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ScienceNews

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Portal to New Physics

A decade after its discovery, the Higgs boson may point beyond the standard model

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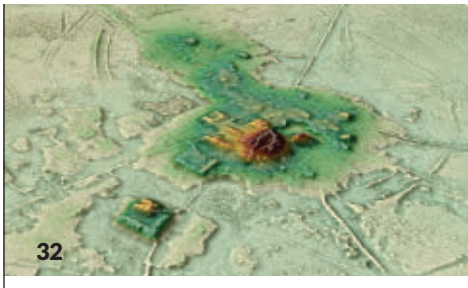

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Departments

COVER Physicists have spent the last decade probing the Higgs boson, in hopes of finding unexpected properties or behavior. *Nicolle R. Fuller/SayoStudio*

FROM TOP: CLAUDIA TOTIR/MOMENT/GETTY IMAGES PLUS; H. PRÜMERS/GERMAN ARCHAEOLOGICAL INSTITUTE; ROBERT MAY

The Higgs boson discovery was just the beginning

Emily Conover spent one of the most consequential moments in recent physics history in a cavern near a nuclear power plant in France.

At the time, Conover was a Ph.D. student in particle physics (she's now physics senior writer for *Science News*). She was part of a team building a detector in the cavern to observe elusive particles called neutrinos. It was the Fourth of July 2012. A few hundred kilometers away, scientists were announcing the discovery of another elusive subatomic particle, the Higgs boson, which physicists had been hunting for decades. As hundreds of researchers cheered in the main auditorium at the CERN particle physics lab near Geneva, Conover and the small group of physicists in the chilly French cavern cheered too, as did scientists worldwide. The Higgs boson filled in a missing piece in the standard model of particle physics, which explains just about everything known about the particles that make up atoms and transmit the forces of nature. No Higgs boson, no life as we know it.

In this issue's cover story, "The Higgs boson at 10," Conover looks back at the excitement around the discovery of the Higgs boson and looks ahead to the many things that researchers hope to find out with its help (Page 18). She also reviews a new biography of Peter Higgs, a modest man who made clear that he was just one of many scientists who contributed to the breakthrough (Page 29).

The discovery is part of *Science News* history too. Journalists around the world were eagerly awaiting the big announcement, which was being kept under wraps. But when Kate Travis, a *Science News* editor at the time, uncovered an announcement video accidentally posted early on CERN's website, we published the big news the day before the official announcement.

"Even though its discovery is 10 years old now, that's still new in the grand scheme of particle physics, so we're still learning lots about it," Conover told me. "It's very cool that I get the opportunity to write about this particle that is still so new to science." And it's very cool that we get to explore it with her.

—*Nancy Shute, Editor in Chief*

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"The most important gemstone discovery in over 2,000 years."
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"This ring is incredibly beautiful — the pictures do not do it justice! ...well worth the price."
— K. M., Palm Coast, FL

African Gem Cutter Makes $2,689,000 Mistake... Will You?

This story breaks my heart every time. Allegedly, just two years after the discovery of tanzanite in 1967, a Maasai tribesman knocked on the door of a gem cutter's office in Nairobi. The Maasai had brought along an enormous chunk of tanzanite and he was looking to sell. His asking price? Fifty dollars. But the gem cutter was suspicious and assumed that a stone so large could only be glass. The cutter told the tribesman, no thanks, and sent him on his way. Huge mistake. It turns out that the gem was genuine and would have easily dwarfed the world's largest cut tanzanite at the time. Based on common pricing, that "chunk" could have been worth close to $3,000,000! The tanzanite gem cutter missed his chance to hit the jeweler's jackpot ... and make history. Would you have made the same mistake then? Will you make it today?

In the decades since its discovery, tanzanite has become one of the world's most coveted gemstones. Found in only one remote place on Earth (in Tanzania's Merelani Hills, in the shadow of Mount Kilimanjaro), the precious purple stone is 1,000 times rarer than diamonds. Luxury retailers have been quick to sound the alarm, warning that supplies of tanzanite will not last forever. And in this case, they're right. Once the last purple gem is pulled from the Earth, that's it. No more tanzanite. Most believe that we only have a twenty year supply left, which is why it's so amazing for us to offer this incredible price break. Some retailers along Fifth Avenue are more than happy to charge you outrageous prices for this rarity. Not Stauer. Staying true to our contrarian nature, we've decided to lower the price of one of the world's rarest and most popular gemstones.

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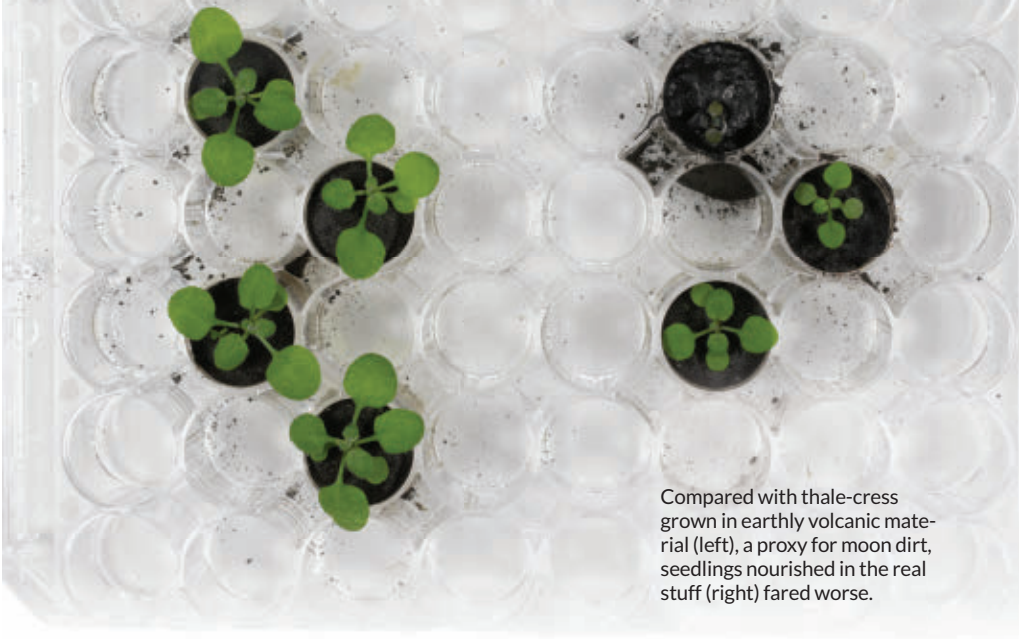
Excerpt from the July 1, 1972 issue of *Science News*

50 YEARS AGO

How the Earth got its core

In the beginning, scientists believe there was an interstellar gas cloud of all the elements comprising the Earth. A billion or so years later, the Earth was a globe of concentric spheres with a solid iron inner core, a liquid iron outer core and a liquid silicate mantle.... The current theory is that the primeval cloud's materials accreted ... and that sometime after accretion, the iron, melted by radioactive heating, sank toward the center of the globe.... Now another concept is gaining ground: that the Earth may have accreted ... with core formation and accretion occurring simultaneously.

UPDATE: Most scientists now agree that the core formed as materials that make up Earth collided and glommed together and that the process was driven by heat from the smashups. The planet's heart is primarily made of iron, nickel and some oxygen, but what other elements may dwell there and in what forms remains an open question. Recently, scientists proposed the inner core could be superionic, with liquid hydrogen flowing through an iron and silicon lattice (*SN: 3/12/22, p. 12*).



Compared with thale-cress grown in earthly volcanic material (left), a proxy for moon dirt, seedlings nourished in the real stuff (right) fared worse.

TYLER JONES, IFAS/UF

FUTUROLOGY

Sprouts grown in moon dirt bode well for lunar farms

That's one small stem for a plant, one giant leap for plant science.

In a tiny lab-grown garden, the first seeds ever sown in moon dirt have sprouted, researchers report May 12 in *Communications Biology*. This small crop, planted in samples returned by Apollo missions, offers hope that astronauts could someday grow food on the moon.

But plants potted in moon dirt grew more slowly and were scrawnier than others grown in similar material from Earth, which suggests that lunar farming would take a lot more than a green thumb.

The dirt, or regolith, that covers the moon is a gardener's worst nightmare. This fine powder is full of metallic iron that is unpalatable to plants, as well as tiny glass shards forged by space rocks pelting the moon (*SN: 10/10/20 & 10/24/20, p. 5*). What it is not full of is nitrogen, phosphorus or much else plants need to grow. Though scientists have coaxed plants to grow in fake moon dirt made of earthly materials, no one knew whether newborn plants could put down their delicate roots in the real stuff.

To find out, a trio of researchers at the University of Florida in Gainesville planted thale-cress (*Arabidopsis thaliana*) seeds in 12 pots that each held about a gram of lunar dirt. Another 16 pots contained earthly volcanic material used in past experiments to mimic moon dirt. All were grown under LED lights in the lab and watered with a broth of nutrients.

"Nothing really compared to when we first saw the seedlings as they were sprouting," says plant molecular biologist Anna-Lisa Paul. "That was a moving experience, to be able to say that we're watching the very first terrestrial organisms to grow in extraterrestrial materials, ever."

> "We're watching the very first terrestrial organisms to grow in extraterrestrial materials, ever."
>
> **ANNA-LISA PAUL**

Plants grew in all pots of lunar dirt, but none grew as well as those cultivated in earthly material. The healthiest moon-grown plants were just small, Paul says, while the sickliest plants were small and purplish—a sign of plant stress.

Paul and colleagues also inspected the genes in their miniature alien Eden. All plants grown in moon dirt pulled out genetic tools typically used by plants struggling with stress from salt, metals or reactive oxygen. The most severely stressed seedlings sprouted from moon dirt that spent the most time laid bare, offering more evidence that regolith exposed to the lunar surface longer—and thus littered with more glass and metallic iron—is more toxic to plants.

Future space explorers could pick the site for their lunar habitat accordingly. Perhaps moon dirt could be altered to make plants more comfortable, Paul says. Or plants could be genetically engineered to feel more at home in alien soil. —*Maria Temming*

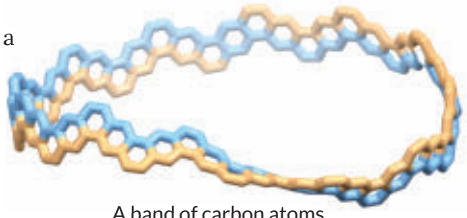
INTRODUCING

Scientists made a Möbius strip out of a tiny carbon nanobelt

From cylindrical nanotubes to the hollow spheres known as buckyballs, carbon is famous for forming tiny, complex nanostructures (SN: 9/14/19, p. 13). Now, scientists have added a new geometry to the list: a twisted strip called a Möbius carbon nanobelt.

Möbius strips are twisted bands that are famous for their weird properties. A rubber band, for example, has an inside and an outside. But if you cut the rubber band crosswise, twist one end half a rotation and glue it back together, you get a Möbius strip, which has only one continuous face.

In 2017, chemist Yasutomo Segawa of the Institute for Molecular Science in Okazaki Japan and colleagues created carbon nanobelts, thin loops of carbon that look like tiny slices of a carbon nanotube. That feat suggested it might be possible to create a nanobelt with a twist, a Möbius carbon nanobelt. To make the itsy-bitsy twisty carbon, described May 19 in *Nature Synthesis*, some of the same researchers stitched together individual smaller molecules using a series of 14 chemical reactions.



A band of carbon atoms (illustrated) twists to form a tiny Möbius strip. Colors highlight the twisting behavior of the band, with the yellow side flipping from top to bottom.

While carbon nanotubes can be used to make new types of computer chips and added to textiles to create fabric with unusual properties, scientists don't yet know of any practical applications for the twisty nanobelts (SN: 9/28/19, p. 7; SN: 3/16/19, p. 4). But, Segawa says, the work improves scientists' ability to make tiny carbon structures, especially complicated ones. —*Emily Conover*

FIRST

The fastest supercomputer ushers in a new era

The first exascale computer has officially arrived.

By performing more than a billion billion calculations per second, the world's fastest supercomputer has entered the realm of exascale computing. That's according to TOP500, a ranking of the world's speediest supercomputers announced on May 30. The new computer, called Frontier, marks the first time an exascale computer has been included on the biannual list.

Exascale computing is expected to allow for new advances in scientific fields that depend on vastly complex calculations. The exascale milestone "represents an unprecedented capability for researchers around the world to use the computer to ask their specific scientific questions," says Frontier project director Justin Whitt of Oak Ridge National Laboratory in Tennessee.

Oak Ridge's Frontier performed about 1.1 exaflops, or 1.1 quintillion operations per second. The previous record holder for speediest supercomputer, a Japanese machine called Fugaku, achieved roughly 0.4 exaflops. Tentative reports have suggested that some Chinese supercomputers have achieved exascale performance, but those computers have yet to appear on the TOP500.

Frontier will be ready for use by the end of 2022. With the computer's exascale capability, researchers aim to simulate star explosions, calculate the properties of subatomic particles, investigate new energy sources and more. —*Emily Conover*

RETHINK

Flying high to beat the heat may not be an option for some hummingbirds

For some hummingbirds trying to escape rising temperatures and other effects of climate change, moving to higher, cooler locales may be more difficult than anticipated (SN: 10/10/20 & 10/24/20, p. 5).

Anna's hummingbirds (*Calypte anna*) live no higher than about 2,600 meters above sea level. If the birds attempt to expand their range to include higher altitudes, they may struggle to fly well in the thinner air, researchers report May 26 in the *Journal of Experimental Biology*.

C. anna (shown below) has expanded its range in the past. Once found only in Southern California, the hummingbird now lives as far north as Vancouver, says ecologist Austin Spence of the University of California, Davis. That expansion is probably due in part to rising temperatures, he says.

Spence and colleagues collected 26 wild Anna's hummingbirds in California and took the birds to an aviary about 1,200 meters above sea level. There, the team measured the birds' metabolic rates—a proxy for energy use—when hovering. The researchers repeated the measurements at a field station 3,800 meters above sea level.

The birds' metabolic rates were an average of 37 percent lower at the field station than at the aviary, the team found. Hovering at high altitudes where the air is thin should take more energy, resulting in high metabolic rates. That the average rate at high altitudes was lower than at low altitudes suggests hovering performance suffered, Spence says. "Low oxygen and low air pressure may be holding them back as they try to move upslope."

Additional work is needed to see whether the birds might acclimate if given weeks or months at gradually higher altitudes. —*Rachel Crowell*

FROM TOP: Y. SEGAWA ET AL/*NATURE SYNTHESIS* 2022; JEROME GAW

A destroyed Russian tank sits in a field outside Kharkiv, Ukraine. Tanks can pack down the region's fertile, fluffy soil, and that compaction can cut crop yields.

DIMITAR DILKOFF/AFP VIA GETTY IMAGES

EARTH & ENVIRONMENT

How war could harm Ukraine's rich soil

Physical and chemical damage might hinder agriculture for years

BY REBECCA DZOMBAK

By now, wheat planted late last year waves in fields across Ukraine. Spring crops of sunflowers and barley are turning swaths of dark earth into a fuzz of bright green. But uncertainty looms over summer harvesting as Russia wages war in some of the most fertile regions in Ukraine.

Ukrainian farmers braved a war zone to carry out close to 80 percent of spring planting, covering roughly 14 million hectares. Still, Russia's invasion has raised fears that not only are this year's crop yields in jeopardy, but also that output could be diminished for years. At the root of this worry, in part, is how warfare impacts soil.

Ukraine is home to some of the world's most fertile soil, making it a top global producer of cereals, such as wheat and maize, as well as seed oils such as sunflower oil. The country's exports feed millions of people from Europe and Africa to China and Southeast Asia.

The Food and Agriculture Organization of the United Nations estimates that at least 20 percent of Ukraine's crops planted in winter will remain unharvested or went unplanted. And despite farmers' best efforts, many spring crops went unplanted. This summer's winter wheat harvest could be cut roughly in half and sunflower products by a third.

With warfare able to degrade and contaminate soil for years, crop yields — and the people who depend on them — could suffer long after a cease-fire.

"In many ways, the welfare of the soil system in postwar nations is really intricately tied to the welfare of the people," says soil scientist Asmeret Asefaw Berhe of the University of California, Merced. "And in many ways, it's going to dictate their long-term future too."

Super soil

A type of highly fertile grassland soil called chernozem covers nearly two-thirds of Ukraine's farmland. Meaning "black earth" in Russian and Ukrainian, the soil is distinguished by one to two meters of dark, rich organic matter. Over the last 10,000 years, it has accumulated in Ukraine and Russia, along the Eurasian steppes, slowly building up as a black bed atop fine, windblown sediments called loess, which coated the area as the glaciers retreated.

Chernozems are rich in elements that plants need to grow, including nitrogen, potassium and calcium. The nutrients come from organic matter and underlying loess. Chernozems also hit the sweet spot of clay content — just enough to help hold the soil together and cling onto nutrients but not so much that roots have a hard time penetrating the ground. "Plants growing in these soils are lucky," Berhe says. "They're growing in an environment that has everything they need … without additional fertilizers."

Bombing fields

There's a term for what war does to soil: bombturbation. It's grim wordplay on the natural process of bioturbation — earthworms and other animals stirring up soil. In this case, though, exploding bombs and artillery fire fling clods of dirt and dig craters. Soil geomorphologist Joseph Hupy of Purdue University in West Lafayette, Ind., coined the term with a colleague in 2006 while studying soils' battlefield scars.

At the French World War I battlefield of Verdun, Hupy dug meter-long trenches with a backhoe across bomb craters and their vicinity, looking for signs of disturbance. He wanted to understand how the landscape recovered, with or without human help. He found decades-old chaos beneath the surface. Cross sections revealed chunks of limestone bedrock embedded in a slurry of sandy soil and organics. That chaos was reflected on the surface too: Where there were craters, water flow had changed, leading to different patterns of vegetation growth, he and a colleague reported in *Geomorphology* in 2012. Because of shifts in hydrology and a lack of human management, the landscape reverted from agriculture to forest. "It's a completely new ecosystem," Hupy says.

He found similar changes at Vietnam's Khe Sanh, which the United States heavily bombed in 1968. Aerial images of battle zones in Ukraine are reminiscent of the pockmarked field sites Hupy studied in Vietnam. Problems in Ukraine may not be limited to the surface. Even if farmers smooth over the top of the soil, underground rubble can act like a barrier or sluice for water, making it harder to grow crops.

When there's a highly compacted area beneath where the teeth of a plow can go, that impermeable layer of soil "can create standing water conditions and all other sorts of problems from an agricultural standpoint," Hupy says.

Trouble with tanks

Bombs aren't the only thing that can physically disturb soil. Early in the war, Ukraine's soggy, thawing soils bogged down Russian tanks as if a metaphor of resistance: The land itself was fighting

back. But what's bad for invading tanks is also bad for the soil. When tanks roll over a field, their weight makes soil clump and stick together. Wet soil can compound the problem, further compacting the soil.

Compaction can temporarily cut crop yields by anywhere from 10 percent to nearly 60 percent because it makes it more difficult for plants to grow roots deep enough to reach nutrients and prevents water and fertilizers from penetrating the soil. Chernozems are particularly vulnerable to compaction: With their thick layer of organic matter, they are light and fluffy. But for all but the worst compaction, several seasons of typical planting can heal the land, says soil scientist DeAnn Presley of Kansas State University in Manhattan.

"If you had tank traffic go right through a crop field, the farmer is probably going to go out and just till up the field pretty well after the conflict is over. And you may never see that [compaction] again," Presley says. Compaction "will definitely look terrible and you'll have yield losses, but I don't think they'll be forever or permanent."

A 2010 study of military vehicles rolling over prairie soils outside Fort Riley, Kan., revealed it took as little as one year for dry soil to recover from compaction, but up to four years for wet soil, both without tilling. Other work has shown that tank traffic can alter the community of soil microbes and reduce the abundance of other organisms, such as earthworms, for several years.

Fluffiness might put chernozems at greater risk of compaction, but it can also help the soils spring back afterward. Hardy, deep-rooting plants like some of Ukraine's native grasses could also loosen stubborn soils, Presley says, but that would take years.

Chemical contamination

Countering compaction can be a relatively quick fix — not so with chemical contamination. Fuel spills, spent ammunition, chemical weapons, and animal and human remains can all foul soil, sometimes for decades or longer.

Potentially toxic metals such as lead, arsenic and mercury can leach out of ammunition and weaponry and into the soil. Pollutants are still found in soils contaminated by wars as old as World War I, researchers reported in *Sustainability* in 2020. At Ypres, a World War I battlefield in Belgium, scientists estimate that shells and artillery left more than 2,800 metric tons of copper in the top half-meter of soil. In Iran, soils remain laced with mercury and chlorine from the 1980s.

As crops grow, they can draw up these potentially toxic elements. Other elements, such as zinc and nickel, can severely stunt crop growth, says Ganga Hettiarachchi, a soil chemist also at Kansas State University. But soil contamination can be a hidden danger. If the elements don't damage the plants, there may be no way of knowing if the soil is contaminated without careful testing, she says.

In some ways, chernozems are well-equipped to stop contaminants in their tracks. The soil's organic matter and clay can trap toxic elements before they can enter a plant, sucking out contaminants. In optimal lab conditions, this can happen in a matter of days, Hettiarachchi says. But in real life, many chernozems are slightly acidic, which means some elements may stay in a form that plants can take up for months before being stopped.

Because of this uncertainty, every potentially contaminated patch of soil must be checked to see if crops can be safely grown. "We have to monitor the soil and the crops as well, at least until we understand what's going on," Hettiarachchi says.

SOIL MUSEUM/SOIL EDUCATION CENTER/UNIV. OF AGRICULTURE IN KRAKÓW, COURTESY OF PIOTR PACANOWSKI

Chernozem is a type of nutrient-rich dark soil that is essential for agriculture in Ukraine.

In some cases, farmers could remediate their fields by growing plants known to extract certain elements over time, Hettiarachchi says, but that would require several years of planting. Other options include altering soil pH to lock away metals or adding extra fertilizer, which can also immobilize potentially toxic elements. But even after remediation, farmers must test to see if soil conditions are keeping the contaminants locked away.

Depending on the extent of contamination, "it might not be possible for Ukrainian farmers to avoid growing in contaminated soils," Hettiarachchi says. Soil testing and time will tell.

Looking toward the future

With Russia's bombardment of Ukraine still ongoing, the effect on soil is still uncertain. There are some hints, though. This isn't the first time the Donbas region — a disputed area in eastern Ukraine — has come under fire. Russian-backed separatists attacked it beginning in 2014 too.

Scientists working in the Donbas to improve soil health have faced a litany of challenges. Even before 2014, the region's agriculture suffered from degradation, as a result of coal mines polluting irrigation water, researchers reported in 2020 in *Mineralogical Journal*. Decades of intense farming had also taken a toll. Since 2014, conflict has exacerbated those issues, creating new problems and hampering scientists' ability to help.

The region's "chernozems have suffered and are experiencing irreparable military degradation," two Ukrainian soil scientists and a lawyer wrote in 2021 in *Scientific Papers Series A. Agronomy*. "It is easy to predict [the degradation of chernozems], but very difficult to overcome."

Though fighting has been concentrated in the east, this assessment may apply to a far broader swath of the country. "Our unique soils, chernozems, are in unprecedented conditions," representatives from Ukraine's Institute for Soil Science and Agrochemistry Research wrote in an e-mail to *Science News*. "The extent of the damage has yet to be ascertained. In fact, we have just begun to work in this direction … in difficult military conditions." ■

EARTH & ENVIRONMENT

Penguin bones reveal Antarctic ice loss

Key glaciers are shrinking faster now than in the last 5,500 years

BY DOUGLAS FOX

Antarctica's Pine Island and Thwaites glaciers are losing ice more quickly than they have at any time in the last few thousand years, ancient penguin bones and limpet shells suggest.

Scientists worry that the glaciers, two of Antarctica's fastest-shrinking ones, are in the process of unstable, runaway retreat. By reconstructing the history of the glaciers using the old bones and shells, researchers wanted to find out whether these glaciers have ever been smaller than they are today.

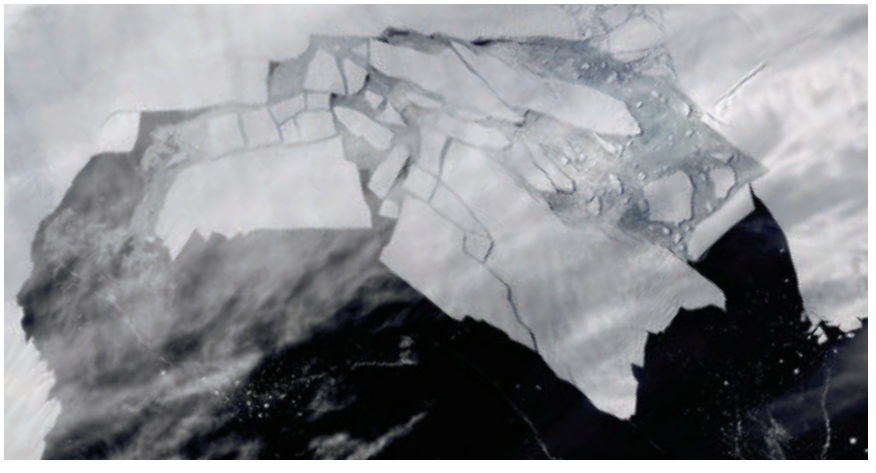
"If the ice has been smaller in the past, and did readvance, that shows that we're not necessarily in runaway retreat," says glacial geologist Brenda Hall of the University of Maine in Orono. The new result, described June 9 in *Nature Geoscience*, "doesn't give us any comfort," Hall says. "We can't refute the hypothesis of a runaway retreat."

Pine Island and Thwaites glaciers sit in a broad ocean basin shaped like a bowl, deepening toward the middle. This makes the ice vulnerable to melting from warm currents of dense, salty water that hug the ocean floor (SN: 5/8/21 & 5/22/21, *p.* 14). Scientists have speculated that as the glaciers retreat farther inland, they could tip into an irreversible collapse (SN: 1/29/22, *p.* 12). That collapse could play out over centuries and raise global sea level by roughly a meter.

To reconstruct how the glaciers have changed over thousands of years, the researchers turned to old penguin bones and shells, collected by Scott Braddock, a glacial geologist in Hall's lab, during a research cruise in 2019 on the U.S. icebreaker *Nathaniel B. Palmer*.

One afternoon, Braddock clambered from a bobbing inflatable boat onto the barren shores of Lindsey 1—one of a dozen or more rocky islands that sit roughly 100 kilometers from where Pine Island Glacier terminates in the ocean. As he climbed the slope, his boots slipped over rocks covered in penguin guano and dotted with dingy white feathers. Then, he came upon a series of ridges—rocks and pebbles that were piled up by waves during storms thousands of years before—that marked ancient shorelines.

Twelve thousand years ago, just as the last ice age was ending, this island would have been entirely submerged in the ocean. But as nearby glaciers shed billions of metric tons of ice, the removal of that weight allowed Earth's crust to spring up like a bed mattress—pushing Lindsey 1 and other nearby islands out of the water, a few millimeters per year.



Antarctica's Pine Island Glacier, shown shedding ice into Pine Island Bay in this 2020 satellite image, is losing ice more quickly today than at any other time in the last few thousand years.

NASA EARTH OBSERVATORY, USGS

As Lindsey 1 rose, a series of shoreline ridges formed on the edge of the island—and then were lifted, one after another, out of reach of the waves. By measuring the ages and heights of those stranded shorelines, the researchers could tell how quickly the island had risen. Because the rate of uplift is determined by the amount of ice being lost from nearby glaciers, this would reveal how quickly Pine Island and Thwaites glaciers had retreated—and whether they had gotten smaller than they are today and then readvanced.

Braddock dug into the pebbly ridges, collecting ancient cone-shaped limpet shells and marble-sized fragments of penguin bones deposited when the shorelines formed. Back in Maine, he and colleagues radiocarbon-dated those objects to estimate the ages of the shorelines. Ultimately, the team dated nearly two dozen shorelines spread across several islands.

These dates showed that the oldest and highest beach formed 5,500 years ago. Since that time, up until the last few decades, the islands have risen at a steady rate of about 3.5 millimeters per year. This is far slower than the roughly 15 to 40 millimeters per year that the land around Pine Island and Thwaites is currently rising, suggesting that the rate of ice loss from nearby glaciers has skyrocketed due to the onset of rapid human-caused global warming.

"We're going into unknown territory," Braddock says. "We don't have an analog to compare what's going on today with what happened in the past."

Slawek Tulaczyk, a glaciologist at the University of California, Santa Cruz, sees the newly dated shorelines as "an important piece of information." But he cautions against overinterpreting the results. While these islands are 100 kilometers from Pine Island and Thwaites, they are less than 50 kilometers from several smaller glaciers—and changes in these closer glaciers might have obscured whatever was happening at Pine Island and Thwaites long ago. He suspects that Pine Island and Thwaites could still have retreated and then readvanced a few dozen kilometers: "I don't think this study settles it." ■

HUMANS & SOCIETY

Health workers may reduce crime

A Colorado program lowered minor offenses, study suggests

In June 2020, Denver launched a pilot program that sends trained health professionals (shown) rather than police officers to respond to 911 calls for help involving nonviolent behavior.

DENVER POLICE DEPARTMENT

BY SUJATA GUPTA

For the last two years, people acting erratically in downtown Denver have probably first encountered unarmed health care workers rather than police officers. That shift stems from the rollout of a program known as Support Team Assisted Response, or STAR, which sends a mental health clinician and paramedic to respond to certain 911 calls about nonviolent behavior.

The program, and others like it, aim to defuse the tensions that can arise when police officers confront civilians in distress. Critics of these experimental programs have suggested that such reduced police involvement could allow crime to flourish. Now, researchers have found that during STAR's pilot phase, the program did not appear to lead to more violent crime. And reports of minor crimes substantially decreased, the researchers conclude in the June 10 *Science Advances*.

Much of that reduction occurred because the health responders do not issue citations or make arrests (SN: *12/18/21 & 1/1/22, p. 10*). But even that reduction in reported crime is beneficial, says economist Thomas Dee of Stanford University. "That person is getting health care instead of being arrested."

Following the death of George Floyd at the hands of a white police officer in 2020 and the subsequent surge of the Black Lives Matter movement, cities throughout the country have been rolling out programs like STAR. "We cannot police our way out of every social problem," says sociologist Temitope Oriola of the University of Alberta in Edmonton, Canada. But so far there have been few studies of the programs' effects on crime, let alone on the reduction of violence between police and the public (SN: *8/15/20, p. 10*).

Dee and Jayme Pyne, a sociologist also at Stanford, looked at the STAR program's impact on crime reports. The duo investigated STAR's pilot phase, which ran from June to November 2020 and encompassed eight of the city's 36 police precincts. Police officers and 911 operators in those eight precincts redirected calls for minor and nonviolent complaints to STAR providers. These calls included concerns about trespassing, indecent exposure, intoxication and similar low-level offenses. During the six-month pilot, STAR providers responded to 748 calls, averaging roughly six incidents per eight-hour shift.

Dee and Pyne analyzed police reports of criminal offenses in all 36 precincts from December 2019 to November 2020. The pair then compared the change in crime rates from before and after the STAR program's initiation. The rate of violent crime remained unchanged across the board, including in the eight precincts that received STAR services, Dee and Pyne found. But reports of minor offenses in the STAR precincts dropped 34 percent, from an average of about 84 offenses per month in each district to an average of about 56 citations.

34 percent
Drop in police reports of minor criminal offenses in STAR precincts

The data also suggest that the actual level of minor crimes and complaints dropped too — that is, the drop wasn't just due to a lack of reporting, the researchers say. Before the pilot, minor offenses in the eight precincts receiving STAR services resulted in an average of 1.4 citations per incident. So having health care workers rather than police respond to 748 such calls should generate roughly 1,000 fewer citations, the authors calculated. Instead, citations dropped by almost 1,400. Providing people in crisis with access to health services may be preventing them from reoffending, Dee says.

Research into these sorts of programs is crucial, says justice policy researcher Michael Vermeer of the RAND Corporation, a public policy research organization headquartered in Santa Monica, Calif. But Vermeer cautions against drawing firm conclusions from a single study launched at the onset of the COVID-19 pandemic, which dramatically changed crime rates and patterns across the country. "They just got confounded by the pandemic," Vermeer says.

Dee agrees that he and other researchers need to replicate this study in more cities, and also scale up in Denver. The city has now expanded the STAR program beyond the pilot's eight precincts.

Even if researchers eventually find that STAR and similar programs don't budge crime rates much, that doesn't mean that the programs are unsuccessful, says sociologist Brenden Beck of the University of Colorado Denver. He points to the potential to save taxpayer dollars. Dee and Pyne estimated that responding to a would-be minor offense through STAR costs about $150, compared with the roughly $600 it costs to process an offense through the criminal justice system.

What's more, getting help for people having nonviolent mental health crises instead of sending them to jail lets these individuals hold onto their jobs and stay present in their family members' lives, Beck says. "I would hope we as a research community move on to study the benefit of these programs not just in terms of crime but also in terms of human welfare." ■

The Cerro Pelado Fire, its smoke is shown here on April 29, came close to Los Alamos National Laboratory in New Mexico.

ROBERT BROWMAN/*ALBUQUERQUE JOURNAL* VIA AP

EARTH & ENVIRONMENT

Wildfire threat heats up for nuclear lab

Is Los Alamos prepared as climate change fans the risk of flames?

BY JAMES R. RIORDON

There are things I will always remember from my time in New Mexico. The way the bark of towering ponderosa pines smells of vanilla when you lean in close. Sweeping vistas that embellish even the most mundane shopping trip. The trepidation that comes with the tendrils of smoke rising on the horizon during the dry, wildfire-prone summer months.

There were no major wildfires near Los Alamos National Laboratory during the year and a half that I worked in public communications there. I'm in Maryland now, and social media has brought me images of the wildfires that have been devastating New Mexico this year, including the Cerro Pelado Fire in the Jemez Mountains just west of the lab.

That fire, which started mysteriously on April 22 and grew to cover an area as large as Washington, D.C., was mostly contained as of mid-June. But at one point, the fire came within 5.6 kilometers of the lab, threatening a place that's responsible for creating and maintaining key portions of the H-bombs in the U.S. nuclear arsenal.

That close call may be a hint of the growing fire risk to come for the weapons lab as the Southwest suffers through an epic drought made worse by human-caused climate change (SN: 5/9/20 & 5/23/20, *p.* 8). May and June typically mark the start of New Mexico's wildfire season. This year, fires erupted in April and were amplified by a string of warm, dry and windy days. The Hermits Peak and Calf Canyon fires east of Santa Fe merged to become the largest wildfire in the state's recorded history.

The primary efforts of the Los Alamos lab, about 56 kilometers northwest of Santa Fe, revolve around nuclear weapons. The lab is currently capable of producing 10 hollow plutonium spheres every year, known as "pits" because they are the cores of nuclear bombs. That capability will triple by 2026. The site is also home to radioactive waste and debris that has been a consequence of weapons production since the first atom bomb was built in Los Alamos in the early 1940s.

What's the danger due to fire approaching the lab's nuclear material and waste? According to literature that Peter Hyde, a lab spokesperson, sent to me, not much. But an audit last year suggests otherwise.

Preparing for wildfires

Over the last few years, the Los Alamos lab has removed more than 3,000 metric tons of trees and other potential wildfire fuel from the 93-square-kilometer complex. Lab facilities, a lab pamphlet says, "are designed and operated to protect the materials that are inside, and radiological and other potentially hazardous materials are stored in containers that are engineered and tested to withstand extreme environments, including heat from fire."

What's more, most of the roughly 20,000 drums of nuclear waste stored under tents on the lab's grounds have been removed. According to the most recent available numbers, all but 3,812 of those drums have been shipped off to be stored 655 meters underground at the Waste Isolation Pilot Plant near Carlsbad, N.M.

But there's still 3,500 cubic meters of nuclear waste in the storage area, according to a March 2022 Department of Energy strategic planning document for Los Alamos. So potentially disastrous quantities of relatively exposed nuclear waste remain at the lab—a single drum from the lab that exploded after transport to Carlsbad in 2014 resulted in a two-year shutdown of the storage facility. With a total budgeted cleanup cost of $2 billion, the incident is one of the most expensive nuclear accidents in U.S. history.

Since 2011, the last time a major wildfire threatened the lab, a wider buffer space around the storage tents has been cleared of vegetation. In conjunction with fire suppression systems, it's unlikely that a wildfire will be a danger to the waste-filled drums, according to a 2016 risk analysis conducted by Los Alamos.

But a 2021 audit by the DOE's Office of Inspector General is less rosy. It found that, despite wildfire mitigation efforts and the removal of most waste drums, the lab's wildfire protection is still lacking. According to the audit, the lab had not developed a "comprehensive, risk-based approach to wildland fire management" in accordance with federal policies. The report also noted compounding issues, including the absence of federal oversight of wildfire management activities.

Among the ongoing risks, not all fire roads were maintained well enough to provide a safe route for firefighters and others, "which could create dangerous conditions for emergency responders and delay response times," the auditors wrote.

And a canyon between the lab and the town of Los Alamos was identified as being packed with 10 times as many trees as would be ideal from a wildfire safety

perspective. To make matters worse, the auditors wrote, a hazardous waste site currently at the canyon's bottom could "produce a health risk to the environment and to human health during a fire."

"The report was pretty stark," says Edwin Lyman, director of nuclear power safety at the Union of Concerned Scientists. "And certainly, after all the warnings, if they're still not doing all they need to do to fully mitigate the risk, then that's just foolishness." An audit in 2007 found similar problems.

Los Alamos spokespeople did not respond to my questions about the lab's efforts to address the problems identified in the latest report, despite repeated requests.

A growing threat

The Los Alamos area has experienced multiple wildfires since the lab was founded during World War II. The largest include a fire in 2000, one in 2011 and this year's Cerro Pelado. But climate change is expected to turn the area into a tinderbox. A 2018 study in *Climatic Change* found that the region extending from the higher elevations in New Mexico, where Los Alamos is located, into Colorado and Arizona will experience the greatest increase in wildfire probabilities in the Southwest. A new risk projection tool called Risk Factor also shows increasing fire risk in the Los Alamos area over the next 30 years.

"We are at the point where we are imagining, as we have to, things that we've never experienced," says Alice Hill, senior fellow for energy and the environment at the Council on Foreign Relations, a nonpartisan think tank. "That is fundamentally different than how we have approached these problems throughout human history, which is to look to the past to figure out how to be safer in the future.... The nature of wildfire has changed as more heat is added [to the planet] as temperatures rise."

Meanwhile, increased plutonium pit production will add to the waste that needs to be shipped. "Certainly, the radiological assessments in sort of the worst case of wildfire could lead to a pretty significant release of radioactivity, not only affecting the workers on-site but also the off-site public. It's troubling," says Lyman, who suggests that nuclear labs shouldn't be located in such fire-prone areas.

For now, although the Cerro Pelado Fire appears contained, some risks remain. Monitoring the fire's footprint until rain or snow finally snuffs it out late in the year will be vital. Even then, some danger will linger in the form of "zombie fires" that can flame up long after wildfires appear to have been extinguished (SN: 6/19/21, p. 7). "We've had fires come back in the springtime because there was a root underground that somehow stayed lit all winter long," Jeff Surber, operations section chief for the U.S. Forest Service's efforts to fight the fire, said during a May 9 briefing.

So the Cerro Pelado Fire will probably be a part of life in northern New Mexico for months to come. And the future will likely be as fiery, if not worse. That's something all residents, including the lab, need to prepare for. ■

ATOM & COSMOS

Neutrinos could spy nuclear rogues

Detectors might spot when submarine fuel is weaponized

BY EMILY CONOVER

Nuclear submarines might provide rogue nations with a path to nuclear weapons. But neutrinos could help reveal attempts to go from boats to bombs.

Neutrinos, lightweight subatomic particles that are released from the reactors that power nuclear subs, could expose the alteration or removal of the nuclear fuel for weapons, physicists report in a paper accepted in *Physical Review Letters*. Crucially, monitoring those neutrinos could be done remotely while a submarine is in a port with its reactor shut off.

To ensure that countries without nuclear weapons don't develop them, international inspectors monitor the use of nuclear technologies around the world. Nuclear submarines are particularly worrisome. Many use highly enriched uranium, a fuel that can be weaponized relatively easily. But submarines are protected from monitoring by a loophole. Because the submarines are used for military purposes, physical inspections could infringe on a country's national security.

"Neutrino-based methods can considerably reduce the intrusiveness by making measurements at a distance, without having to physically access the vessel," says Igor Jovanovic, a nuclear scientist at the University of Michigan in Ann Arbor who was not involved with the research.

These particles — specifically their antimatter variety, antineutrinos — stream from operating nuclear reactors. The particles barely interact with other matter, allowing them to pass through solid material, including a submarine hull. A neutrino detector placed nearby could reveal what's going on inside, say neutrino physicists Bernadette Cogswell and Patrick Huber of Virginia Tech in Blacksburg.

But submarines, often on the move, are hard to monitor with stationary instruments. When the vessels do sit in port, their nuclear reactors may be off. So the researchers came up with a solution: They'd look at neutrinos produced by the decays of varieties of chemical elements, or isotopes, that remain after a reactor shuts down. A detector located in the water about five meters beneath the sub's reactor could measure neutrinos produced in decays of certain isotopes. Those measurements would reveal if nuclear material had been removed or swapped out.

This monitoring method is "very clever," says physicist Ferenc Dalnoki-Veress of the Middlebury Institute of International Studies at Monterey in California.

But the idea would still require buy-in from each country to agree to detectors in submarine berths. "Something like this would be so much better if it wouldn't require cooperation," says physicist Giorgio Gratta of Stanford University.

So far, all countries that have nuclear submarines already possess nuclear weapons, so the issue has been hypothetical. But that's set to change. The United States and the United Kingdom, two nuclear weapon states, announced last September that they are entering into a cooperative security agreement with Australia, a non–nuclear weapon state, to help it acquire nuclear submarines.

There's little suspicion that Australia would use submarines as a cover for a nuclear weapons program. But "you still have to worry about the precedent that that sets," Cogswell says. So monitoring nuclear submarines is newly important, she says. "The question was how the heck to do that." ■

F. DEMETER *ET AL*/*NATURE COMMUNICATIONS* 2022

HUMANS & SOCIETY

Tooth places Denisovans in Southeast Asia

A molar tooth found in Tam Ngu Hao 2, or Cobra Cave, in Laos probably belonged to a member of a cryptic group of hominids called Denisovans, who are known from ancient DNA pegging them as close Neandertal relatives. If so, the tooth joins only a handful of other known Denisovan fossils.

Estimated ages of sediment and fossilized animal bones in the cave suggest the tooth (shown at left) is between 164,000 and 131,000 years old. It strongly resembles a Denisovan molar dating to at least 160,000 years ago that was previously found on the Tibetan Plateau (*SN: 12/21/19 & 1/4/20, p. 27*). That similarity indicates that the new find is probably Denisovan, researchers report May 17 in *Nature Communications*. Before the Tibetan Plateau tooth, which was attached to a jawbone along with another tooth, all known Denisovan fossils came from Siberia. Paleoanthropologist Fabrice Demeter of the University of Copenhagen and colleagues hope to extract DNA from the new tooth to confirm its identity.

Some scientists regard Denisovans as one of several closely related, ancient *Homo* populations while others see them as a distinct species. Whatever evolutionary ID Denisovans held, the tooth adds to suspicions that the hominids lived in Southeast Asia's tropical forests, as well as Central Asia's cold mountain ranges and Siberia. — *Bruce Bower*

ATOM & COSMOS

Why UFOs deserve scientific attention

Two researchers explain what's needed to study these mysteries

BY LIZ KRUESI

The U.S. defense and intelligence communities are taking unidentified flying objects, officially known as unidentified aerial phenomena, or UAP, seriously. Some researchers think the scientific community should too.

In May, the U.S. Congress held its first public hearing in decades about these phenomena. Two intelligence officials described efforts to catalog and analyze sightings, many by military personnel such as pilots, because of the potential threat to national security.

Scott Bray, deputy director of naval intelligence, shared details on a database of some 400 reports of UAP sightings from 2004 to 2021. While officials can attribute some of the sightings to artifacts of certain sensors or other mundane explanations, others cannot yet be explained, Bray said.

He stressed that nothing in the database or studied by a task force set up to investigate the sightings "would suggest it is anything nonterrestrial in origin."

Both Bray and Ronald Moultrie, under secretary of defense for intelligence and security, identified "insufficient data" as a barrier to understanding what the unidentified phenomena are. "That is one of the challenges we have," Moultrie said.

That's something scientists can help with, say astrobiologists Jacob Haqq Misra and Ravi Kopparapu. NASA seems to agree. On June 9, the agency announced it will bring together scientists, data researchers and aeronautics experts to investigate publicly available data for UAP. *Science News* spoke with Haqq Misra, of the Blue Marble Space Institute of Science in Seattle, and Kopparapu, of NASA's Goddard Space Flight Center in Greenbelt, Md., to learn more about how and why scientists should study the phenomena. The conversation has been edited for brevity and clarity.

What are UAP?

Haqq Misra: It's the term that the military uses. It's a little different from UFO in the sense that a phenomenon could be something that's not necessarily a solid object.

Why should scientists study UAP?

Kopparapu: We conduct scientific studies of unknown phenomena all the time. This should not be any different. The most critical point is that we should not let our speculations drive the conclusions.

Haqq Misra: With UAP, some observations are difficult to explain. Maybe they're a sign of something like new physics, or maybe it's just instrumental artifacts or things that birds are doing. It could be anything, but any of the possibilities would teach us something. It's also about safety, especially if there's something in the sky that pilots consider a safety risk.

How can we study UAP?

Haqq Misra: If you want to understand data, you need to know something about the instrument that collected them. Military instruments are probably classified for good reason. We're not going to get the kind of data from the [military] that we need to scientifically answer the question. Even if you had that data, it has not been intentionally collected. These have been accidental, sporadic observations.

You would need a network of detectors around the world. Ideally, you'd have ground-based sensors and satellites.

Kopparapu: Some of these are transient events. We need fast-tracking cameras and optical, infrared and radar observations to collect data to find patterns in the events' behaviors. We need to share such data with scientists so that independent groups can reach a consensus.

What are some next steps?

Haqq Misra: Some groups are trying to build detectors. Fundraising is the hardest part. [The nonprofit] UAPx is one, and the Galileo Project [at Harvard University] is another. But stigma has been a big problem. It seems like the military is trying to not only streamline the reporting process, but also destigmatize it. That's important for science too. The NASA announcement is a good step in the direction of UAP being considered an important scientific problem.

An unidentified aerial phenomenon (circle seen on the hazy white band) is visible in this still from a video of the sky filmed from the cockpit of a U.S. Navy jet.

KEVIN DIETSCH/GETTY IMAGES

Kopparapu: The scientific study of UAP should not be stigmatized. There should be open discussions, comments and constructive criticisms.

How did you get interested in UAP?

Kopparapu: Over a couple of years, I read articles either dismissing or advocating for a particular explanation of UAP. Then I started digging into it, and I found physicist James McDonald's 1969 "Science in default" report on UFOs. It was written like a scientific article. That resonated with me as a scientist, and I started to think that a science investigation is the only way we can understand UAP.

Haqq Misra: I'm an astrobiologist and other people asked me about UFOs. UFOs are not necessarily an astrobiology topic, but I felt a little silly having nothing to say.

I realized for a scientist who wants to understand what's going on with this UFO thing, there's a lot of noise to sift through. There's a lot of public discourse about crop circles, alien abductions and paranormal stories that muddy the waters, and the more we can be clear about specific aerial anomalies, the more we can solve the problem. ■

Editor's note: The researchers' opinions are their own and do not necessarily represent those of their employers.

ATOM & COSMOS

Slowpoke pulsar stuns scientists

According to theory, the star should not release radio waves

BY LIZ KRUESI

Astronomers have added a new species to the neutron star zoo, showcasing the wide diversity among the compact magnetic remains of dead, once-massive stars.

A newfound highly magnetic pulsar has a surprisingly long rotation period, which is challenging the theoretical understanding of these objects, researchers report May 30 in *Nature Astronomy*. Dubbed PSR J0901-4046, this pulsar sweeps its lighthouse-like radio beam past Earth about every 76 seconds. The previous record holder for slowest pulsar has a rotation period that's about three times as fast.

While it's an oddball, some of the newfound pulsar's characteristics are common among its relatives. That means this object may help astronomers better connect the evolutionary phases of neutron stars.

Astronomers know of many types of neutron stars. Each one is the compact object left over after a massive star's explosive death, but their characteristics can vary. A pulsar is a neutron star that astronomers detect at a regular interval thanks to its cosmic alignment: The star's strong magnetic field produces beams of radio waves emanating from near the star's poles, and every time one of those beams sweeps across Earth, astronomers can see a radio pulse.

The slowpoke pulsar sits in our galaxy, about 1,300 light-years from Earth. Astrophysicist Manisha Caleb of the University of Sydney and colleagues found it in data from the MeerKAT radio telescope in South Africa. Further observations with MeerKAT revealed not only the pulsar's slow, steady radio beat — a measure of how fast it spins — but also the rate at which the spin slows as the pulsar ages. Those two bits of info revealed something odd. According to theory, the pulsar should not be emitting radio waves, and yet, it is.

As neutron stars age, they lose energy and spin more slowly. According to calculations, "at some point, they've exhausted all their energy, and they cease to emit any sort of emission," Caleb says.

A pulsar's rotation period and the slowdown of its spin relate to the strength of the pulsar's magnetic field, which accelerates subatomic particles streaming from the star and, in turn, generates radio waves. Any neutron stars spinning as slowly as PSR J0901-4046 aren't expected to produce radio signals.

But "we just keep finding weirder and weirder pulsars that chip away at that understanding," says astrophysicist Maura McLaughlin of West Virginia University in Morgantown, who wasn't involved with this work.

The newfound pulsar could be its own unique species of neutron star. But in some ways, it also looks familiar, Caleb says. The estimated strength of the pulsar's magnetic field is incredibly strong and similar to that of a type of neutron star called a magnetar. Caleb says PSR J0901-4046 could be a "quiescent magnetar," a pulsar with a very strong magnetic field that occasionally emits very energetic bursts of X-rays or other radiation. "We're going to need either X-ray emission or [ultraviolet] observations to confirm whether it is indeed a magnetar," she says.

Caleb and colleagues are now looking at additional observations to see how the object's brightness and spin change over time.

The team is also altering its automated computer programs, which scan the radio data and flag intriguing signals, to look for more longer-duration spin periods — or even weirder and more mysterious neutron star phenomena. "The sweet thing about astronomy, for me, is what's out there waiting for us to find," says team member Ian Heywood, an astrophysicist at the University of Oxford. ■

JAXA

ATOM & COSMOS

A pristine piece of solar system history

Samples of the asteroid Ryugu are the most pristine pieces of the solar system that scientists have in their possession. An analysis of Ryugu debris confirms that the asteroid is extraordinarily primitive, researchers report June 9 in *Science*. The team studied material from the Japanese mission Hayabusa2, which collected 5.4 grams of dust and rock from the surface of Ryugu and brought that material to Earth in December 2020 (*SN: 1/16/21, p. 15*). The abundances of several chemical elements in a sample of the debris (part of that sample is shown at left) match CI-type chondrites. These are the most primitive known meteorites and fewer than 10 have been found on Earth. The analysis also showed that unlike Ryugu, the meteorites appear to have been altered, or contaminated, by Earth's atmosphere or even human handling over time. "The Ryugu sample is a much more fresh sample" of the early solar system, says Hisayoshi Yurimoto, a geochemist at Hokkaido University in Sapporo, Japan. — *Liz Kruesi*

A wood frog will mate in a wild, watery grab fest. How females choose which pool of eager males to visit could get clearer as biologists start using acoustic cameras.

CHRIS JOHNSON

LIFE & EVOLUTION

How a crooning frog boosts sex appeal

Serenading with like voices may help males attract females

BY SUSAN MILIUS

Loud sounds matter in both car design and frog flirting.

So a New Hampshire biologist lugged an acoustic camera used by car designers to springtime frog-mating pools to explore female preferences. Now researchers suspect that a male's chances of becoming a dad depend in part on which pool's boy band he belongs to.

We humans can name our own examples of ho-hum guys getting an allure boost from membership in the right group, says evolutionary biologist Ryan Calsbeek of Dartmouth College. "If Ringo Starr hadn't been a Beatle…," he muses.

An acoustic camera gives biologists a new tool to explore the power of membership, Calsbeek and colleagues write in the June *Ecology Letters*. Calsbeek credits Dartmouth colleague Hannah ter Hofstede, who has studied insect sounds and was not part of this study, with telling him about this industrial camera and its value to biologists.

The high-tech setup "looks a little like something you might find on a Mars rover," he says. A hula hoop–like antenna on a pole holds stubby microphones feeding 48 independent channels of sound to location-calculating software. It uses the slight differences in when the same frog call reaches different microphones to calculate the frog's location.

Calsbeek hauled camera gear and its substantial battery (sometimes "up 800 vertical feet with 90 pounds on my back") to 11 early-spring rendezvous pools for wood frogs (*Rana sylvatica*). In a pool, eager males "generate this huge, chaotic gobbling sound" like a turkey flock. Calsbeek's spirited imitations over the phone — imagine sort of half-swallowed honking sounds — indeed give a poultry vibe.

Wood frogs keep their species going in splashy, thrashing singles night–style crowds at these pools where males gather and females shop. The gatherings start early in the year, as wood frogs have the rare ability to survive cold nestled here and there in leaf litter, in some latitudes literally freezing solid with a stopped heart. Once thawed back to life, they gather with other guys at a pool gobbling their little warmed-up hearts out waiting for females to find their way to the party.

Male wood frogs lack the anatomy to insert sperm. A dad-wannabe fights to grab a female and position himself tight against her so his sperm will reach eggs as she releases them. With a good grip then, a male turns frog mating from crowdsourcing into a couples' event.

Such frantic grabby males can inadvertently drown females. So once a female hops into a mating pool, she may not have much choice about who fathers her offspring. However, the researchers wondered, in places with more than one pool, might she at least choose one bunch of grabby gobblers over another? Perhaps some features of the chorus help her decide.

Most of the vast research on mating preferences and flirtatious performances — mockingbirds singing, hummingbirds swoop-diving, crickets chirping and so on — looks at a single suitor showing off, usually for a female (SN: 6/20/09, *p.* 8; SN: 1/16/21, *p.* 10). Instead, Calsbeek's team asked: Does she have a favorite band?

To see how a male's membership in a group might give him a sex appeal bonus, the researchers created their own frog bands for females in the lab. Combining individual male's serenades pulled from the trove of poolside recordings, the researchers made a variety of hypothetical choruses. Some had the overall pitch of shrill little guys; some were mostly rumbly bass performances, and some were mixed.

The clearest outcome so far is that lab females seem to like chorus consistency itself, whether shrill in dominant pitch or deeper and rumbly. As a hint that this also might be true outside the lab, researchers typically found more of the jelly-gob egg masses, signs of mating success, floating in pools where choruses kept more consistent pitches.

The wood frog paper caught the attention of long-time frog researcher Michael Ryan of the University of Texas at Austin. Now he would like to know about the female side of these choruses, such as how far away a female can hear the pools she might approach.

The acoustic camera itself also intrigues Ryan, who was already window-shopping online as he answered journalist questions. For decades, he and colleagues have studied wild frog calls in harder and iffier ways. He would set out at least three fixed microphones to triangulate sound position ahead of a night's chorusing. Then he'd hope the few males he could track showed up and basically stayed put. A movable acoustic camera with 48 sound inputs, he says, sounds "really cool." ■

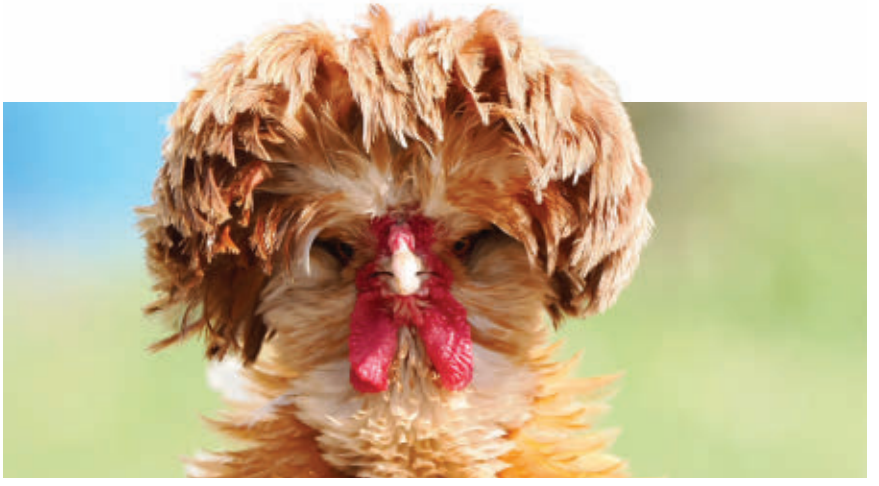
Watch an acoustic camera identify singing frogs at **bit.ly/SN_FrogCall**

HUMANS & SOCIETY

Chickens arose in Southeast Asia

The birds' origin story begins in rice fields, archaeologists say

BY BRUCE BOWER



Modern chickens originated about 3,500 years ago in Southeast Asia, later than previously thought, scientists say. New studies lay out how the birds went from wild fowl to the dinner plate.

ROBERT MAY

It turns out that chicken and rice may have always gone together, from the bird's initial domestication to tonight's dinner.

In two new studies, scientists lay out a potential story of chicken origins. This poultry tale begins surprisingly recently in rice fields planted by Southeast Asian farmers around 3,500 years ago, zooarchaeologist Joris Peters and colleagues report. From there, the birds were transported westward not as food but as exotic or culturally revered creatures, the team suggests in the June 14 *Proceedings of the National Academy of Sciences*.

"Cereal cultivation may have acted as a catalyst for chicken domestication," says Peters, of Ludwig Maximilian University of Munich.

Domesticated fowl then arrived in Mediterranean Europe no earlier than about 2,800 years ago, archaeologist Julia Best of Cardiff University in Wales and colleagues report June 7 in *Antiquity*. The birds appeared in northwest Africa between 1,100 and 800 years ago, the team says.

Researchers have debated where and when chickens (*Gallus gallus domesticus*) originated for more than 50 years. India's Indus Valley, northern China and Southeast Asia have all been touted as domestication centers. Proposed dates for chickens' first appearance have mostly ranged from about 4,000 to 10,500 years ago. A 2020 genetic study of modern chickens suggested that domestication occurred among Southeast Asian red jungle fowl. But DNA analyses couldn't specify when domesticated chickens first appeared.

Using chicken remains previously excavated from more than 600 sites in 89 countries, Peters' group determined whether the chicken bones had been found where they were originally buried by soil or, instead, had moved downward into older sediment over time and thus were younger than previously assumed.

After establishing the timing of chicken appearances at various sites, the researchers used historical references to chickens and data on subsistence strategies in each society to develop a scenario of domestication and spread.

The new story begins in Southeast Asian rice fields. The earliest known chicken remains come from Ban Non Wat, a dry rice–farming site in central Thailand that roughly dates to between 1650 B.C. and 1250 B.C. Dry rice farmers plant the crop on upland soil soaked by seasonal rains rather than in flooded fields or paddies. That would have made rice grains at Ban Non Wat fair game for chicken ancestors.

These fields attracted hungry wild birds called red jungle fowl. Red jungle fowl increasingly fed on rice grains, and probably grains of another cereal crop called millet, grown by regional farmers, Peters' group speculates. A cultivated familiarity with people launched chicken domestication by around 3,500 years ago, the researchers say.

Chickens did not arrive in central China, South Asia or Mesopotamian society in what's now Iran and Iraq until around 3,000 years ago, the team estimates.

Peters and colleagues have for the first time assembled available evidence "into a fully coherent and plausible explanation of not only where and when, but also how and why chicken domestication happened," says archaeologist Keith Dobney of the University of Sydney.

But the new insights into chickens don't end there. Using radiocarbon dating, Best's group determined that 23 chicken bones from 16 sites in Eurasia and Africa were generally younger, in some cases by several thousand years, than previously thought. These bones had apparently settled into lower sediment layers over time, where they were found with items made by earlier human cultures.

Archaeological evidence indicates that chickens and rice cultivation spread across Asia and Africa in tandem, Peters' group says. But rather than eating early chickens, people may have viewed them as special or sacred creatures. At Ban Non Wat and other early Southeast Asian sites, partial or whole skeletons of adult chickens were placed in human graves. That behavior suggests chickens enjoyed some sort of social or cultural significance, Peters says.

In Europe, several of the earliest chickens were buried alone or in human graves and show no signs of having been butchered.

The expansion of the Roman Empire around 2,000 years ago prompted more widespread consumption of chicken and eggs, Best and colleagues say. In England, chickens were not eaten regularly until around 1,700 years ago, primarily at Roman-influenced urban and military sites. Overall, about 700 to 800 years elapsed between the introduction of chickens in England and their acceptance as food, the researchers conclude. Similar lag times may have occurred at other sites where the birds were introduced. ■

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On July 4, 2012, at the European particle physics lab CERN, scientists announced the discovery of the Higgs boson. Physicist Lyn Evans (standing second from left), who led construction of the Large Hadron Collider, celebrates alongside former CERN directors.

DENIS BALIBOUSE/AFP/GETTYIMAGES

The Higgs boson at 10

Big questions persist after a decade studying the famous particle

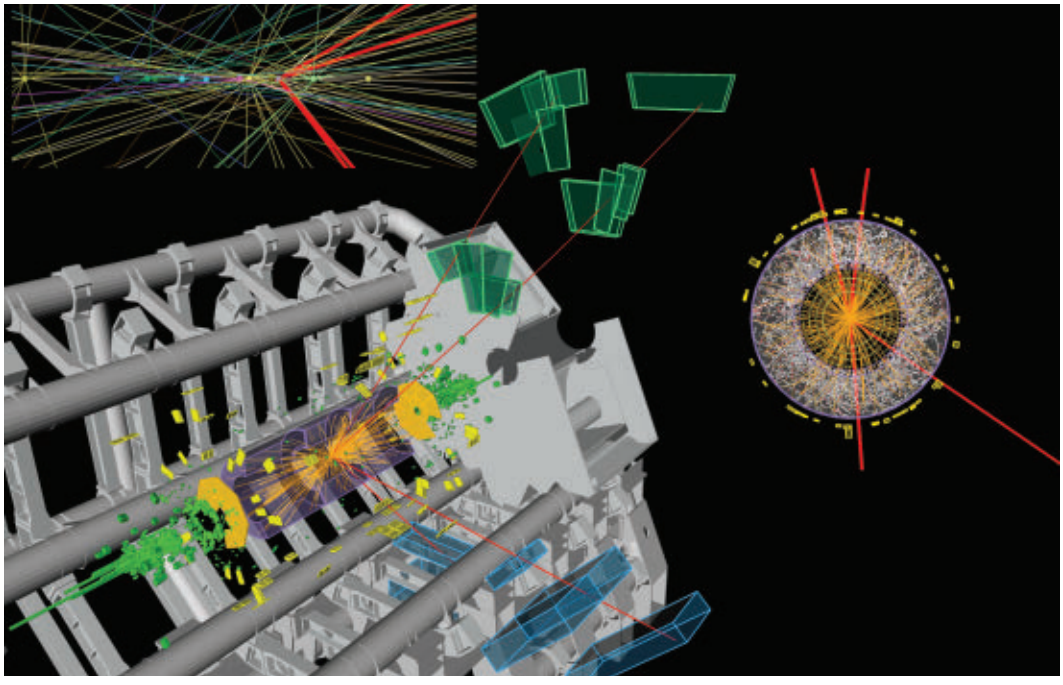
By Emily Conover

Javier Duarte kicked off his scientific career by witnessing the biggest particle physics event in decades. On July 4, 2012, scientists at the laboratory CERN near Geneva announced the discovery of the Higgs boson, the long-sought subatomic particle that reveals the origins of mass. Duarte was an eager graduate student who'd just arrived at CERN.

"I was physically there maybe a week before the announcement," Duarte says. As buzzing throngs of physicists crowded together to watch the announcement at CERN, Duarte didn't make it to the main auditorium. That space was for VIPs — and those determined enough to wait in line all night to snag a seat. Instead, he says, he found himself in the basement, in an overflow room of an overflow room.

But the enthusiasm was still palpable. "It was a very exciting time to be getting immersed into that world," he says. Since then, he and thousands of other physicists from around the world working on CERN experiments have gone all out exploring the particle's properties.

Scientists predicted the existence of the Higgs boson back in 1964, as a hallmark of the process that gives elementary particles mass. But finding



The ATLAS experiment was one of two detectors to see definitive signs of the Higgs boson. In this event, recorded on June 10, 2012, and shown here in three different views, a candidate Higgs particle decays into four muons (red tracks).

the particle had to wait for CERN's Large Hadron Collider, or LHC. In 2010, the LHC began smashing protons together at extremely high energies, while two large experiments, ATLAS and CMS, used massive detectors to look through the debris.

The particle's discovery filled in the missing keystone of the standard model of particle physics. That theory explains the known elementary particles and their interactions (SN: 7/28/12, *p.* 5). Those particles and interactions are behind just about everything we know. The particles serve as building blocks of atoms and transmit crucial forces of nature, such as electromagnetism. And the mass of those particles is key to their behavior. If electrons were massless, for example, atoms wouldn't form. Without the Higgs boson, then, one of scientists' most successful theories would collapse.

The Higgs boson discovery dominated headlines around the globe. About half a million people tuned in to watch the livestreamed announcement, and footage from the event appeared on more than 5,000 news programs. Even oddball minutiae made it into the press, with a few articles analyzing the physicists' use of the often-scorned font Comic Sans in their presentation. Little more than a year later, the discovery garnered a Nobel Prize for two of the scientists who developed the theory behind the Higgs boson, François Englert and Peter Higgs—for whom the particle is named (see Page 29).

Now, as the discovery turns 10 years old, that initial excitement persists for Duarte and many other particle physicists. As a professor at the University of California, San Diego and member of the CMS experiment, Duarte's research still revolves around the all-important particle. Progress in understanding the Higgs has been "stunning," he says. "We've come so much farther than we expected to."

Physicists have been working through a checklist of things they want to know about the Higgs boson. They spent the last decade cataloging its properties, including how it interacts with several other particles. Though measurements have so far been in line with the predictions made by the standard model, if a discrepancy turns up in the future, it may mean there are unknown particles yet to be discovered.

And there's still more on the agenda. An especially important item is the Higgs boson's interaction with itself. To help pin down this and other Higgs properties, scientists are looking forward to collecting more data. Scientists turned on an upgraded LHC for a new round of work in April. That run will continue until 2026. At the time of the Higgs discovery, collisions at the LHC reached an energy of 8 trillion electron volts. Collisions are expected to roll in at a record 13.6 trillion electron volts this summer. These higher energies offer opportunities to spot heavier particles. And the High-Luminosity LHC, a more powerful iteration of the LHC, is expected to start up in 2029.

"Finding a particle, it sounds like the end of something, but it's really only the beginning," says experimental particle physicist María Cepeda of CIEMAT in Madrid, a member of the CMS collaboration.

Coupling up

Studying the Higgs boson is like geocaching, says theoretical particle physicist Gudrun Heinrich of the Karlsruhe Institute of Technology in Germany. Much like hobbyists use a GPS device to uncover a hidden stash of fun trinkets, physicists are using their wits to uncover the treasure trove of the Higgs boson. In 2012, scientists merely located the cache; the next 10 years were devoted to revealing its contents. And that investigation continues. "The hope is that the contents will contain something like a map that is guiding us towards an even bigger treasure," Heinrich says.

Detailed study of the Higgs boson could help scientists solve mysteries that the standard model fails to explain. "We know that the theory has limitations," says theoretical particle physicist Laura Reina of Florida State University in Tallahassee. For instance, the standard model has no explanation for dark matter, a shadowy substance that throws its weight around the cosmos, exerting a gravitational pull necessary to explain a variety of astronomical observations. And the theory can't explain other quandaries, like why the universe is composed mostly of matter rather than its alter ego, antimatter. Many proposed solutions to the standard model's shortcomings require new particles that would alter how the Higgs interacts with known particles.

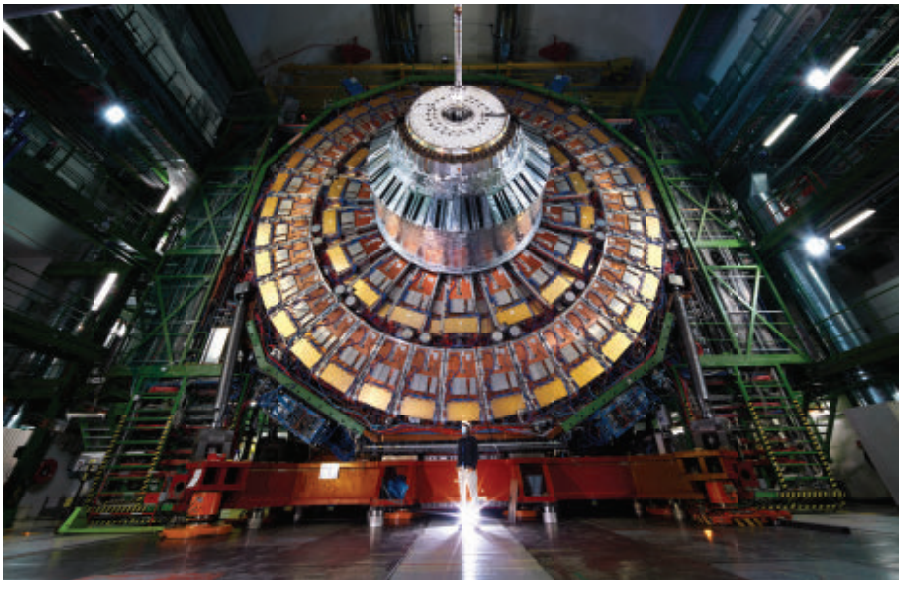
The Higgs boson itself isn't responsible for mass. Instead, that's the job of the Higgs field. According to quantum physics, all particles are actually blips in invisible fields, like ripples atop a pond. Higgs bosons are swells in the Higgs field, which pervades the entire cosmos. When elementary particles interact with the Higgs field, they gain mass. The more massive the particle, the more strongly it interacts with the Higgs field, and with the Higgs boson. Massless particles, like photons, don't directly interact with the Higgs field at all.

One of the best ways to hunt for Higgs-related treasure is to measure those interactions, known as "couplings." The Higgs couplings describe what particles the Higgs boson decays into, what particles can fuse to produce Higgs bosons and how often those processes occur (SN: 9/3/16, *p.* 13). Scientists gauge these couplings by sifting through and analyzing the showers of particles produced when Higgs bosons pop up in the debris of proton smashups.

Even if unknown particles are too heavy to show up at the LHC, the Higgs couplings could reveal their existence. "Any of these couplings not being what you expect them to be is a very clear sign of incredibly interesting new physics behind it," says particle physicist Marumi Kado of Sapienza University of Rome and CERN, who is the deputy spokesperson for the ATLAS collaboration.

Physicists have already checked the couplings to several elementary particles. These include both major classes of particles in physics: bosons (particles that carry forces) and fermions (particles that make up matter, such as electrons). Scientists have measured the Higgs' interactions with a heavy relative of the electron called a tau lepton (a fermion) and with the W and Z bosons, particles that transmit the weak force, which is responsible for some types of radioactive decay. Researchers also pegged the Higgs' couplings to the top quark and bottom quark. Those are two of the six types of quarks, which glom together into larger particles such as protons and neutrons. (The Higgs is responsible for the mass of elementary particles, but the mass of composite particles, including protons and neutrons, instead comes mostly from the energy of the particles jangling around within.)

The couplings measured so far involve the standard model's heavier elementary particles. The top quark, for example, is about as heavy as an entire gold atom. Since the Higgs couples more strongly to heavy particles, those interactions tend to be easier to measure. Next up, scientists want to observe the lighter particles' couplings. ATLAS and CMS have used their giant detectors to see hints of the Higgs decaying to muons, the middleweight sibling in the electron family, lighter than the tau but heavier than the electron. The teams have also begun checking the coupling to charm quarks, which are less massive than top and bottom quarks.



SAMUEL JOSEPH HERTZOG/CERN

The CMS detector, one of the detectors that discovered the Higgs boson, got upgraded in advance of a new run of particle collisions that started at the Large Hadron Collider this year.

So far, the Higgs has conformed to the standard model. "The big thing we discovered is it looks pretty much like we expected it to. There have been no big surprises," says theoretical particle physicist Sally Dawson of Brookhaven National Laboratory in Upton, N.Y.

But there might be discrepancies that just haven't been detected yet. The standard model predictions agree with measured couplings within error bars of around 10 percent or more. But no one knows if they agree to within 5 percent, or 1 percent. The more precisely scientists can measure these couplings, the better they can test for any funny business.

One of a kind

Before the LHC turned on, scientists had a clear favorite for a physics theory that could solve some of the standard model's woes: supersymmetry, a class of theories in which every known particle has an undiscovered partner particle (SN: 10/1/16, p. 12). Physicists had hoped such particles would turn up at the LHC. But none have been found yet. Though supersymmetry isn't fully ruled out, the possibilities for the theory are far more limited.

With no consensus candidate among many other theories for what could be beyond the standard model, a lot of focus rests on the Higgs. Physicists hope studies of the Higgs will reveal something that might point in the right direction to untangle some of the standard model's snarls. "Measuring [the Higgs boson's] properties is going to tell us much more about what is beyond the standard model … than anything before," Reina says.

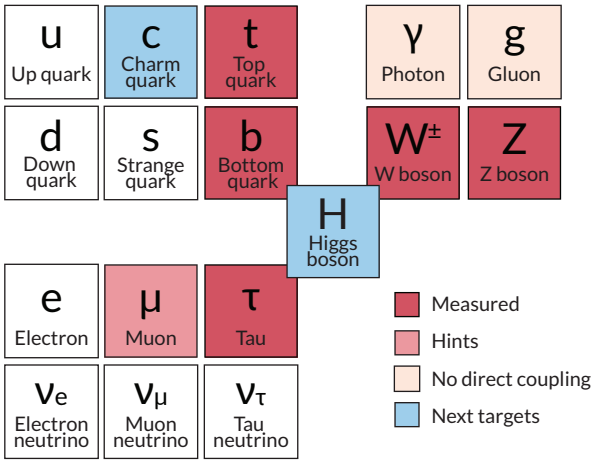
One question that scientists are investigating in LHC smashups is whether the Higgs is truly unique. All the other known elementary particles have a quantum form of angular momentum, known as spin. But the Higgs has a spin of zero, what's known as a "scalar." Other types of particles tend to come in families, so it's not outlandish to imagine that the Higgs boson could have scalar relatives. "It could be there's a huge scalar sector somewhere hiding and we just saw the first particle of it," Heinrich says. Supersymmetry predicts multiple Higgs bosons, but there are plenty of other ideas that envision Higgs accomplices.

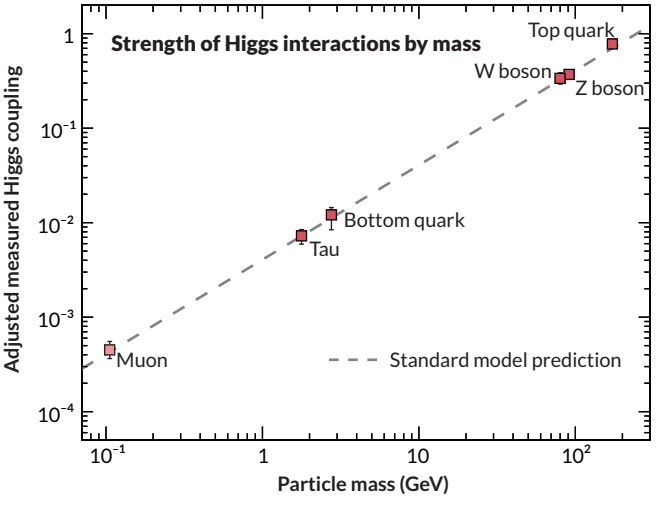
It's also possible that the Higgs is not actually elementary. Combinations of particles, such as quarks, are known to make up larger particles with spins of zero. Perhaps the Higgs, like those other scalars, is made up of yet unknown smaller stuff.

While hunting for these answers, physicists will be watching closely for any connection between the Higgs' behavior and other recent puzzling results. In 2021, the Muon g–2 experiment at Fermilab in Batavia, Ill., reported hints that muons have magnetic properties that don't agree with predictions of the standard model (SN: 5/8/21 & 5/22/21, p. 6). And in April, scientists with the CDF experiment — which studied particle collisions at Fermilab until 2011 — found that the W boson's mass is heavier than the standard model predicts (SN: 5/7/22 & 5/21/22, p. 12).

The Higgs boson's relative newness makes it ripe for discoveries that could help sort out these quandaries. "The Higgs boson is the least explored

An interaction checklist Studying how the Higgs boson interacts with other particles is one way to test whether it fits with predictions of the standard model, the time-tested theory of particle physics. Scientists have measured the Higgs' interactions, or "couplings," with five standard model particles, and have early evidence of coupling with a sixth (left). Heavier particles have been the first targets since they interact more strongly with the Higgs boson (as seen in the graph at right), so are easier to measure. So far, all measured couplings agree with predictions.





FROM LEFT: E. OTWELL; CMS COLLABORATION/CERN

elementary particle, and it could be a door to the other mysteries we still have to uncover or to shed light on," Heinrich says.

Self-talk

To work out thorny puzzles, physicists sometimes talk to themselves. Fittingly, another puzzle atop scientists' Higgs to-do list is whether the particle, likewise, talks to itself.

This "self-coupling," how Higgs bosons interact with one another, has never been measured before. But "it turns out to be really just an incredible barometer of new physics," says theoretical particle physicist Nathaniel Craig of the University of California, Santa Barbara. For example, measuring the Higgs self-coupling could suss out hidden particles that interact only with the Higgs, oblivious to any of the other standard model particles.

The Higgs self-coupling is closely related to the Higgs potential, an undulating, sombrero-shaped surface that describes the energy of the universe-pervading Higgs field. In the early universe, that potential determined how the fundamental particles gained mass, when the Higgs field first turned on.

How, exactly, that transition from massless to massive happened has some big implications for the cosmos. It could help explain how matter gained the upper hand over antimatter in the early universe. If the Higgs field did play that role in the universe's beginnings, Craig says, "it's going to leave some fingerprints on the Higgs potential that we measure today."

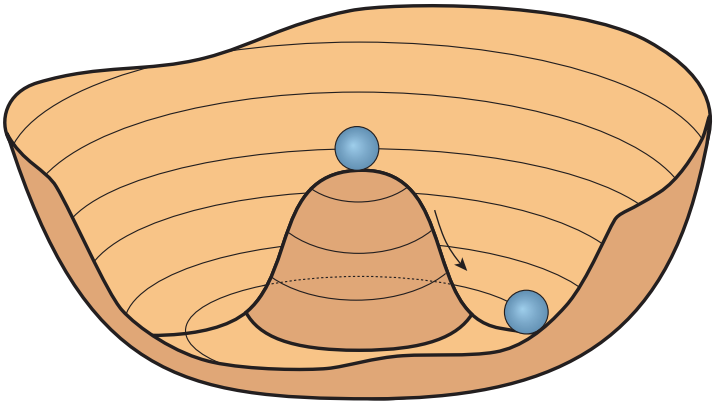
Depending on the full shape of the Higgs potential's sombrero, at some point in the exceedingly distant future, the Higgs field could shift again, as it did in the early universe. Such a jump would change the masses of fundamental particles, creating a universe in which familiar features, including life, are probably obliterated.

To better understand the Higgs potential, scientists will attempt to measure the self-coupling. They'll do it by looking for Higgs bosons produced in pairs, a sign of the Higgs interacting with itself. That's thought to happen at less than a thousandth the rate that individual Higgs bosons are produced in the LHC, making it extremely difficult to measure.

Even with the planned High-Luminosity LHC, which will eventually collect about 10 times as much data as the LHC, scientists predict that the self-coupling will be measured with large error bars of about 50 percent, assuming the standard model is correct. That's not enough to settle the matter.

If scientists just do what they're on track to do, "we're going to fall short," Duarte says. But new techniques could allow physicists to better identify double-Higgs events. Duarte is studying collisions in which two particularly high-energy Higgs bosons each decay into a bottom quark and a bottom antiquark. Using a specialized machine learning technique, Duarte and colleagues put together one of the most sensitive analyses yet of this type of decay.

By improving this technique, and combining results with those from other researchers looking at different types of decays, "we have a good hope that we'll be able to observe [the self-coupling] definitively," Duarte says.



The Higgs potential can be represented as a sombrero-shaped surface that describes the energy of the Higgs field. At some point in the early universe, the energy of the field dropped from a higher value atop the sombrero to a lower energy in the sombrero's well (illustrated). That's when particles acquired mass.

JOHN ELLIS/ARXIV.ORG 2013, CERN, ADAPTED BY E. OTWELL

Waiting game

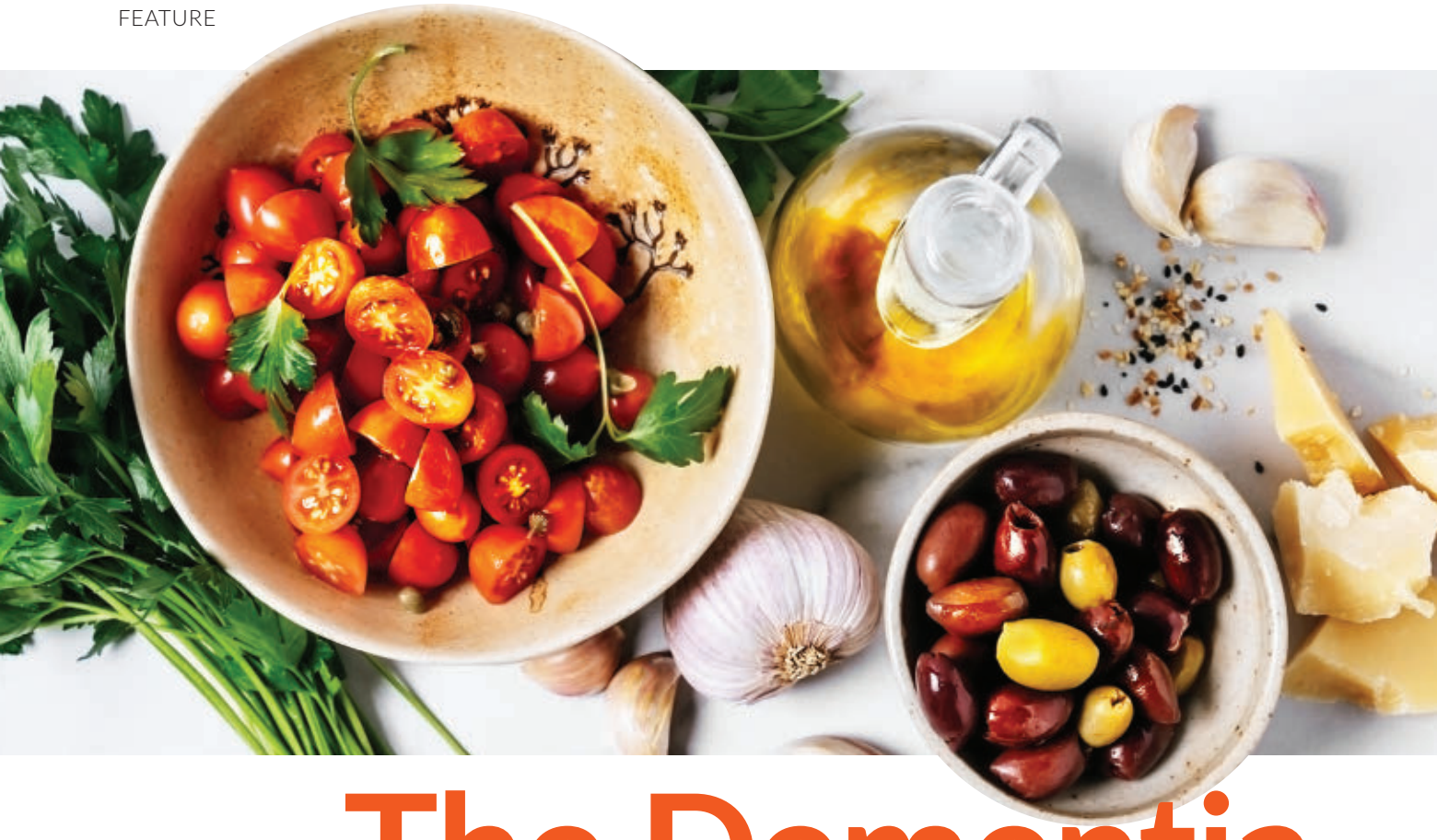
Despite all his passion for the Higgs, Duarte notes that there have been disappointments. After that first rush of the Higgs announcement, "I was hoping for a Higgs-level discovery every year." That didn't happen. But he hasn't lost his optimism. "We expect there to be another twist and turn coming up," he says. "We're still hoping it's around the corner."

The wait for new physics is no shock to veterans of earlier particle hunts. Meenakshi Narain, a particle physicist at Brown University in Providence, R.I., and a member of the CMS experiment, was an undergraduate student around the time the bottom quark was discovered in the 1970s. After that discovery, Narain joined the search for the top quark. Even though physicists were convinced of the particle's existence, that hunt still took nearly 20 years, she says. And it took nearly 50 years to uncover the Higgs boson after it was postulated.

The standard model's flaws make physicists confident that there must be more treasures to unearth. Because of her past experiences with the long-haul process of discovery, Narain says, "I have a lot of faith." ■

Explore more

- More on the Higgs boson: home.cern/science/physics/higgs-boson



The Dementia Diet Dilemma

Scientists are having a hard time figuring out which foods can help the brain stay sharp

By Cassandra Willyard

The internet is rife with advice for keeping the brain sharp as we age, and much of it is focused on the foods we eat. Headlines promise that oatmeal will fight off dementia. Blueberries improve memory. Coffee can slash your risk of Alzheimer's disease. Take fish oil. Eat more fiber. Drink red wine. Forgo alcohol. Snack on nuts. Don't skip breakfast. But definitely don't eat bacon.

One recent diet study got media attention, with one headline claiming, "Many people may be eating their way to dementia." The study, published last December in *Neurology*, found that people who ate a diet rich in anti-inflammatory foods like fruits, vegetables, beans and tea or coffee had a lower risk of dementia than those who ate foods that boost inflammation, such as sugar, processed foods, unhealthy fats and red meat.

But the study, like most research on diet and dementia, couldn't prove a causal link. And that's not good enough to make recommendations that people should follow. Why has it proved such a challenge to pin down whether the foods we eat can help stave off dementia?

First, dementia, like most chronic diseases, is the result of a complex interplay of genes, lifestyle and environment that researchers don't fully understand. Diet is just one factor. Second, nutrition research is messy. People struggle to recall the foods they've eaten, their diets change over time, and modifying what people eat—even as part of a research study—is exceptionally difficult.

Some studies have linked the Mediterranean diet, with its abundance of fatty fish, olive oil and vegetables, with a lower risk of dementia.

CLAUDIA TOTIR/MOMENT/GETTY IMAGES PLUS

For decades, researchers devoted little effort to trying to prevent or delay Alzheimer's disease and other types of dementia because they thought there was no way to change the trajectory of these diseases. Dementia seemed to be the result of aging and an unlucky roll of the genetic dice.

While scientists have identified genetic variants that boost risk for dementia, researchers now know that people can cut their risk by adopting a healthier lifestyle: avoiding smoking, keeping weight and blood sugar in check, exercising, managing blood pressure and avoiding too much alcohol — the same healthy behaviors that lower the risk of many chronic diseases.

Diet is wrapped up in several of those healthy behaviors, and many studies suggest that diet may also directly play a role. But what makes for a brain-healthy diet? That's where the research gets muddled.

Despite loads of studies aimed at dissecting the influence of nutrition on dementia, researchers can't say much with certainty. "I don't think there's any question that diet influences dementia risk or a variety of other age-related diseases," says Matt Kaeberlein, who studies aging at the University of Washington in Seattle. But "are there specific components of diet or specific nutritional strategies that are causal in that connection?" He doubts it will be that simple.

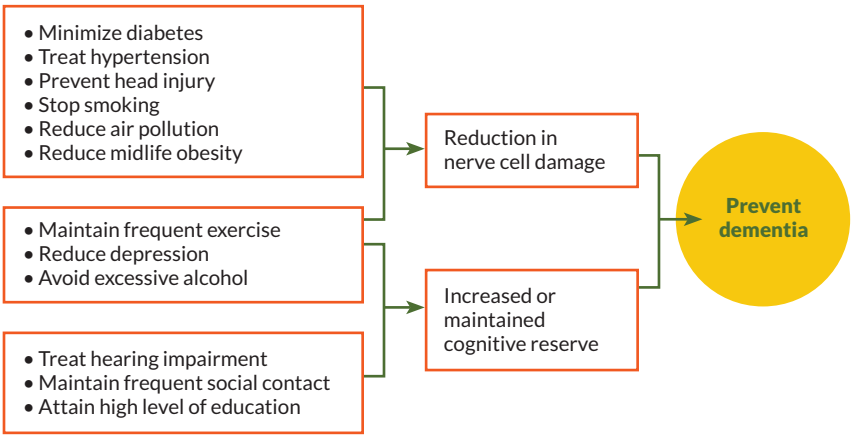
Worth trying

In the United States, an estimated 6.5 million people, the vast majority of whom are over age 65, are living with Alzheimer's disease and related dementias. Experts expect that by 2060, as the senior population grows, nearly 14 million residents over age 65 will have Alzheimer's disease. Despite decades of research and more than 100 drug trials, scientists have yet to find a treatment for dementia that does more than curb symptoms temporarily (SN: 7/3/21 & 7/17/21, p. 8). "Really what we need to do is try and prevent it," says Maria Fiatarone Singh, a geriatrician at the University of Sydney.

Forty percent of dementia cases could be prevented or delayed by modifying a dozen risk factors, according to a 2020 report commissioned by the *Lancet*. The report doesn't explicitly call out diet, but some researchers think it plays an important role. After years of fixating on specific foods and dietary components — things like fish oil and vitamin E supplements — many researchers in the field have started looking at dietary patterns.

That shift makes sense. "We do not have vitamin E for breakfast, vitamin C for lunch. We eat foods in combination," says Nikolaos Scarmeas, a neurologist at National and Kapodistrian University of Athens and Columbia University. He led the study on dementia and anti-inflammatory diets published in *Neurology*. But a shift from supplements to a whole diet of myriad foods complicates the research. A once-daily pill is easier to swallow than a new, healthier way of eating.

Twelve modifiable risk factors for dementia



Where diet fits
Up to 40 percent of dementia cases could be prevented or delayed by modifying 12 risk factors. Targeting some of these risks reduces nerve cell loss in the brain; other interventions protect the brain's ability to function and adapt even if some nerve loss has occurred, a concept called cognitive reserve. Diet plays a role in at least four of these risk factors. SOURCE: G. LIVINGSTON *ET AL/LANCET* 2020

Earning points

Suspecting that inflammation plays a role in dementia, many researchers posit that an anti-inflammatory diet might benefit the brain. In Scarmeas' study, more than 1,000 older adults in Greece completed a food frequency questionnaire and earned a score based on how "inflammatory" their diet was. The lower the score, the better. For example, fatty fish, which is rich in omega-3 fatty acids, was considered an anti-inflammatory food and earned negative points. Cheese and many other dairy products, high in saturated fat, earned positive points.

During the next three years, 62 people, or 6 percent of the study participants, developed dementia. People with the highest dietary inflammation scores were three times as likely to develop dementia as those with the lowest. Scores ranged from −5.83 to 6.01. Each point increase was linked to a 21 percent rise in dementia risk.

Such epidemiological studies make connections, but they can't prove cause and effect. Perhaps people who eat the most anti-inflammatory diets also are those least likely to develop dementia for some other reason. Maybe they have more social interactions. Or it could be, Scarmeas says, that people who eat more inflammatory diets do so because they're already experiencing changes in their brain that lead them to consume these foods and "what we really see is the reverse causality."

C. CHANG

To sort all this out, researchers rely on randomized controlled trials, the gold standard for providing proof of a causal effect. But in the arena of diet and dementia, these studies have challenges.

Dementia is a disease of aging that takes decades to play out, Kaeberlein says. To show that a particular diet could reduce the risk of dementia, "it would take two-, three-, four-decade studies, which just aren't feasible." Many clinical trials last less than two years.

As a work-around, researchers often rely on some intermediate outcome, like changes in cognition. But even that can be hard to observe. "If you're already relatively healthy and don't have many risks, you might not show much difference, especially if the duration of the study is relatively short," says Sue Radd-Vagenas, a nutrition scientist at the University of Sydney. "The thinking is if you're older and you have more risk factors, it's more likely we might see something in a short period of time." Yet older adults might already have some cognitive decline, so it might be more difficult to see an effect.

Many researchers now suspect that intervening earlier will have a bigger impact. "We now know that the brain is stressed from midlife and there's a tipping point at 65 when things go sour," says Hussein Yassine, an Alzheimer's researcher at the Keck School of Medicine of the University of Southern California in Los Angeles. But intervene too early, and a trial might not show any effect. Offering a healthier diet to a 50- or 60-year-old might pay off in the long run but fail to make a difference in cognition that can be measured during the relatively short length of a study.

And it's not only the timing of the intervention that matters, but also the duration. Do you have to eat a particular diet for two decades for it to have an impact? "We've got a problem of timescale," says Kaarin Anstey, a dementia researcher at the University of New South Wales in Sydney.

And then there are all the complexities that come with studying diet. "You can't isolate it in the way you can isolate some of the other factors," Anstey says. "It's something that you're exposed to all the time and over decades."

Food as medicine?

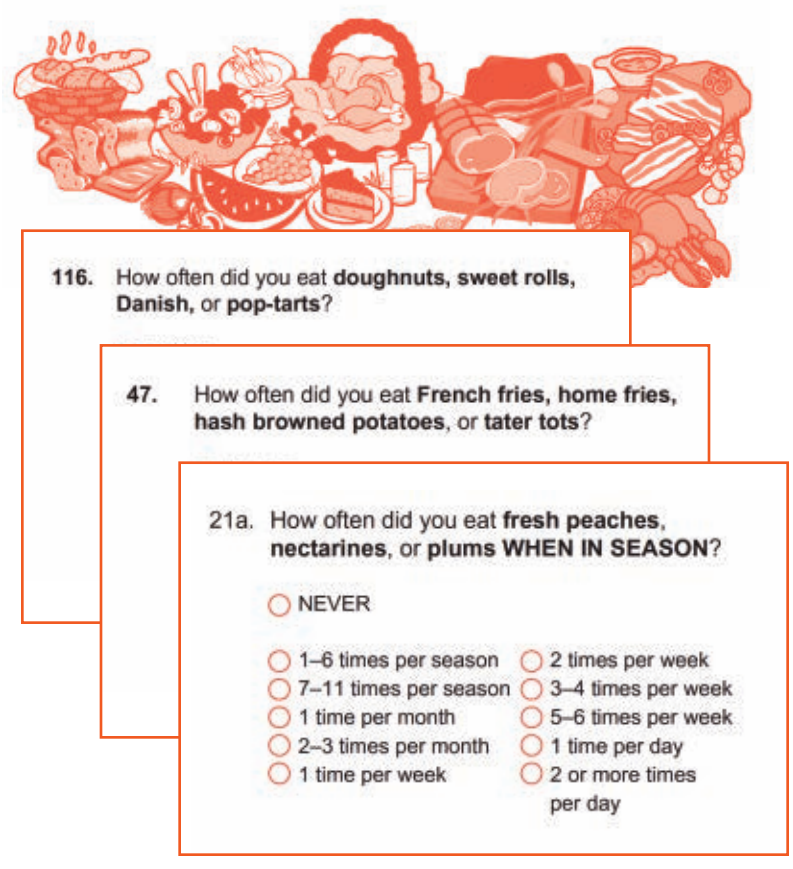
In a clinical trial, researchers often test the effectiveness of a drug by offering half the study participants the medication and half a placebo pill. But when the treatment being tested is food, studies become much more difficult to control. First, food doesn't come in a pill, so it's tricky to hide whether participants are in the intervention group or the control group.

Imagine a trial designed to test whether the Mediterranean diet can help slow cognitive decline. The participants aren't told which group they're in, but the control group sees that they aren't getting nuts or fish or olive oil. "What ends up happening is a lot of participants will start actively increasing the consumption of the Mediterranean diet despite being on the control arm, because that's why they signed up," Yassine says. "So at the end of the trial, the two groups are not very dissimilar."

Second, we all need food to live, so a true placebo is out of the question. But what diet should the control group consume? Do you compare the diet intervention to people's typical diets (which may differ from person to person and country to country)? Do you ask the comparison group to eat a healthy diet but avoid the food expected to provide brain benefits? (Offering them an unhealthy diet would be unethical.)

And tracking what people eat during a clinical trial can be a challenge. Many of these studies rely on food frequency questionnaires to tally up all the foods in an individual's diet. An ongoing study is assessing the impact of the MIND diet (which

Weighty survey
Lengthy food frequency questionnaires (a snapshot of some questions below) are a common tool for assessing an individual's eating habits over time. But the accuracy of results depends on how well participants can recall what they ate and how often.



NIH

combines part of the Mediterranean diet with elements of the low-salt DASH diet) on cognitive decline. Researchers track adherence to the diet by asking participants to fill out a food frequency questionnaire every six to 12 months. But many of us struggle to remember what we ate a day or two ago. So some researchers also rely on more objective measures to assess compliance. For the MIND diet assessment, researchers are also tracking biomarkers in the blood and urine—vitamins such as folate, B12 and vitamin E, plus levels of certain antioxidants.

Another difficulty is that these surveys often don't account for variables that could be really important, like how the food was prepared and where it came from. Was the fish grilled? Fried? Slathered in butter? "Those things can matter," says dementia researcher Nathaniel Chin of the University of Wisconsin–Madison.

Plus there are the things researchers can't control. For example, how does the food interact with an individual's medications and microbiome? "We know all of those factors have an interplay," Chin says.

The few clinical trials looking at dementia and diet seem to measure different things, so it's hard to make comparisons. In 2018, Radd-Vagenas and her colleagues looked at all the trials that had studied the impact of the Mediterranean diet on cognition. There were five at the time. "What struck me even then was how variable the interventions were," she says. "Some of the studies didn't even mention olive oil in their intervention. Now, how can you run a Mediterranean diet study and not mention olive oil?"

Another tricky aspect is recruitment. The kind of people who sign up for clinical trials tend to be more educated, more motivated and have healthier lifestyles. That can make differences between the intervention group and the control group difficult to spot. And if the study shows an effect, whether it will apply to the broader, more diverse population comes into question. To sum up, these studies are difficult to design, difficult to conduct and often difficult to interpret.

Kaeberlein studies aging, not dementia specifically, but he follows the research closely and acknowledges that the lack of clear answers can be frustrating. "I get the feeling of wanting to throw up your hands," he says. But he points out that there may not be a single answer. Many diets can help people maintain a healthy weight and avoid diabetes, and thus reduce the risk of dementia. Beyond that obvious fact, he says, "it's hard to get definitive answers."

A better way

In July 2021, Yassine gathered with more than 30 other dementia and nutrition experts for a virtual symposium to discuss the myriad challenges and map out a path forward. The speakers noted several changes that might improve the research.

One idea is to focus on populations at high risk. For example, one clinical trial is looking at the impact of low- and high-fat diets on short-term changes in the brain in people who carry the genetic variant *APOE4*, a risk factor for Alzheimer's. One small study suggested that a high-fat Western diet actually improved cognition in some individuals. Researchers hope to get clarity on that surprising result.

Another possible fix is redefining how researchers measure success. Hypertension and diabetes are both well-known risk factors for dementia. So rather than running a clinical trial that looks at whether a particular diet can affect dementia, researchers could look at the impact of diet on one of these risk factors. Plenty of studies have assessed the impact of diet on hypertension and diabetes, but Yassine knows of none launched with dementia prevention as the ultimate goal.

Yassine envisions a study that recruits participants at risk of developing dementia because of genetics or cardiovascular disease and then looks at intermediate outcomes. "For example, a high-salt diet can be associated with hypertension, and hypertension can be associated with dementia," he says. If the study shows that the diet lowers hypertension, "we achieved our aim." Then the study could enter a legacy period during which researchers track these individuals for another decade to determine whether the intervention influences cognition and dementia.

One way to amplify the signal in a clinical trial is to combine diet with other interventions likely to reduce the risk of dementia. The Finnish Geriatric Intervention Study to Prevent Cognitive Impairment and Disability, or FINGER, trial, which began in 2009, did just that. Researchers enrolled more than 1,200 individuals ages 60 to 77 who were at an elevated risk of developing dementia and had average or slightly impaired performance on cognition tests. Half received nutritional guidance, worked out at a gym, engaged in online brain-training games and had routine visits with a nurse to talk about managing dementia risk factors like high blood pressure and diabetes. The other half received only general health advice.

After two years, the control group had a 25 percent greater cognitive decline than the intervention group. It was the first trial, reported in the *Lancet*

> "I get the feeling of wanting to throw up your hands."
>
> MATT KAEBERLEIN

Embracing complexity To untangle the role of diet in dementia, researchers are designing trials that intervene earlier in life and last longer. Some studies combine multiple interventions, like diet, exercise and brain training, as well as measure a wider range of outcomes. SOURCE: R. STEPHEN *ET AL/FRONTIERS IN NEUROLOGY* 2021

Dementia and diet studies are due a makeover

Then	Now
Target one risk factor at a time	Target multiple risk factors and disease mechanisms simultaneously
Enroll individuals with substantial cognitive impairment	Enroll at-risk individuals who do not yet have symptoms of dementia
Trials last 6–12 months	Trials last 18–24 months
Focus on cognitive and functional outcome measures	Look at multiple outcome measures, including surrogate measures like biomarkers

in 2015, to show that targeting multiple risk factors could slow the pace of cognitive decline.

Now researchers are testing this approach in more than 30 countries. Christy Tangney, a nutrition researcher at Rush University in Chicago, is one of the investigators on the U.S. arm of the study, enrolling 2,000 people ages 60 to 79 who have at least one dementia risk factor. The study is called POINTER, or U.S. Study to Protect Brain Health Through Lifestyle Intervention to Reduce Risk. The COVID-19 pandemic has delayed the research—organizers had to pause the trial briefly—but Tangney expects to have results in the next few years.

This kind of multi-intervention study makes sense, Chin says. "One of the reasons why things are so slow in our field is we're trying to address a heterogeneous disease with one intervention at a time. And that's just not going to work." A trial that tests multiple interventions "allows for people to not be perfect," he adds. Maybe they can't follow the diet exactly, but they can stick to the workout program, which might have an effect on its own. The drawback in these kinds of studies, however, is that it's impossible to tease out the contribution of each individual intervention.

"One of the reasons why things are so slow in our field is we're trying to address a heterogeneous disease with one intervention at a time. And that's just not going to work."

NATHANIEL CHIN

Preemptive guidelines

Two major reports came out in recent years addressing dementia prevention. The first, from the World Health Organization in 2019, recommends a healthy, balanced diet for all adults, and notes that the Mediterranean diet may help people who have normal to mildly impaired cognition.

The 2020 *Lancet* Commission report, however, does not include diet in its list of modifiable risk factors, at least not yet. "Nutrition and dietary components are challenging to research with controversies still raging around the role of many micronutrients and health outcomes in dementia," the report notes. The authors point out that a Mediterranean or the similar Scandinavian diet might help prevent cognitive decline in people with intact cognition, but "how long the exposure has to be or during which ages is unclear." Neither report recommends any supplements.

Plenty of people are waiting for some kind of advice to follow. Improving how these studies are done might enable scientists to finally sort out what kinds of diets can help hold back the heartbreaking damage that comes with Alzheimer's disease. For some people, that knowledge might be enough to create change.

"Inevitably, if you've had Alzheimer's in your family, you want to know, 'What can I do today to potentially reduce my risk?'" says molecular biologist Heather Snyder, vice president of medical and scientific relations at the Alzheimer's Association.

But changing long-term dietary habits can be hard. The foods we eat aren't just fuel; our diets represent culture and comfort and more. "Food means so much to us," Chin says.

"Even if you found the perfect diet," he adds, "how do you get people to agree to and actually change their habits to follow that diet?" The MIND diet, for example, suggests people eat less than one serving of cheese a week. In Wisconsin, where Chin is based, that's a nonstarter, he says.

But it's not just about changing individual behaviors. Radd-Vagenas and other researchers hope that if they can show the brain benefits of some of these diets in rigorous studies, policy changes might follow. For example, research shows that lifestyle changes can have a big impact on type 2 diabetes. As a result, many insurance providers now pay for coaching programs that help participants maintain healthy diet and exercise habits.

"You need to establish policies. You need to change cities, change urban design. You need to do a lot of things to enable healthier choices to become easier choices," Radd-Vagenas says. But that takes meatier data than exist now. ■

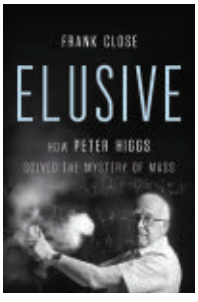
Explore more

- Gill Livingston *et al*. "Dementia prevention, intervention and care: 2020 report of the *Lancet* Commission." *Lancet*. August 8, 2020.
- World Health Organization. "Risk reduction of cognitive decline and dementia: WHO guidelines." January 1, 2019. bit.ly/WHO-DementiaReduction

Cassandra Willyard is a freelance science journalist based in Madison, Wis.

Physicist Peter Higgs stands in front of a photograph of a detector at the Large Hadron Collider, where the Higgs boson was discovered.

PETER MACDIARMID/GETTY IMAGES



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Namesake particle steals the spotlight in Peter Higgs biography

There's a lot more to the story of the Higgs boson than just one man named Higgs.

Despite the appeal of the "lone genius" narrative, it's rare that a discovery can be attributed solely to the work of one scientist. At first, *Elusive*, a biography of Peter Higgs written by physicist and author Frank Close, seems to play into that misleading narrative: The book is subtitled "How Peter Higgs solved the mystery of mass."

But the book quickly—and rightfully—veers from that path as it delves into the theoretical twists and turns that kicked off a decades-long quest for the particle known as the Higgs boson, culminating with its discovery in 2012 (SN: 7/28/12, *p.* 5). That detection verified the mechanism by which particles gain mass (see Page 18). Higgs, of the University of Edinburgh, played a crucial role in establishing mass's origins, but he was one of many contributors.

The habitually modest and attention-averse Higgs makes the case against himself as the one whiz behind the discovery, the book notes: According to Higgs, "my actual contribution was only a key insight right at the end of the story."

The Higgs boson itself doesn't bestow fundamental particles with mass. Instead, its discovery confirmed the correctness of a theory cooked up by Higgs and others. According to that theory, elementary particles gain mass by interacting with a field, now known as the Higgs field, that pervades all of space.

A paper from Higgs in 1964 was not the first to propose this process. Physicists Robert Brout and François Englert just barely beat him to it. And another team of researchers published the same idea just after Higgs (SN: 11/2/13, *p.* 4). Crucial groundwork had already been laid by yet other scientists, and still others followed up on Higgs' work. Higgs, however, was the one to make the pivotal point that the mass mechanism implied the existence of a new, massive particle, which could confirm the theory.

Despite this complicated history, scientists slapped his name on not just the particle, the Higgs boson, but also the process behind it, traditionally called the Higgs mechanism, but more recently and accurately termed the Brout-Englert-Higgs mechanism. (Higgs has reportedly proposed calling it the "ABEGHHK'tH mechanism," using the first letter of the last names of the parade of physicists who contributed to it, Anderson, Brout, Englert, Guralnik, Hagen, Higgs, Kibble and 't Hooft.) The postmortem of how Higgs' name attained outsize importance is one of the most interesting sections of *Elusive*, revealing much about the scientific sausage-making process and how it sometimes goes awry. Equally fascinating is the account of how the media embraced Higgs as a titan of physics based on his association with the boson, lofting him to a level of fame that, for Higgs, felt unwelcome and unwarranted.

The book admirably tackles the complexities of the Brout-Englert-Higgs mechanism and how particles gain mass, covering details that are usually glossed over in most popular explanations. Close doesn't shy away from nitty-gritty physics terms like "perturbation theory," "renormalization" and "gauge invariance." The thorniest bits are most appropriate for amateur physics aficionados who desire a deeper understanding, and those bits may require a reread before sinking in.

Higgs is famously not a fan of the limelight—he disappeared for several hours on the day he won a Nobel Prize for his work on mass. The physicist sometimes seems to fade into the background of this biography as well, with multiple pages passing with no appearance or contribution from Higgs. Once the scientific community got wind of the possibility of a new particle, the idea took on a life of its own, with experimental physicists leading the charge. Higgs didn't make many contributions to the subject beyond his initial insight, which he calls "the only really original idea I've *ever* had."

Thus, the book sometimes feels like a biography of a particle named Higgs, with the person playing a backup role. Higgs is so reserved and so private that you get the sense that Close still hasn't quite cracked him. While interesting details of Higgs' life and passions are revealed—for example, his fervent objection to nuclear weapons—deeper insights are missing. In the end, Higgs is, just like the particle named after him, elusive. —*Emily Conover*

Congratulations to the winners of

REGENERON ISEF 2022

The Regeneron International Science and Engineering Fair, a program of Society for Science, is the world's largest international pre-college science and engineering competition. In May, a total of 1,750 young scientists from 63 countries, regions and territories participated in the event, which took place both virtually and in person in Atlanta, for nearly $8 million in awards and scholarships.

Robert Sansone (above center), 17, of Fort Pierce, Fla., won the first place George D. Yancopoulos Innovator Award of $75,000.

Abdullah Al-Ghamdi (above right), 17, of Dammam, Saudi Arabia, received one of two Regeneron Young Scientist Awards of $50,000.

Rishab Jain (above left), 17, of Portland, Ore., received the second Regeneron Young Scientist Award of $50,000.

Napassorn Litchiowong, 17; **Chris Tidtijumreonpon**, 16; and **Wattanapong Uttayota**, 17, all from Mueang Chiang Mai, Thailand, shared the Gordon E. Moore Award for Positive Outcomes for Future Generations of $50,000.

Amon Schumann, 17, of Berlin, Germany, received the Craig R. Barrett Award for Innovation of $10,000.

Rebecca Cho, 17, of Jericho, N.Y., received the H. Robert Horvitz Prize for Fundamental Research of $10,000.

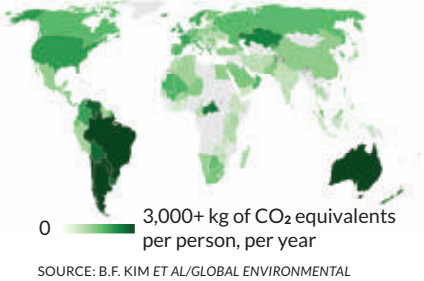
Anika Puri, 17, of Chappaqua, N.Y., received the Peggy Scripps Award for Science Communication of $10,000.

MAY 7, 2022 & MAY 21, 2022

Putting emissions on the map

At least one reader wanted to know more about a map that shows how countries' average diets contribute to global greenhouse gas emissions (see "Meaty data," right). The map captures emissions from food production, but not from processing, transportation, retail or waste. Data are not available for countries in gray.

Greenhouse gas emissions caused by the average person's diet, by country



SOURCE: B.F. KIM *ET AL/GLOBAL ENVIRONMENTAL CHANGE* 2020

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Meaty data

*Food production contributes substantially to global greenhouse gas emissions. Altering your diet can reduce those emissions, **Betsy Ladyzhets** reported in "Food choices"* (SN: 5/7/22 & 5/21/22, p. 22).

The story displayed a map showing the impact of an average person's diet, by country, on greenhouse gas emissions (see "Putting emissions on the map," left). Reader **Steve Woodbury** wondered whether the map depicts emissions attributable to countries' consumption or exportation of food products.

On this map, the greenhouse gas emissions are counted only in the country where the food use is happening, **Ladyzhets** says. The scientists who worked on this analysis chose to focus on modeling consumption habits because "the majority of food produced in most countries is consumed domestically," she says.

All about the fight

A hole in the skull of a Triceratops *dubbed "Big John" may have been a battle scar sustained during a fight with a peer, **Anna Gibbs** reported in "*Triceratops *hole may be a combat injury"* (SN: 5/7/22 & 5/21/22, p. 20).

Reader **Dale S. Smith** asked how scientists know that Big John was male, and whether the injury could have resulted from mating with a female.

We know that Big John is most likely male because of the morphology and measurements of the skeleton, particularly the skull and pelvis, says **Ruggero D'Anastasio**, a paleopathologist at the "G. D'Annunzio" University of Chieti-Pescara in Italy.

It's unlikely that the injury happened during mating, **D'Anastasio** says. The location and shape of the wound indicates that it was inflicted from behind, which is probably not where a female *Triceratops* would be positioned during mating, he says. The shape of the hole also suggests that a large horn penetrated perpendicular to the skull's bony frill. If the injury was sustained during mating, the lesion would likely have a different shape, caused by a big horn that pierced the skull's fan at an acute rather than perpendicular angle, he says.

But it's possible that mating rivalry had a part in the brawl. "In many animal species, males struggle with each other to acquire the right to mate with females," **D'Anastasio** says. "It is all about fighting."

Mass mismatch

*A new measurement suggests the W boson may have a higher mass than expected, revealing a potential flaw in the standard model of particle physics, **Emily Conover** reported in "Subatomic particle may be extra hefty"* (SN: 5/7/22 & 5/21/22, p. 12).

The W boson's newly measured mass is 80,433.5 million electron volts, **Conover** reported. That exceeds the predicted mass of 80,357 MeV by roughly 0.1 percent. Reader **Jerry Boehm** asked if such a tiny discrepancy is significant enough for scientists to discuss the prospect of new particles.

In short, yes, **Conover** says. "Even though that sounds like a very small mismatch, physicists have determined the measured and predicted W boson masses so precisely that the discrepancy is much bigger than expected," she says. "The W boson mass was measured to a precision of 0.01 percent, similar to that of the predicted mass. So we'd expect those values to be much closer together, unless we're missing something. That 'something' could be an exciting find, like new particles, or it could mean that there's something else that's not accounted for properly in either the measurement or the prediction."

Lasers reveal ancient urban sprawl hidden in the Amazon

A massive urban landscape that contained interconnected campsites, villages, towns and monumental centers thrived in the Amazon rainforest more than 600 years ago.

In what is now Bolivia, members of the Casarabe culture built an urban system that included straight, raised causeways running for several kilometers, canals and reservoirs, researchers report May 25 in *Nature*. Such low-density urban sprawl from pre-Columbian times was previously unknown anywhere in South America, say archaeologist Heiko Prümers of the German Archaeological Institute in Bonn and colleagues.

Rather than constructing huge cities packed with people, a substantial Casarabe population seems to have spread out in a network of settlements that incorporated plenty of open space for farming, the team concludes.

For about a century, researchers have known that Casarabe people constructed large earthen mounds, causeways and ponds. But these finds were located at isolated forest sites that are difficult to excavate, leaving the reasons for mound building and the nature of Casarabe society, which existed from about the year 500 to 1400, a mystery.

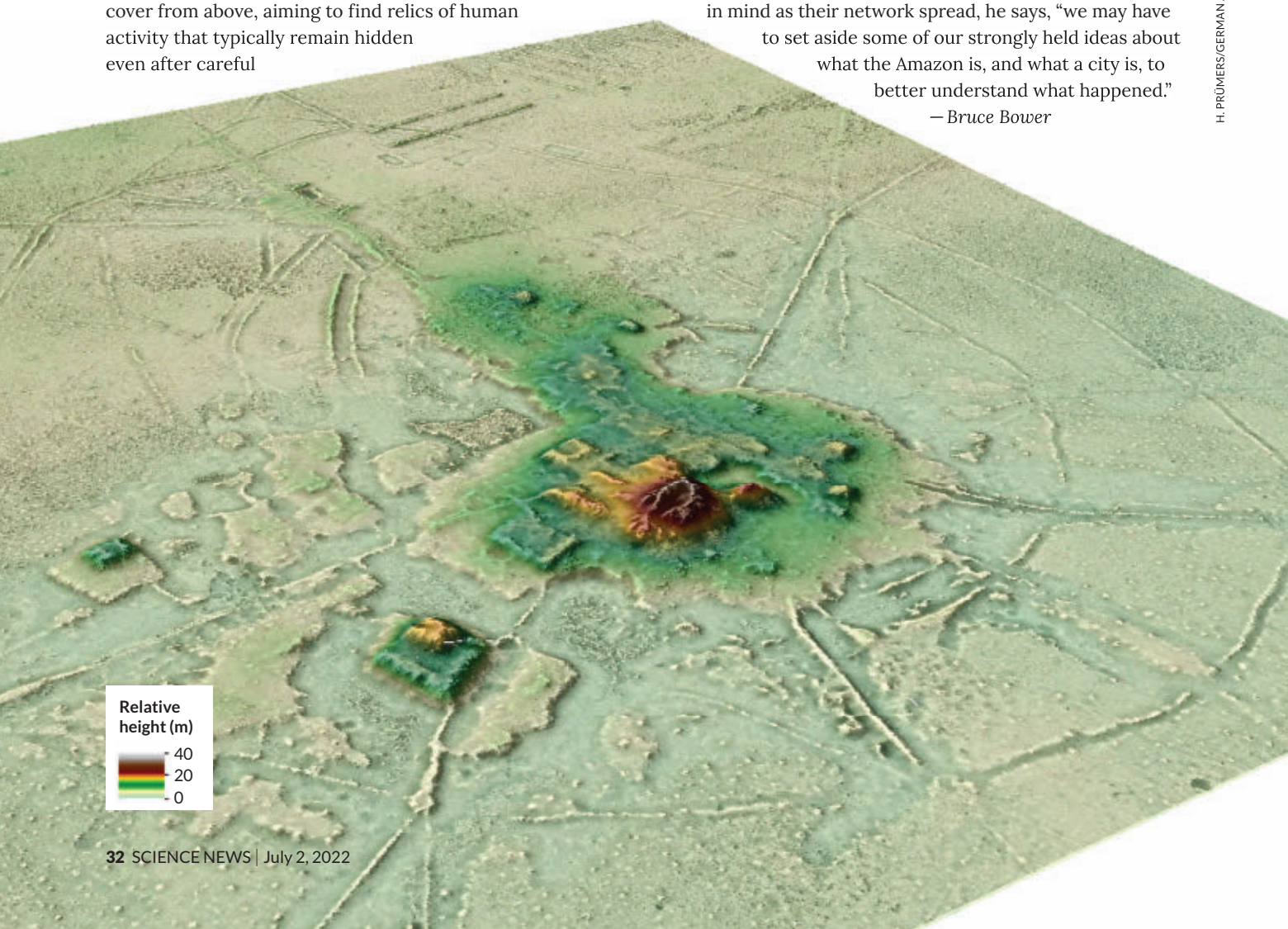
Prümers' team opted to look through the Amazon's lush cover from above, aiming to find relics of human activity that typically remain hidden even after careful ground surveys. From a helicopter, the scientists fired laser pulses at the ground. By detecting pulses that reflect back, the researchers could map the contours of now-obscured structures.

Looking at the laser-derived maps, "it is obvious that the mounds are platforms and pyramids standing on artificial terraces at the center of well-planned settlements," Prümers says.

Two of the largest settlements—Cotoca (shown below in a screenshot from a laser-based 3-D animation) and Landívar—feature rectangular and U-shaped platform mounds and cone-shaped earthen pyramids atop human-made terraces. Curved moats and defensive walls border each of the two sites. Causeways radiate out in all directions, connecting those primary sites to smaller sites with fewer platform mounds that then link up to what were probably small campsites or areas for specialized activities, such as butchering animals.

Casarabe culture's urban sprawl must have encompassed a considerable number of people in the centuries before the Spanish arrived and the broader Indigenous population plummeted, says archaeologist John Walker of the University of Central Florida in Orlando. Whatever Casarabe honchos had in mind as their network spread, he says, "we may have to set aside some of our strongly held ideas about what the Amazon is, and what a city is, to better understand what happened."

—*Bruce Bower*



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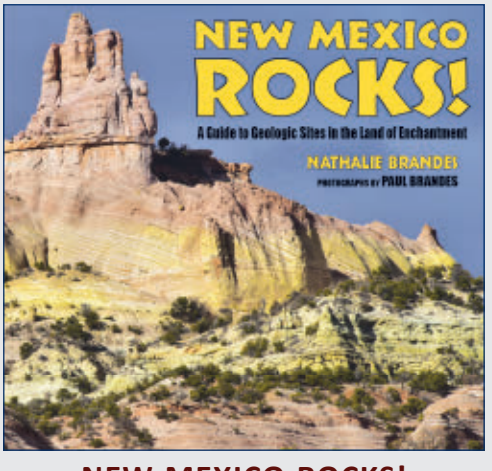

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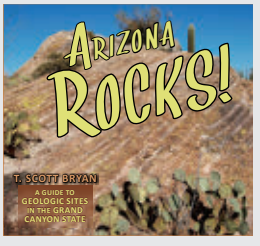

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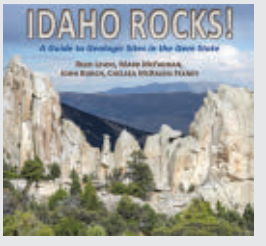

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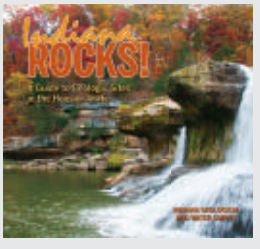

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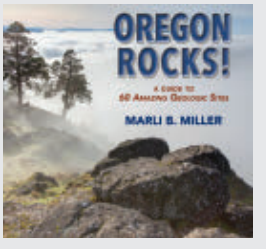

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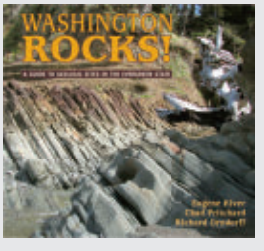

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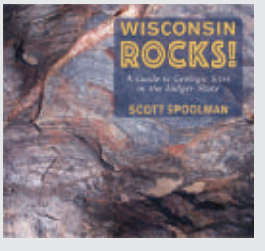

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