat, a medieval temple that's famous for massive towers and majestic stone carvings of Hindu gods, spirits and mythological battle scenes. The site, considered the world's largest religious monument, drew more than 2.3 million visitors in 2014.

Angkor Wat's sightseers encounter a study in contrasts. This architectural wonder of human civilization ascends skyward, on the verge of being engulfed by nature below. Tourists walk along a path that crosses over a moat and through the temple's western side, the one entrance cleared of vegetation. Lush forest stops just short of the rest of the structure. Outside the moat, trees, thick ground cover and ponds dominate the landscape.

While adventurous visitors snap pictures, scientists are using high-tech approaches to uncover Angkor Wat's hidden side, long obscured by all that vegetation. After more than a century of research on the parts of Angkor Wat that are visible with the naked eye, many scientists assumed that the site was a sacred city contained within the bounds of a square moat. But even though its name roughly translates as "temple city," new finds show that Angkor Wat was not a sacred city at all. It was a gigantic temple connected to residential districts, canals and other structures that stretched beyond the moat and blended into a sprawling city called Greater Angkor, which covered about the same area as Berlin or Columbus, Ohio.

Angkor Wat's unveiling by modern laser technology began in April 2012. Archaeologist Damian Evans of Cambodia's Siem Reap Center and several colleagues made daily helicopter flights for almost two weeks over a 370-square-kilometer area around the temple. The helicopter carried \$250,000 worth of special equipment that fired millions of laser pulses every few seconds at the forest below. A small percentage of those pulses zipped in between trees and foliage to the forest floor. The Earth's hard surface bounced those laser shots back to a sensor on the helicopter. This technique, known as light detection and ranging, or lidar for short, picked up differences in the contours of the land now obscured by jungle. With the findings, researchers could draw a picture of city blocks, residential areas, dried-out ponds and other archaeological remains. Results gleaned from lidar and from new ground-based investigations appeared in the December 2015 *Antiquity*.

Lidar has been around since the early 1960s. Scientists have used it to measure pollutants in the atmosphere, map shorelines and guide robotic and manned vehicles around obstacles. Lower costs over the last decade have made the technology accessible to archaeologists.

With their laser eye in the sky, Evans and colleagues uncovered big surprises at Angkor Wat. Just

beyond one side of the roughly 1.3-kilometersquare moat surrounding the temple, the researchers found six massive and mysterious lines of earth arranged in precise coils — as well as adjacent areas where later canal construction had apparently destroyed

Scientists are retelling the story of Angkor Wat, a medieval temple built in the 12th century by a powerful Khmer ruler. two more coiled mounds. These Khmer creations resemble the spiraling paths of labyrinths. Lidar-guided excavations within the moat's boundary upended ideas about who lived on temple grounds. Rather than religious or political bigwigs, residents were workers who kept the place running. And on-the-ground research found evidence of unexplained towers, built and then demolished during Angkor Wat's construction, as well as defensive platforms used, perhaps, to fight off invaders.

"It's an embarrassingly exciting time for archaeologists who study Angkor Wat," says University of Sydney archaeologist Roland Fletcher. "Researchers have driven and walked over many of these new discoveries for a century." Fletcher directs the Greater Angkor Project, which combines remote sensing technology with archaeological digs.

If Angkor Wat blended into Greater Angkor's 1,000 square kilometers of urban sprawl, so did hundreds of other temples and shrines of lesser grandeur built by rulers of Southeast Asia's Khmer Empire from the ninth to 15th centuries, he says.

"There was nothing like Greater Angkor until the advent of 19th century industrial cities," says Fletcher, who estimates it held about 750,000 residents in the 12th and 13th centuries. Cities of around 1 million people arose in China by the ninth century, but those metropolises covered one-half or less the area of Greater Angkor. Spread-out cities in the mold of Greater Angkor became more common in the 1800s as trains and cars made long-distance travel easier. But discoveries at Greater Angkor shatter

a long-standing assumption that urban sprawl was impossible without mechanical forms of transportation, he says.

Big grids

Carved inscriptions at Angkor Wat describe the structure as the pet project of Suryavarman II, who ruled the Khmer Empire from 1113 until his death in 1149. Serving first as a temple dedicated to the Hindu god Vishnu, Angkor Wat also became a mausoleum for Suryavarman II when he died.

The temple hosted Hindu ceremonies into the 13th century. In the 14th or 15th century, it became a Buddhist temple. Like tourists and scientists, Angkor Wat's modern-day Buddhist monks had no idea that the site was once so extensive.

Lidar revealed a grid of pathways forming four rectangular blocks, each the size of a small town, that encircle the main temple inside the moat. Forest and vegetation surround Angkor Wat (top). A lidar map (bottom) stripped away ground cover to reveal previously unknown archaeological features of the temple and its surroundings.

2.4 km

Earthen mounds and an estimated 250 to 300 ponds – now dried-out depressions on the forest floor – dotted these grid-ded areas.

Excavations in 2010 and 2013, the latter guided by lidar findings, uncovered remains of modest wooden dwellings and household goods, such as pots and a ceramic cooking device, in the mounds. Archaeologist Miriam Stark of the University of Hawaii at Manoa in Honolulu led that work.

Radiocarbon dating conducted by Stark's team indicates that houses situated around the ponds appeared at least as



Urban living A map of Greater Angkor, based on radar and other conventional imaging techniques, shows the spread of this massive medieval city in Cambodia (inset, yellow). Reservoirs, shown as blue rectangles, were situated to the east and west of Angkor Wat and nearby temple Angkor Thom. Laser mapping of the area is expanding Greater Angkor's reach even farther.

FEATURE | CAMBODIA'S HIDDEN CITY



Lidar imagery (far left) revealed massive coiled patterns just south of Angkor Wat's moat. A preliminary map (near left) based on laser data shows coils separated by a long dike, in blue, that once connected to a nearby reservoir. Now-empty ponds sat among the coils.

early as the sixth century near the eventual site of Angkor Wat. Other residences date to after the 15th century, supporting evidence — including a 17th century Japanese map of the Angkor Wat temple — of the structure becoming a Buddhist religious center.

No more than 4,500 people lived within Angkor Wat's moated boundary in the 12th century, Fletcher estimates. His calculation is based on the account of a 13th century Chinese emissary to Greater Angkor, who wrote that one to three families shared each pond in the area around the temple.

Stone inscriptions at nearby Ta Prohm, a late–12th century Greater Angkor temple, record a workforce of 12,640 people that included only about 2,000 on-site residents. Another 66,625 people were described as being "in service" to the temple, delivering food and other supplies.

At roughly twice the size of Ta Prohm, Angkor Wat probably relied on a workforce of about 25,000, Fletcher suspects. An additional 125,000 people must have shuttled in supplies. Each Greater Angkor temple apparently supported a vast economy.

If that's true, it makes sense that crisscrossing roads forming residential blocks fan out far beyond Angkor Wat's moat on the 2012 lidar map. "Urban grids stretched beyond temple walls into the hinterlands," Evans says.

Lidar data showed a comparable street network at a nearby 12th century temple, Angkor Thom. Here too, "to our complete surprise, the layout of houses and streets continues beyond

the moated confines of the temple," says archaeologist Charles Higham of the University of Otago in New Zealand. He studies Greater Angkor and is familiar with the lidar results.

Religious and political big shots lived somewhere in the urban sprawl outside Angkor Wat and other temples, Fletcher suspects. Why they did so is unclear.

Mystery coils

Finding that Angkor Wat extended far beyond its moat was unexpected. But a discovery just south of the temple's moat was unprecedented.

Lidar unveiled long banks of earth that formed six wellpreserved coiled or spiral-shaped patterns. Each formation is roughly 1 kilometer long and 0.5 kilometers wide, or about 10 times the length and width of a football field. The precise alignment of these earthworks with the moat suggests they were assembled around the time of Angkor Wat's construction.

A ground survey in late 2012 and early 2013 determined that the coils consisted of 18-meter-wide sandbanks separated by 12-meter-wide channels. After using laser maps to locate the spirals on the ground, investigators walked through the channels searching for signs of human activity. They found no pottery or other artifacts to suggest that anyone had lived or worked there.

"Nothing like the shape and design of these spirals has been seen anywhere else," Fletcher says.

Suryavarman II's reasons for building the coils are

unknown. These mounds might have served as raised fields for growing herbs used in temple rituals. Or the coils might have been sites of formal gardens that would have been unrivaled in size and complexity until the construction of 18th century palace gardens in Europe, Evans suggests.

Rainwater could have flowed through channels between the coils. Evans doubts, however, that enough water collected to support farming.

It's also possible that Angkor Wat's spiral structures held special spiritual meaning for Khmer people and had no practical use. Yet Fletcher says that nothing resembling these coiled forms appears in Hindu writings and art.

After what must have been several decades of construction coinciding with work on the temple, "the spirals may never have been completed and might never have become operational," Evans says.

Researchers are now examining fossilized pollen recovered from the coils for signs of cultivation or gardening.

Buried towers

Another surprising discovery at Angkor Wat comes not from lidar but from ground-penetrating radar. While lidar reveals characteristics of the ground's surface covered by vegetation, ground-penetrating radar can detect objects buried deep under several dozen meters or more of soil.



Angkor Wat statues depict Hindu gods and goddesses and tell stories from Hindu scriptures.

In December 2009, a team led by archaeologist Till Sonnemann of Leiden University in the Netherlands dragged a wheeled device reminiscent of a lawn mower over Angkor Wat's vast outer section for two weeks. High-frequency radio waves emitted by the contraption bounced off buried objects, signaling locations of possible archaeological remains.

Sonnemann was looking for remnants of houses or administrative buildings from the 12th century or later. Something far more intriguing turned up.

At Angkor Wat's western entrance, where visitors enter the grounds of the temple, the radar machine identified what looked like the foundations of eight towers. Excavations in

2010 and 2012 confirmed their existence. Foundation remains lie roughly 21 meters belowground, about 10 times as deep as an Olympic swimming pool.

Each cross-shaped foundation, held in place by walls made of a reddish rock called laterite, had a square central section bound by porches jutting out on each side. Intact shrine towers from other Khmer Empire sites, which were dedicated to various gods, feature side porches.

Angkor Wat's former towers were intentionally destroyed, Sonnemann says. Radiocarbon dating of burned wood from the foundations suggests the towers were built around the time that work started on Angkor Wat. Demolition occurred when Angkor Wat's outer wall and western gate were completed, Sonnemann suspects.

Perhaps 12th century residents of Greater Angkor used the gateway towers as a temporary religious shrine to the Hindu god Vishnu while erecting Suryavarman II's temple, which was dedicated to the same deity, Sonnemann says. Of the eight towers, four formed a square that stood within a larger square formed by the four others. Angkor Wat itself features four towers arranged in a square around a central tower.

The gateway towers may have served as an outline of Angkor Wat's permanent towers, Sonnemann speculates. But they



Holes (circled) in the inside of Angkor Wat's largest enclosure wall may have held supports for wooden platforms where defenders could stand to fight off foreign attackers.



A digital reconstruction from radar imaging shows the position of towers (lower left, bright yellow) that were built and intentionally destroyed during construction of the temple (upper right).

were not identical. Remote sensing identified no remnants of a central tower at the western entrance.

Wall defenses

Tourists and researchers have long gazed at Angkor Wat's impressive stone outer wall without realizing it holds clues to warfare between the Khmer Empire and regional foes, says archaeologist David Brotherson of the University of Sydney.

Archaeologist Christophe Pottier of the Bangkok Center in Thailand first noticed holes that had been intentionally carved in parts of the wall constructed later. When Brotherson took a closer look, he speculated that those openings once supported wooden platforms and fences.

Angkor Wat's defenders stood on the platforms and positioned themselves between the fences to repel attacks by nearby Thai kingdoms, Brotherson proposes. Those confrontations probably took place sometime between the late 13th and early 17th centuries.

Brotherson studied 6,257 wall cavities. Most consist of groups of seven square holes, at the same height, running across the inside of the wall near its top. Sets of holes, notches and grooves also run across adjacent areas on top of the wall.

These alterations appear at spots where six nearly 20-meterwide gaps in the wall — which probably framed wooden gates — were later filled in with stone blocks. Differences in detailing and finish distinguish original masonry from filledin sections.

Holes on the inner part of the wall held wooden beams that supported platforms about 3.5 to 4 meters above the ground that must have had stairs at each end, Brotherson says. Angkor Wat's fighters would have stood on platforms while raining down arrows or other weapons on attackers. Wall-top holes probably held fence posts for additional protection, he suspects. Yet researchers have found no arrowheads or other

FEATURE | CAMBODIA'S HIDDEN CITY

Like the Angkor Wat studies, lidar investigations at the ancient Maya site of Caracol in Belize (far right) revealed unknowns. Farming terraces (wavy lines in digital reconstruction, left) and other land modifications appeared around former settlements.

weapons and no evidence of military damage to Angkor Wat, such as wall marks from catapulted boulders or remnants of torched wooden buildings.

Still, it's more likely that the wall's inside holes held platforms for temple defenders to stand on than wooden roofs that sheltered people or animals underneath, Brotherson says. Gateway spaces would not have been filled in simply to construct shelter roofs, he contends. And roofs would not have required holes carved on top of the wall.

"There are no historical references to defensive fortifications at Angkor Wat," Fletcher says. "Sometimes archaeology tells us things that history cannot."

Tropical trajectories

Lidar's bird's-eye view of forest floors has guided archaeologists not only to lost parts of Angkor Wat, but to a greater appreciation of similarities between Greater Angkor and other ancient tropical cities.

Lidar surveys of west-central Belize in 2009 and 2013 showed that the ancient Maya city of Caracol sprawled across now-forested landscape much as Greater Angkor did. A dense urban area, incorporating agricultural fields into a planned city, spread 10 kilometers in all directions from central Caracol in 650. Researchers estimate that more than 140,000 people lived at Caracol (*SN: 12/15/12, p. 14*).

Laser maps revealed farming terraces, housing tracts and roads leading to public plazas that ranged far beyond Caracol's urban center. Anthropologists Arlen and Diane Chase of the University of Central Florida in Orlando directed lidar research at Caracol.

At 1,000 square kilometers, Greater Angkor covered a much larger area than Caracol. "Lidar surveying has just begun, but we now know that Maya cities were shrimps compared with mighty Angkor," says Yale University anthropologist Michael Coe, a long-time investigator of the Maya and other ancient American civilizations.

Nothing like Angkor's street grids stretching with geometric precision toward the horizon appears at Caracol, adds Coe, who is familiar with work at both sites.

Still, common factors inspired the rise and fall of Greater Angkor, Maya urban centers such as Caracol and the tropical city of Anuradhapura in Sri Lanka between the ninth and



16th centuries, Fletcher and two colleagues concluded in the October 2015 *Antiquity*.

Rulers in each region directed the construction of reservoirs and canals that allowed spread-out cities to flourish. Effective water management cemented the power of kings by enabling masses of farmers to make a steady living.

Severe periods of drought, indicated by analyses of tree rings and lake sediments, strained water supplies in each tropical setting, Fletcher says. Periodic monsoon rains in Southeast Asia and Sri Lanka added insult to injury, overwhelming reservoirs and damaging canals.

Unable to supply enough water, political systems at Greater Angkor and other tropical cities crumbled, Fletcher argues. But societies didn't vanish. Farmers reorganized into smaller communities based near coasts and along major rivers. Cultivation continued in fields that had once been part of massive cities.

Laser quest

Fletcher's rise-and-disperse scenario for ancient tropical cities is being put to a broader test. From March to May 2015, a second set of lidar flights expanded laser mapping of northern Cambodia to a total area of 2,000 square kilometers. Researchers want to see if, like Angkor Wat, other ancient temples in the region sat in the center of dispersed settlements tied together by reservoirs, canals and ponds. Archaeological investigations based on the new lidar data are under way. Evans plans to announce initial findings in June.

Over the next 10 to 15 years, lidar technology will become smaller and cheaper, Evans predicts. Laser-wielding drones will replace lidar-toting helicopters. But laser mapping is already a game changer for tropical archaeology.

Around Angkor, "the impact of lidar data is like turning on a light after groping in the dark for over a century," says archaeologist John Miksic of the National University of Singapore.

Suryavarman II, a politically ambitious warrior who tried to expand his kingdom by launching wars and allying himself with Imperial China, would surely celebrate Angkor Wat's laser revival if he was around today. It's a revival of sorts for the once-mighty king, as well.

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EXHIBIT High fashion goes high-tech

You wouldn't expect wardrobe classics like leather jackets or denim jeans at an exhibit celebrating fashion at its most forward. But "#techstyle" at the Museum of Fine Arts in Boston features those sartorial mainstays and others, each with a technological twist.

A feast for the eyes, the diversity of pieces is matched by the diversity of artists and approaches. Yet a single theme unites: The fusion of technology and fashion will increasingly influence both. Visitors are introduced to this theme via a room featuring works by prominent designers already known for merging fashion and tech: A digitally printed silk dress by Alexander McQueen hangs next to a fiberglass "airplane dress" by Hussein Chalayan that has flaps that open and shut via remote control.



The largest part of the exhibit focuses on how technology is changing design and construction strategies. In addition to clothes made with mainstream techniques like laser-cutting, several 3-D printed garments are on display. These include a kinematic dress made of more than 1,600 interlocking pieces

that can be customized to a wearer's body via a 3-D scan. The dress comes off the printer fully assembled. Other pieces are made with technologies still being developed, such as the laser-welded fabrics from sustainable textile researcher Kate Goldsworthy.

The real standouts are in the "Performance" section, which displays attire that uses data from the immediate environment to generate some visible aspect of the garment. These interactive pieces "reveal something to the eye that you wouldn't see normally, something that science often captures with graphs and charts," says Pamela Parmal, a curator of the exhibit. For instance, the interactive dress "Incertitudes" is adorned with pins that flex in response to nearby voices, creating waves in the fabric; a dress embedded with thousands of tiny LEDs can display tweeted messages or other illuminated patterns.

And there are two leather jackets that, at first glance, look like their innovation is merely a stylish cut. But the jackets are coated in reactive inks that shimmer with iridescent colors in response to the wind and heat generated by heat guns in the display case. (These creations were born after designer and trained chemist Lauren Bowker used the reactive compounds to reveal the aerodynamics of race cars in a wind tunnel in a project for Formula One.)

Visitors seeking in-depth explanations of the science behind the fashions will have to look elsewhere. But "#techstyle" still has something for everyone, whether fashionista or engineer. And while the fashions represented are all cutting edge, the show harks back to an era when clothes were custom-made. Technology might have brought us mass-produced cookie-cutter clothing, but it can also enable clothing tailored to the individual. – *Rachel Ehrenberg*

BOOKSHELF



Candid Creatures Roland Kays Filled with what look like animal selfies, this book highlights the benefits of camera

traps. Johns Hopkins Univ., \$39.95



Patterns in Nature Philip Ball This coffee-table book showcases the spots, stripes, spirals, fractals and other intricate

patterns found in the natural world. *Univ. of Chicago*, \$35



Group Theory in a Nutshell for Physicists A. Zee A compendium of the in-depth details of group

theory, this book covers the essential math for advanced work in many realms of physics, from subatomic particles to cosmology. *Princeton Univ.*, *\$90*

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SOCIETY UPDATE

Science is universal at Broadcom MASTERS International



Broadcom MASTERS International brings together middle school students from across the world to share their love of science. Past delegates built school servers, created games, and studied brain activity. The 2016 Broadcom MASTERS International program takes place during the Intel International Science & Engineering Fair (Intel ISEF), May 8-13 in Phoenix.

The Broadcom MASTERS International program is so much more than an "international science camp," says Raghav Ganesh, an international delegate from the United States, and a Broadcom MASTERS 2014 finalist and 2015 semifinalist. "Science is universal and this is a terrific program that brings middle school students from across so many countries together to exchange ideas, cultures and interests with the backdrop of science. I am grateful to have been part of this fantastic program."

The international delegates have the chance to go on various field trips and attend Intel ISEF during the program. "I used the opportunity to talk to many budding scientists about their projects, learn about their research and become introduced to new fields in science," Raghav says.

Broadcom MASTERS International is the best youth science program you'll ever attend, says Phoebe Chew Tingyu, a 2015 delegate from Singapore. "You get to make wonderful friends who share similar interests, and see science and technology from all over the world – and it's amazing. It really motivated me to improve my project further so I can help make the world a better place to live in."

Above: Broadcom MASTERS International 2015 delegates at the Phipps Conservatory in Pittsburgh. Below: Raghav Ganesh won a Broadcom MASTERS 2014 Rising Stars Award for creating an interactive add-on for canes for the visually impaired.

ISING STARS



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FEEDBACK



MARCH 19, 2016

Folsom arachnid

Researchers discovered a new species of tarantula that lives near the grounds of Folsom State Prison in California, **Helen Thompson** reported (*SN*: 3/5/16, *p*. 5). Clad entirely in black, the fearsome-looking but relatively harmless creature was named after the iconic man in black himself — Johnny Cash. That inspired some online readers to arachnify some of Cash's lyrics:

> "I bit a man in Reno, just to watch him die." **Asher**

"I walk the web." John Fleischman

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Gaga for gravity waves

With a single chirp, scientists confirmed the existence of gravitational waves created by the collision of two black holes. Science News' special report (SN: 3/5/16) and subsequent stories in the March 19 issue sparked a flurry of reader questions on the physics of gravitational waves. Reader Peter Toot wondered if gravitational waves' ability to bend spacetime stretches light waves. "It seems to me that the expansion and contraction effects of the waves on the [LIGO] detector and surroundings would also apply equally to the wavelength of the light beams used by the detector," Toot wrote. "If so, it then seems like the impact on phase difference between the recombinant beams would net out to zero phase shift. That clearly didn't happen. Why not?"

It's true that gravitational waves affect both the LIGO observatory and the laser light. However, the interferometer contains two perpendicular arms, says **Tom Siegfried.** While one arm is shortened by the wave, the other is lengthened. Since the speed of light remains the same in both arms, the change in arm lengths means the two laser beams will not arrive at the same time. Because of this setup, the change in the light's wavelength is irrelevant.

In his article on the power generated by the black holes' collision (*SN: 3/19/16, p. 5*), **Christopher Crockett** reported that three suns' worth of mass transformed into gravitational wave energy as the black holes merged. "Was this mass converted to energy or was it momentum (already energy) transferred into a radiating spacetime wave?" asked **Ron Blachman**. "In any event, the mind reels.... Entropy'll get us all."

It appears that the mass was turned directly into energy, **Crockett** says. LIGO researchers estimated the black holes' masses before and after the collision. "The energy that came out is roughly what you would expect from that much mass transforming into wave energy," he said. "The mind does, indeed, reel."

Fascinating fat

Researchers worldwide are attempting to use stem cells from discarded fat to repair body parts damaged by injury, disease and age, **Susan Gaidos** reported in "Fat as a fixer" (SN: 3/19/16, p. 22). Clinical studies are currently under way to test these stem cells as potential treatments for chronic obstructive pulmonary disease, type 1 diabetes and other conditions. In the case of COPD, **Harry Walker** wondered how stem cells know to target lungs and what potential side effects might be.

When stem cells are injected back into the body through a vein, they go directly to the heart and then travel to the lungs. "Results from studies have shown that once stem cells are directed into the lungs, the cells become 'trapped,'" **Gaidos** says. "This sounds scary, but the presence of stem cells in the lungs has been shown to have an anti-inflammatory effect and can help regenerate damaged lung tissue."

Editor's note

Thomas Sumner's feature "Mystery at the center of the Earth," (*SN: 9/19/15, p. 18*) explored the scientific debate over the mechanisms that power Earth's magnetic field. Over the last few years, multiple research teams reported that iron conductivity in the planet's interior is much higher than once thought, creating a paradox concerning the strength of the early Earth's magnetic field.

On April 13, 2016, researchers retracted a study in *Nature* featured in the article. Computer simulations by Peng Zhang and colleagues suggested that the electrons responsible for ferrying heat crash into one another and reduce the iron's conductivity. After other scientists failed to reproduce these results, the team discovered that the initial simulations contained an error.

Revised calculations suggest that electron-electron scattering is not significant to the resistivity of iron in the Earth's core. This revision supports the high iron conductivities proposed by other groups. The paradox remains.

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Death by bubble By imaging a maidenhair fern leaflet (1) at 30-second intervals, researchers could subtract the difference between the images (2) to see where an embolism formed. Images were colorized (3) by how much time had elapsed and combined (4) to give a complete picture (below) of the leaf's response to water stress.





When plumbing breaks down in plants

A decent office scanner has beaten X-ray blasts from multimillion-dollar synchrotron setups in revealing how air bubbles kill plant leaves during drought.

Intricate fans and meshes of plant veins carrying water are "among the most important networks in biology," says Timothy Brodribb of the University of Tasmania in Hobart, Australia. When drought weakens the water tension in veins, air from plant tissues bubbles in, killing leaves much as bubble embolisms and clots in blood vessels can kill human tissue. As climate change and population growth increase risks of water shortage, Brodribb and other researchers are delving into the details of what makes some plants more resistant than others to drought.

The high energy of X-rays destroys delicate leaf tissue. So, based on a chat with microfluidics specialist Philippe Marmottant of the French National Center for Scientific Research, Brodribb tried repeatedly scanning a leaf with a light source below it to reveal darkening lines as air bubbles shot through the veins. A microscope or scanner proved perfect. Tracked this way, an invasion of killer bubbles "looks like a lightning storm," he says.

He was surprised to see that bigger veins, despite their robust looks, fail before tiny ones (blue indicates earliest failures; red, the latest), as seen in an oak leaf (upper right) and *Pteris* fern (center). And networks in ferns with simpler branching patterns, as in the *Adiantum* ferns at bottom left and right, crash quickly.

This system of visualizing plant plumbing gave better resolution than expensive and elaborate X-ray techniques had, Brodribb, Marmottant and Diane Bienaimé report online April 11 in the *Proceedings of the National Academy* of Sciences. — Susan Milius You weigh slightly less with the moon overhead.

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