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Ancient Power Plays

New discoveries upend ideas about who was in charge in Maya cities

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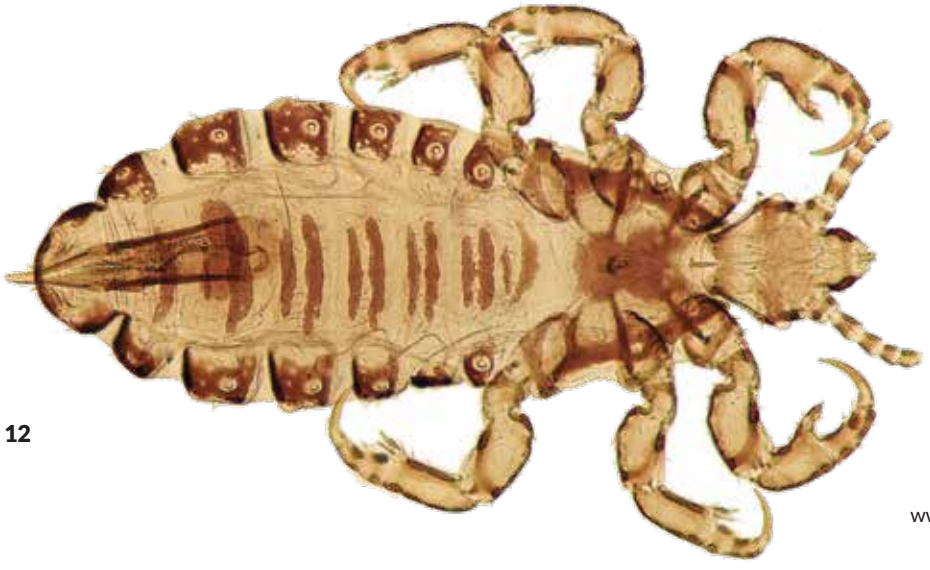
News



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Departments

COVER A stone pyramid rises up from the jungle at the ancient Maya site of Caracol in what's now Belize. *KaraGrubis/iStock/Getty Images Plus*

Under the jungle, a more pluralistic Maya society

The stone temple in the ancient city of Caracol soars above the jungle in western Belize, an enduring symbol of the Maya dynasties that ruled Central America for centuries. Caracol's central temple and others like it have long been viewed as symbols of the authoritarian structure of ancient Maya government, with kings holding all the power. But what lurks below the jungle tells a different story.

With the help of aerial lidar, a remote sensing technology that maps the Earth's surface with aircraft-mounted lasers, archaeologists have discovered the remains of sprawling urban areas beneath the vegetation at Caracol and other Maya sites in recent years. Those discoveries are helping to rewrite the history of Maya society.

"It's increasingly clear Maya cities were organized in a greater variety of ways than was often thought," behavioral sciences writer Bruce Bower told me.

In this issue's cover story, Bower reports on new studies of this vast urban sprawl. For instance, in Caracol, which covered as much area as Milwaukee, communities more distant from the central pyramid had distinct artifacts and stone buildings that suggest that these "suburbs" had their own cultural practices and local governments (Page 24).

Ancient Maya society is not the only civilization where archaeologists are reconsidering the king/vassal paradigm. Last year, Bower reported on research showing that as early as around 3,000 years ago, some societies were following "good government" practices that included fair taxation, control over political officials' power and a voice for all citizens. Examples include the 16th century city of Tlaxcallan in Mexico and Indigenous clans in eastern North America (SN: 11/5/22, *p.* 16).

On the archaeology beat, Bower has been covering new findings about the ancient Maya and other civilizations for decades. In 1998, he reported on the discovery of caves located beneath Maya temples that were used for ritual ceremonies. He wrote about "immense plazas, elaborate buildings reserved for powerful officials, and ballcourts on which some type of organized game was played appear as regularly as shopping malls in suburban neighborhoods" (SN: 1/24/98, *p.* 56).

That's just one of many evocative descriptions of Maya cities that Bower has penned over the years, despite never having visited one himself. "That would be very cool," he says. "I've never been to any of the sites I write about. I've never even been to Stonehenge."

And there's another theme in Caracol's story, Bower notes, one that's repeated in civilizations around the world throughout history. Governments rise and fall; more pluralistic societies can be replaced by authoritarian ones, and vice versa. "There's something humbling about the lidar data," Bower says. "Here were these great cities and civilizations that are now covered up by jungle. The Classic Maya, that's gone and those cities were abandoned."

But that's not the end of the story. "Maya culture kept right on going," Bower says. "It's still vital today." — *Nancy Shute, Editor in Chief*

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Excerpt from the December 1, 1973 issue of *Science News*

50 YEARS AGO

No planet for Barnard's star?

Over the years evidence has been brought forward for planetary companions revolving around two or three stars other than the sun. The first of these was Barnard's star, which had been studied by Peter van de Kamp.... The presence of a planet could cause a wobble in a star's motion across the sky. Van de Kamp found a wobble.... [Further] scrutiny does not find the [wobble].... Thus there would be no planet.

UPDATE: Astronomers now know of thousands of exoplanets in the Milky Way (*SN: 4/23/22, p. 5*). But Barnard's star is still without a confirmed exoplanet despite careful scrutiny. A 2018 claim of an exoplanet about three times as massive as Earth has been questioned. In July, a survey of 200 low-mass red dwarfs, including Barnard's star, found no Jupiter-sized exoplanets (*SN: 7/15/23 & 7/29/23, p. 9*). Such stars may have enough debris around them to form only small exoplanets.

THE SCIENCE LIFE

Playing with paper leads to a Möbius strip discovery

Any attempt to better understand Möbius strips is bound to run into some kinks.

The twisted loops are so strange that mathematicians have struggled to answer some basic questions about them. For example: What's the shortest Möbius strip you can make for a paper band of a given width?

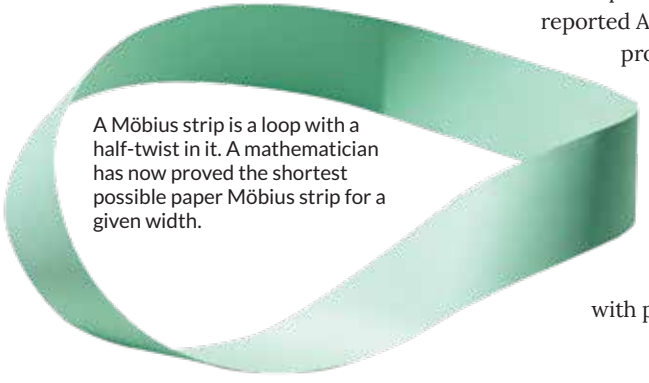
The question hooked mathematician Richard Evan Schwartz of Brown University in Providence, R.I. A mistake in a computer program almost prevented him from finding the answer. Simply messing around with strips of paper helped him solve the mystery.

Mathematician Richard Evan Schwartz dons a paper mask he made. Paper helped him find an error in his study of the triangular Möbius strip.

A Möbius strip is a mathematical oddity that anyone can make. Cut a strip of paper, twist one end halfway around and tape the ends together to form a loop with a twist in it. The result is a one-sided surface. The strips have inspired mathematicians, artists and scientists (SN: 7/2/22, p. 5).

A long, skinny Möbius strip is easier to make than a stumpy one. With a very short strip, the paper has to contort so much that it flattens into an equilateral triangle. The triangular Möbius strip is made from a piece of paper that has a length that's $\sqrt{3}$, or about 1.73, times its width.

In 1977, mathematicians hypothesized that the triangular Möbius strip was the shortest possible. Specifically, it's the limit for a theoretical version of paper that, like real-world paper, can't pass through itself. But no one had been able to prove it. Researchers could show only that the length-to-width ratio must be greater than $\pi/2$, or about 1.57.



A Möbius strip is a loop with a half-twist in it. A mathematician has now proved the shortest possible paper Möbius strip for a given width.

The stumper piqued Schwartz's interest. He focused on a key property of Möbius strips: While the paper curves this way and that to form the loop, at every point on the band there's a direction in which the paper follows a straight line from edge to edge, with no curvature at all. He realized that, in any Möbius strip, there must always be two such lines that are perpendicular and in the same plane, as in the letter T.

Based on how the paper contorts to form this T shape, Schwartz found a new minimum ratio. It was not $\sqrt{3}$ but a number achingly close to it, about 1.69, he reported in 2021 in *Geometriae Dedicata*.

Schwartz moved on to other topics but couldn't stop thinking about the problem. One day, on a whim, he began playing with strips of paper. In a head-smacking jolt, he realized he'd made an error. Schwartz had assumed that slicing open a Möbius strip along a diagonal and flattening it forms a parallelogram. But when he cut open a paper Möbius strip, he saw a trapezoid.

It turns out that Schwartz had flubbed the setup of the computer program he used to study the strips, which led to the parallelogram whoopsie. "Once I'd made the mistake," he says, "it's like it got locked into my brain."

Schwartz hardly ever used paper Möbius strips in his research. But that's what it took to break his stagnant thought pattern. It's curious that he didn't turn to paper earlier, since he makes paper masks as a hobby.

Once Schwartz redid the calculation with the trapezoid fix, $\sqrt{3}$ popped out, Schwartz reported August 24 at arXiv.org. He had proved a nearly 50-year-old mathematical hypothesis.

Schwartz wants to take the work further. What, he wonders, are minimum lengths for Möbius strips with more than one twist? This time, perhaps, he'll spend more time playing with paper. —*Emily Conover*

FROM TOP: BRIENNE BROWN; MIRAGEC/MOMENT/GETTY IMAGES PLUS

MYSTERY SOLVED

A rare bacterium joins the list of elephant-killing pathogens

Three years ago, dozens of African elephants mysteriously died in Zimbabwe. Now scientists have nabbed the killer: a rare and little known bacterium that can cause organ inflammation leading to deadly hemorrhaging.

The bacterium, *Pasteurellaceae* Bisgaard taxon 45, turned up in samples from six of 15 dead elephants analyzed, researchers report October 25 in *Nature Communications*. The pathogen is closely related to *Pasteurella multocida*, which can cause hemorrhagic septicemia, or fatal blood poisoning, in elephants. Bisgaard taxon 45 had not been previously implicated in blood poisoning.

It's still unclear how the elephants became infected, say epidemiologist Laura Rosen and colleagues. Rosen works with the Kavango-Zambezi Transfrontier Conservation Area's Animal Health Sub-Working Group in Victoria Falls, Zimbabwe. But the results do solve one part of a mystery that has haunted efforts to protect endangered *Loxodonta africana* elephants in the country.

From August to November 2020, 35 elephants turned up dead in northwestern Zimbabwe. Earlier the same year in Botswana, as many as 350 elephants died from cyanobacteria infections. But there's no evidence that cyanobacteria were involved in the deaths of Zimbabwe's elephants, Rosen and colleagues say. Instead, necropsies and lab tests found the Zimbabwe elephants had enlarged spleens and livers as well as extensive internal bleeding and tissue death—symptoms of hemorrhagic septicemia. Blood poisoning from *P. multocida* infections had been seen in Asian elephants, but never before in African elephants.

African elephants (one in Zimbabwe, shown) can develop blood poisoning from infections of *Pasteurellaceae* Bisgaard taxon 45 bacteria.

Upon further testing, it became clear that "we did not have *P. multocida* but something else similar," Rosen says. Genetic analysis of samples from six elephants confirmed Bisgaard taxon 45 was the culprit in those deaths. Samples from nine other elephants were too degraded to get an ID. Still, the team suspects that Bisgaard taxon 45 is to blame for all the deaths. Whether the bacterium is part of the typical elephant microbiome, and if so, what may have caused it to become deadly, remain unclear.

35
African elephants in Zimbabwe killed by a rare bacterium in 2020

The findings add to the growing list of pathogens to look for in mysterious wildlife deaths in Africa, says veterinary microbiologist Shahan Azeem of the University of Veterinary and Animal Sciences in Lahore, Pakistan. —*Tawanda Karombo*

INTRODUCING

Newfound fossilized lampreys probably feasted on flesh

Found in roughly 160-million-year-old rocks in northern China, the Yanliao Biota is a diverse array of beautifully preserved fossils, including dinosaurs, pterosaurs and even early mammals. Paleontologists have now unearthed fossils of two surprisingly large ancient lamprey species there, swimming menaces that latched onto and bored holes into their unsuspecting neighbors.

Modern lampreys' funnel-shaped, toothy mouths tend to be adapted to consume either blood or flesh. Based on the arrangement of teeth and other feeding apparatuses in the fossils, the newly discovered species were probably flesh eaters, scientists report October 31 in *Nature Communications*.

The fossilized mouth of the newfound ancient lamprey *Yanliaomyzon ingensdentes*, shown in this artist's rendition, suggests the species ate flesh instead of sucking blood.

The fossils are the oldest lamprey specimens to clearly indicate a preference in feeding mode, say paleontologist Feixang Wu of the Chinese Academy of Sciences in Beijing and colleagues. In fact, the tooth arrangement of both ancient species strongly resembles that of a modern species of flesh-eating lamprey in the Southern Hemisphere.

Yanliaomyzon occisor was larger than *Y. ingensdentes*. At about 64 centimeters, the length of a Dachshund, *Y. occisor* fell within the size range of modern lampreys.

Lampreys, a lineage of jawless vertebrates, have been around for 360 million years. But they rarely fossilize well, leaving large gaps in their evolutionary record and uncertainty about their ecology and when their feeding styles evolved.

The earliest lampreys were only a few centimeters long and lacked the powerful teeth of later species. The newfound fossils suggest that by this time in the Jurassic Period, lampreys had become fierce predators, acquiring larger body sizes and complex feeding structures. —*Carolyn Gramling*

FROM TOP: DAVID FETTES/IMAGE SOURCE/GETTY IMAGES; HEMING ZHANG

CLIMATE

Earth's hottest 12 months on record

A new report attributes recent extreme heat to climate change

Andres Matamoros wipes sweat from his face as he sells fresh fruit from his roadside stand in Houston amid a record-breaking heat wave in the city last summer.

AP PHOTO/DAVID J. PHILLIP

BY CAROLYN GRAMLING

Earth just had its hottest 12 months in nearly 150 years of recordkeeping — and probably in the last 125,000 years — due to human-caused climate change, a new report finds.

From November 2022 through October 2023, the planet's average temperature was about 1.3 degrees Celsius higher than the average temperature from 1850 to 1900, say researchers with the nonprofit group Climate Central. That's just shy of the 1.5-degree threshold often cited as a benchmark for avoiding irreversible impacts on the climate. Over the last year, about 1 in 4 people globally experienced a climate change–driven heat wave that lasted at least five days.

Climate Central released the report on November 9, ahead of the United Nations Framework Convention on Climate Change, which began in Dubai on November 30. Fossil fuels are driving most of this heat, says Andrew Pershing, Climate Central's vice president for science. Hopefully, he says, participating nations will take note of the findings as they negotiate how to reduce fossil fuel emissions (SN: 5/7/22 & 5/21/22, *p.* 8).

Global average numbers can be hard to grasp. So the report also quantifies temperatures that people experience day-to-day, and how much those temperatures are attributable to climate change.

"We have these super important global numbers such as the 1.5- or 2-degree warming targets, but that isn't the experience that people on planet Earth have," Pershing says. "We wanted to develop a way to really localize that experience … to talk about how climate change influenced that day's temperatures on any given day anywhere in the planet."

To that end, the analysis is based on Climate Central's Climate Shift Index, or CSI. It is a daily local temperature attribution system that combines observational data and climate simulations to determine the likelihood that local temperature variations are attributable to climate change.

Because what is considered extreme heat depends on both place and time, the researchers defined it for a given location as daily temperatures that would have been in the 99th percentile for that place from 1991 to 2020. In other words, temperatures that locals would recognize as incredibly high. The team analyzed data from hundreds of countries, states, provinces and major cities.

About 90 percent of the global population, 7.3 billion people, experienced at least 10 different days of extreme temperatures in the last year that were very strongly affected by climate change. Those days had a CSI rating of at least 3, meaning human-caused climate change made those temperatures at least three times as likely. Nearly 3 out of 4 people experienced those temperatures for more than 30 days.

The report also reveals inequities in the burden of climate change. Earth's poorest countries had a relatively high average CSI of 2, though they have contributed the least amount of fossil fuel emissions.

Climate impacts also are accelerating in many of the richest countries, including the United States. Brutal heat waves roasted much of the southern United States over the last 12 months. For instance, Houston endured a 22-day streak of extreme heat, where each day topped 38° C (100° Fahrenheit). That was the longest streak in the 700 cities with 1 million people or more that the team analyzed.

The new analysis, which has not yet been peer-reviewed, is similar to ones performed by World Weather Attribution. WWA is a consortium that looks for the fingerprints of human-caused climate change in specific extreme events around the world. The group examined a handful of extreme heat waves over the last 12 months — all were strongly attributable to climate change, says climate scientist and WWA cofounder Friederike Otto.

Immediately eliminating fossil fuel use would stop global temperatures from rising and heat waves from getting worse, Otto says. Keeping the planet below a 1.5-degree warming threshold "is in reach," she says, "if we want it to be in reach."

In June, Earth experienced the onset of an El Niño climate pattern, which can bring high global temperatures on top of the long-term global warming trend. But the greatest temperature impact from El Niño takes a year or so to develop as heat disperses around the globe, Pershing says. That means 2024 will probably smash records. ■

GENETICS

How Huntington's might be stopped

Future therapies could target a genetic pileup in brain cells

BY TINA HESMAN SAEY

WASHINGTON — Scientists have uncovered a clue about why it takes so long for Huntington's disease to develop. And they may have a lead on how to stop the fatal brain disease.

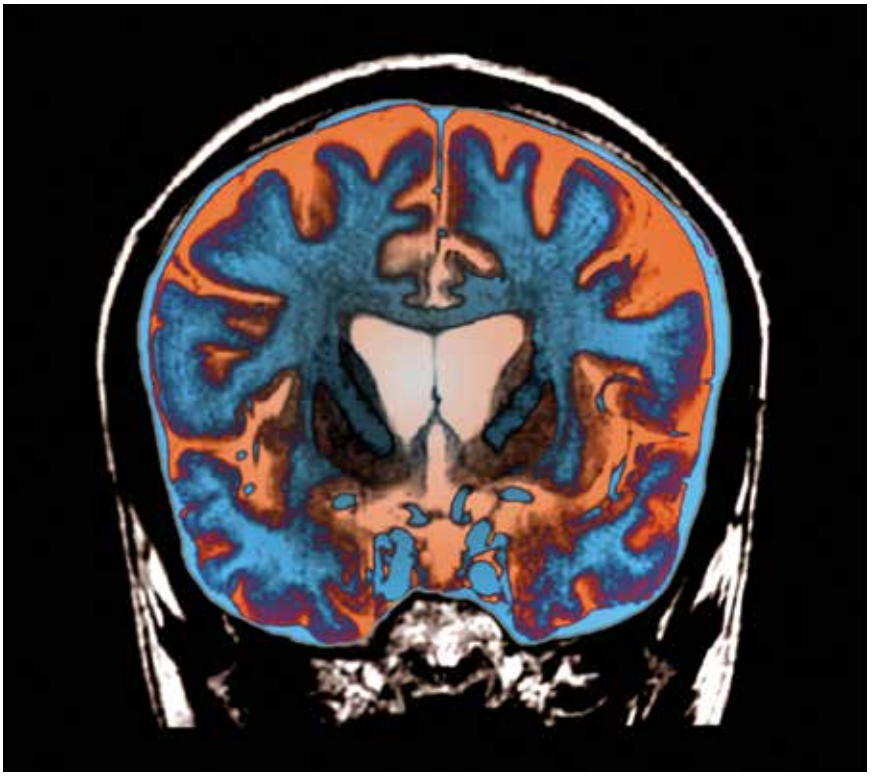
Huntington's is caused by a mistakenly repeated bit of a gene called *HTT*. Researchers had thought the number of repeats a person is born with doesn't change, though repeats may expand when passed to future generations. But in some brain cells, the repeats can grow over time to hundreds of copies, geneticist Bob Handsaker reported November 2 at the annual meeting of the American Society of Human Genetics.

Once the number of repeats passes a certain point, the activity of thousands of other genes in the cells changes drastically, leading to cell death.

The findings suggest that adding repeats to the *HTT* gene in vulnerable brain cells drives Huntington's disease, says Handsaker, of the Broad Institute of MIT and Harvard in Cambridge, Mass. The research also suggests that preventing the repeats from growing may stop the development of the disease.

The new work gives "serious insight into the disease mechanism," says geneticist Russell Snell of the University of Auckland in New Zealand. In the United States, about 41,000 people have symptomatic Huntington's disease and another 200,000 are at risk of developing it. Inheriting just one copy of a repeat-riddled *HTT* gene produces symptoms.

Everyone is born with two copies of the *HTT* gene. In one part of the gene, the DNA bases cytosine, adenine and guanine repeat. *HTT* typically has 26 or fewer CAG repeats. But people who inherit even one copy with 40 or more repeats will develop Huntington's disease. Symptoms generally don't appear until people are in their 30s to 50s. The more repeats a person has, the earlier symptoms start.



ZEPHYR/SCIENCE SOURCE

In this MRI image of a 21-year-old with Huntington's disease, dark areas in the center of the brain indicate cell death. The gene that causes the disease gains extra DNA over time, causing cells to die. Targeting a protein that is thought to add DNA to the gene may be a way to stop the disease.

Those symptoms include depression, mood swings, forgetfulness, balance problems, involuntary movements and slurred speech. Eventually, a person may be paralyzed and can die from complications such as pneumonia or heart failure.

Handsaker and colleagues examined individual cells in donated postmortem brains from people with and without the disease. Measuring the length of the repeated genetic bit in all the cells revealed a "dramatic expansion" of the repeats in cells called striatal projection neurons in people with Huntington's disease, Handsaker said. The extra DNA wasn't found in other types of brain cells in people with or without the disease.

"Some cells had up to 1,000 CAG repeats," Handsaker said. Why the repeats grow only in this type of cell is unclear.

Based on the ages of the donors when they died and on computer simulations, Handsaker's team noticed an unusual pattern. It can take decades to go from about 40 repeats to 80, but then the process picks up steam. It takes only a few years to go from 90 repeats to more than 100.

Once the disease-causing version of *HTT* reached about 150 repeats, the activity of thousands of other genes went haywire, the team found. Precise levels of activity are needed to keep cells healthy, so it may be this change that leads to cell death within months of reaching 150 repeats.

CAG repeats might get added when a protein called MSH3, which is involved in repairing DNA, loses its place. Lowering levels of that protein might be a way to limit the expansion and keep Huntington's from progressing, Handsaker said.

Experimental methods for managing the disease tend to focus on lowering levels of a toxic protein called huntingtin, which is made from the disease-causing version of *HTT* and is thought to damage brain cells. The new work suggests targeting DNA instability also "holds therapeutic potential," says neurobiologist Leora Fox of the Huntington's Disease Society of America in New York City. ■

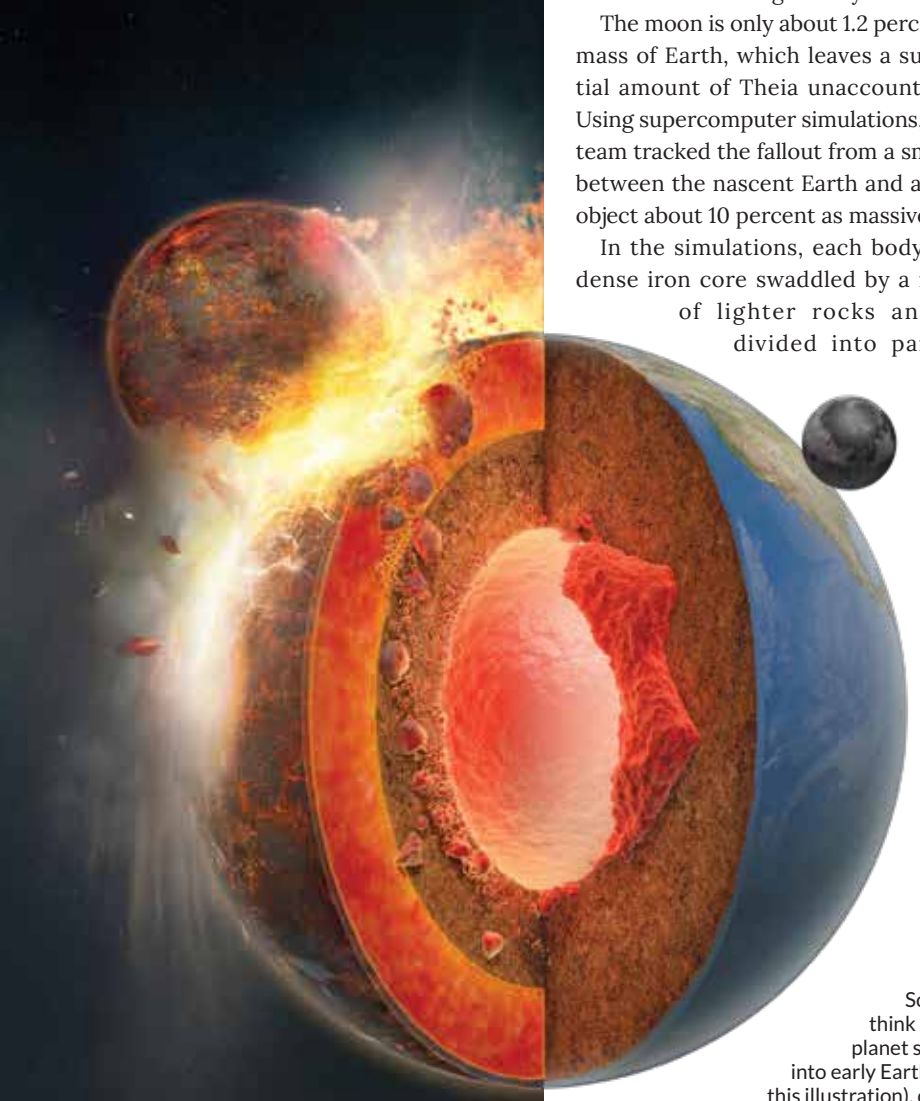
PLANETARY SCIENCE

Pieces of Theia live inside Earth

Mantle rocks may be debris from moon-forming crash

BY SID PERKINS

About 4.5 billion years ago, a Mars-sized object smashed into the young Earth, spraying debris that coalesced to form the moon, many scientists think. Some remnants of that object, called Theia, exist today as large amounts of dense material sitting atop Earth's core, researchers propose in the Nov. 2 *Nature*.



Scientists think a protoplanet smashed into early Earth (left in this illustration), creating the moon and rocky masses that sit atop modern Earth's core (right).

HERNÁN CAÑELLAS

In recent decades, geophysicists have discovered two continent-sized zones of rock at the base of Earth's mantle where seismic waves travel abnormally slowly, suggesting the rock there is denser than the rest of the mantle rock. One of these blobs, known as large low-velocity provinces, lies beneath Africa. The other lies half a world away beneath the Pacific Ocean, says Qian Yuan, a planetary geodynamicist at Caltech.

Some researchers have suggested these masses are the remnants of tectonic plates that were shoved beneath others and then sunk down to the boundary between Earth's outer core and the overlying mantle. But Yuan and colleagues offer a different origin story.

The moon is only about 1.2 percent the mass of Earth, which leaves a substantial amount of Theia unaccounted for. Using supercomputer simulations, Yuan's team tracked the fallout from a smashup between the nascent Earth and another object about 10 percent as massive.

In the simulations, each body had a dense iron core swaddled by a mantle of lighter rocks and was divided into particles about 10 kilometers across. That allowed tracking of the postimpact fragments, says computational physicist Vincent Eke of Durham University in England. In all, the simulations tracked about 100 million particles.

A substantial portion of Theia's core — equivalent to about 3 percent of Earth's mass today — was left on our planet, the simulations suggest. Soon after the collision, that dense molten material would have sunk to join early Earth's core. Meanwhile, a large volume of Theia's mantle, up to 5 percent of Earth's mass, was embedded in the uppermost 1,400 kilometers of early Earth's mantle.

Moon rocks suggest that Theia's mantle contained higher proportions of iron oxide minerals than Earth's mantle and was therefore probably denser, Yuan says. Over a few tens of millions of years after the collision, that material slowly sank to accumulate and form the large low-velocity provinces, the team suggests.

Although many researchers have suggested that these low-velocity provinces are remnants of tectonic plates, others have proposed that they're remnants of Earth's original magma ocean. Attributing the masses to material left in the wake of the collision between Theia and the nascent Earth "is a new idea," says geodynamicist Paul Tackley of ETH Zurich.

Whether or not a run-in with Theia is what created the low-velocity provinces, it's at least plausible that they could have lasted the 4.5 billion years or so since the moon's formation, Tackley says. If the materials in those zones are dense enough to resist mixing with the overlying mantle as it slowly flows across them, he says, "they can survive over geological time."

Known as the giant impact hypothesis, a collision between Earth and a protoplanet remains the leading theory of how the moon formed. Previously, researchers have suggested that such a collision would help explain the slight chemical differences between rocks on the moon and on Earth (SN: 7/12/14, *p.* 14). Besides creating the moon, scientists recently proposed that a collision between the nascent Earth and Theia also may have jump-started plate tectonics (SN: 4/22/23, *p.* 10). ■

PALEONTOLOGY

Fossilization may alter feather proteins

Dinosaur- and bird-feather analyses challenge evolutionary ideas

BY SAIMA S. IQBAL

Many feathered dinosaurs couldn't fly—at least, not like birds do today. But the reptiles' feathers may have been more birdlike than scientists previously thought.

In 2019, fossil analyses found that feathers from a flightless dinosaur mostly contained alpha-keratin, a flexible form of the protein that makes up modern bird beaks, scales and feathers. Scientists suggested that feathers evolved to be stiffer, containing more beta-keratin, as birds, the last living dinosaurs, took to the skies.

That idea may be upended with the new discovery that fossilization can change feather proteins, making one keratin protein resemble another, researchers report in the October *Nature Ecology & Evolution*.

The study raises the possibility that dinosaur feathers may have mainly contained the stiffer beta-keratin proteins found in bird feathers. Such a finding would not imply all feathered dinosaurs flew, but it would raise new questions about feather evolution.

The work also gives scientists valuable insight into one way the fossil record may transform over time, says vertebrate paleontologist Julia Clarke of the University of Texas at Austin. "There's still a lot more to discover about the process of chemical alteration that all structures undergo during the process of rock formation, liquefaction and burial," she says.

For the new study, paleontologist Tiffany Slater and colleagues subjected modern bird feathers to heat conditions that mimicked what dinosaur feathers may have endured during fossilization. Beta-keratin in the feathers unfolded and reformed in the shape of alpha-keratin, hinting that a similar process could have occurred in dinosaur feathers.

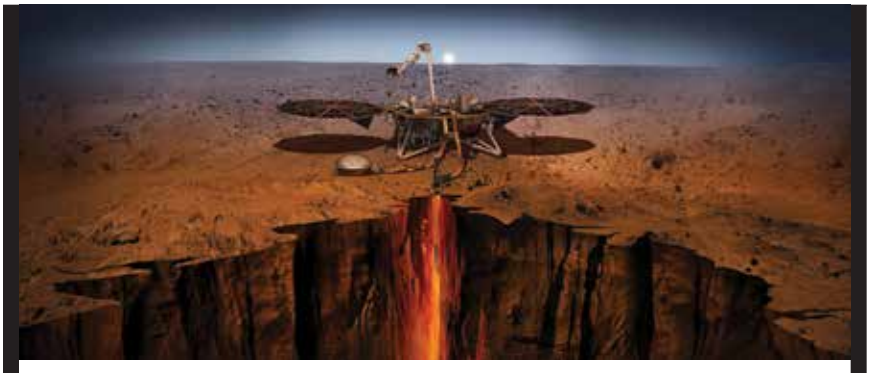
The team then compared a roughly 50-million-year-old bird feather and a 125-million-year-old feather from the nonavian dinosaur *Sinornithosaurus*. The fossilized bird feather consisted mainly of alpha-keratin. Since it should have been rich in the beta variety, the team suspects that the proteins transformed during fossilization. The dinosaur feather had mainly beta-keratin, hinting it wasn't exposed to enough heat to morph its proteins.

The simplest explanation is that fossilization's distorting effects led scientists astray in thinking dinosaur and bird feathers were so different, says Slater, of University College Cork in Ireland.

But the conditions that Slater's team tested may not accurately replicate what occurred during centuries of burial, says Mary Schweitzer, a molecular paleontologist at North Carolina State University in Raleigh who conducted the 2019 research. In Schweitzer's work, feathers exposed to even higher temperatures preserved their proteins well when kept in sediment, rather than removed from it as in the new study. The effect fossilization has on feather proteins may be more complex and as yet misunderstood, she says.

Scientists increasingly think that feathers primarily kept dinosaurs warm and helped them attract mates. But some nonavian dinosaurs flapped their wings as they ran while others glided through the air (SN: *11/26/16, p. 9*).

If feathers are one piece of the flight evolution puzzle, keratin may be an even smaller sliver, says biologist Matthew Shawkey of Ghent University in Belgium. The vasculature, shape and arrangement of feathers may be more important, he says. ■



JPL-CALTECH/NASA

PLANETARY SCIENCE

Seismic waves reveal Mars' true heart

Mars has a heavy heart after all. The Red Planet has a dense core of liquid iron surrounded by a relatively thin layer of molten rock, researchers report in two studies in the Oct. 26 *Nature*.

The finding resolves a recent conundrum that came about when seismic measurements suggested that the planet had a surprisingly large, lightweight core rich in low-density elements. Such a core would have required a mix of elements that wouldn't have matched the proportions in the material that formed the solar system. The new work shows the planet is indeed made of materials common in the solar system at the time Mars formed.

Seismic waves from Marsquakes and meteorite impacts, detected with NASA's InSight lander (illustrated above), have helped scientists deduce the structure of Mars' interior. Previously, waves reflecting off the molten rock layer had suggested the core's radius is about 1,800 kilometers with a density of up to 6,300 kilograms per cubic meter. Now, seismic waves that dipped into the molten layer refine that picture. The core's radius is roughly 10 percent smaller with a density of about 6,500 kg/m^3 to 6,650 kg/m^3. Because Mars and Earth were similar in their youth, better understanding the Red Planet "can tell us a lot about our own," says planetary scientist Henri Samuel of CNRS in Paris. —*James R. Riordon*

PLANTS

Sweat keeps a desert plant hydrated

The Athel tamarisk's salty secretions pull water from the air

BY ARIANA REMMEL

Sweat keeps some animals cool in scorching heat. Salty secretions also serve one desert shrub a refreshing sip of water.

The Athel tamarisk uses a special selection of salts excreted from its leaves to pull water from the air, researchers report in the Nov. 7 *Proceedings of the National Academy of Sciences*. This finding provides new insights into the clever chemical survival strategies that plants have evolved in harsh environments.

The Athel tamarisk (*Tamarix aphylla*) thrives in the arid, salt-rich soils of coastal flats across the Middle East. The tamarisk is a halophyte, a salt-loving plant, and secretes excess salt in concentrated droplets from glands in its leaves. The moisture from these briny excretions dissipates in the heat of the day, leaving the tamarisk encrusted in white crystals that shake off in the wind.

While driving through the deserts of the United Arab Emirates, materials scientist Marieh Al-Handawi of New York University Abu Dhabi noticed water condensing on these crystals. A lot of plants have leaf surface structures that attract liquid water from fog. But Al-Handawi, who looks to nature for strategies to tackle water scarcity, suspected that the composition of the excreted salts — a chemical adaptation — might have something to do with the dew.

The succulent leaves of this Athel tamarisk secrete salts that soak up condensation.

M. AL-HANDAWI

To investigate, Al-Handawi and colleagues recorded time-lapse videos of Athel tamarisk plants in their natural habitat. These recordings showed that salt crystals that form during the day swell with water at night. Back in the lab, the researchers found that at 35° Celsius and 80 percent relative humidity, a naturally encrusted branch collected 15 milligrams of water on its leaves after two hours, while a branch washed of crystals yielded only about one-tenth as much.

"This result was conclusive to us," Al-Handawi says, "because it proved salts are the main contributor to the water harvesting, and it's not the surface of the plant." What's more, the researchers observed dew form on the crystals at just 50 percent relative humidity in the lab.

The tamarisk's saline sprinkles contain more than 10 different types of minerals. Salt crystals are made mostly of sodium chloride and gypsum. Yet the researchers also spotted traces of lithium sulfate. This mineral is exceptionally good at taking in water and at much lower humidity than sodium chloride or gypsum. While sodium chloride brings in the largest volumes of water, the addition of lithium sulfate to the mineral mélange helps explain how the tamarisk collects water even at relatively low humidity, Al-Handawi says.

"This paper provides a new level of detailed understanding of how some desert plants can both excrete salt and use it to take up water from the air into leaves," says Lawren Sack, a plant physiologist and ecologist at UCLA. Sack is excited to see the chemical complexity of the salts. Desert plants have evolved intricate chemical strategies to squeeze every last drop of water from the environment, he says, and most of those systems await discovery.

Al-Handawi notes that the salt recipe may differ across regions and seasons. It makes her hopeful, she says, that there are other exciting water-harvesting materials waiting to be found in the desert. ■

PLANTS

Rising seas help some mangroves

Unique geology may explain unexpected forest growth

BY DARREN INCORVAIA

Some mangrove forests off Australia have flourished in the last several decades. And, counterintuitively, rising sea levels may be responsible.

Off Australia's northern coast, the skeletal remains of ancient coral reefs form the bedrock of numerous wooded islands. These low-lying tropical oases are home to diverse animals and plants, including mangrove forests that pepper the coast and serve as vital habitat and carbon storers. A recent survey of one cluster of those islands — the first in 50 years — shows that swelling seas might have led to a massive mangrove expansion, researchers report in the Nov. 8 *Proceedings of the Royal Society B*.

Elsewhere, rising seas have put mangroves at risk (SN: 7/4/20 & 7/18/20, p. 7). But at the Howick Group of islands in the Great Barrier Reef, the story is different because of its unique geologic history.

"We usually are focusing on areas of mangrove loss," says Temilola Fatoyinbo, a forest ecologist at NASA's Goddard Space Flight Center in Greenbelt, Md., who was not involved with the study. "So it's always encouraging to see areas where there's mangrove gain."

Mangroves — groupings of different plants that have adapted to thrive along coastlines — soak up carbon dioxide and store it as "blue carbon," a term for carbon that is sequestered in marine environments (SN: 9/10/22, p. 16).

"There's a lot of interest in using mangrove blue carbon to mitigate climate change," says study coauthor Kerrylee Rogers, an environmental scientist at the University of Wollongong in Australia. "But there remains a lot of questions around [mangroves'] capacity to adapt to sea level rise."

In 2021, a team led by Wollongong environmental scientist Sarah Hamylton

Mangrove cover on Australia's Bewick Island has grown by 50 percent since 1973.

visited the Howick islands to see how the mangroves there are coping with sea level rise. Hamylton flew a drone over the mangroves to capture aerial imagery, while other researchers walked through the brine to assess the plant diversity and measure individual trees. Using the measured widths and heights of several mangroves, as well as the drones' height data, the team extrapolated tree widths for the rest of the forest to estimate the total mangrove biomass.

The islands host nearly 54,000 metric tons of mangroves, the team estimates, which is roughly 10,000 more metric tons than was there in 1973. The forests' reach has also expanded on many islands. For instance, while about a quarter of Newton Island was covered by mangroves in 1973, the forest has now expanded to blanket close to two-fifths of it.

The Howick islands are uniquely suited to supporting mangroves as the ocean rises. Between 20,000 and 6,000 years ago, with glacial retreat, water levels rose around northern Australia, and coral reefs grew upward to fill the newly available space. When sea levels fell thousands of years later, sediment could build up on the exposed reefs. With sea levels now rising again, the researchers suspect the mixture of saltwater and sediment makes a perfect home for the salt-tolerant mangroves.

"As sea level came back down, it wasn't suitable mangrove habitat," Rogers says. With those parts of the island now inundated by the tides, it "is suitable again, and it's largely because it was set up for those conditions [2,000] to 4,000 years ago."

The findings highlight the need for mangrove research on a local scale, Rogers says. "In a global model, this would get lost." Fatoyinbo agrees. "Studies on the local scale are really useful," she says, "to better understand big patterns."

Rogers and Hamylton are now working on a bigger effort to study mangroves around Australia. "If we're going to invest in mangroves … to provide us blue carbon and to protect shorelines, we need to understand how dynamic they are," Rogers says. "And then get some more understanding of how they're going to adapt to sea level in the future." ■

ECOSYSTEMS

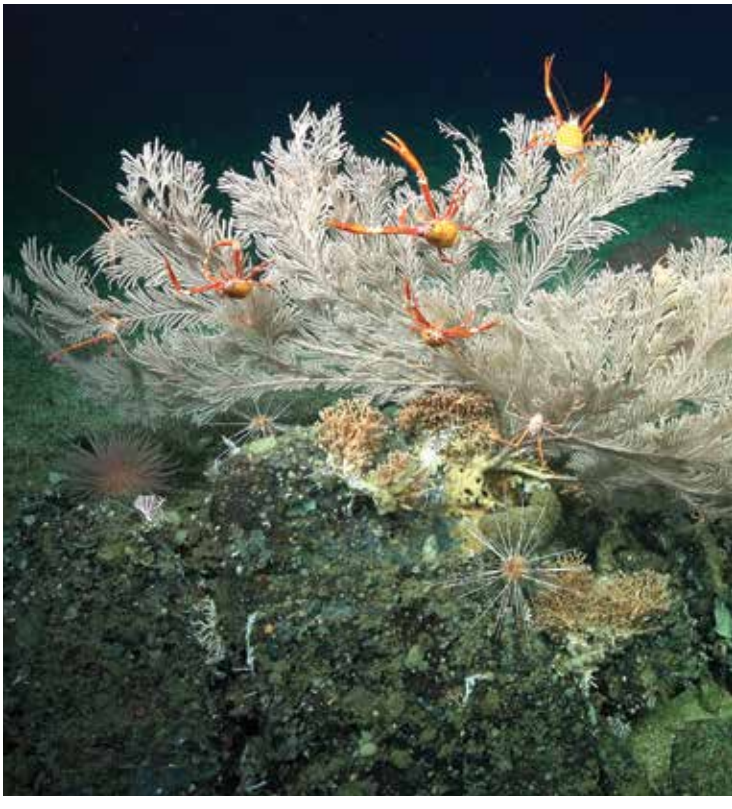
New coral reefs in the Galápagos

Four decades ago, warm waters from an El Niño event killed off nearly all the corals surrounding the Galápagos. Most coral reefs never recovered. But in recent months, researchers have discovered vast landscapes of thriving corals in deeper waters surrounding the equatorial islands.

In April, scientists documented the first known pristine deep coral reef found in the region, dubbed Cacho De Coral (shown at right), which sits atop the ridge of an underwater volcano and stretches about 250 meters. On October 26, another team announced the discovery of an even bigger reef, this one more than 800 meters long, spanning the length of eight football fields.

With coral reefs worldwide in peril due to climate change, the finds are a small piece of good news. Located within the Galápagos Marine Reserve, these newfound reefs have been protected from human influence and the direct impacts of warming waters, probably because they are in such deep water, up to 420 meters below the surface.

Unlike corals that flourish in warm, shallow water with a lot of sunlight to fuel symbiotic algae, deep-sea corals survive in colder, darker parts of the ocean that don't warm up as quickly under climate change. — *Erin Garcia de Jesús*



FROM TOP: OXANA REPINA; SCHMIDT OCEAN INSTITUTE

HEALTH & MEDICINE

CDC tracks more viruses at airports

PCR and wastewater tests now look for dozens of pathogens

Travelers arriving at John F. Kennedy International Airport in New York City and three other major U.S. airports can be tested for over 30 pathogens as part of a monitoring program.

BY BETSY LADYZHETS

The U.S. Centers for Disease Control and Prevention is expanding how it tracks diseases among international travelers, just in time for the fall and winter virus season.

Travelers arriving in four major international airports in the United States now have the option to be tested for more than 30 pathogens, building upon a program that tracks coronavirus variants, the CDC announced November 6.

This expanded testing will continue for several months as a pilot program designed to track respiratory diseases such as seasonal flu. The program will also screen wastewater from airplanes and airports, adding population-level data to information from voluntary nasal swabs.

This program could catch potential health threats that might be "the next COVID," says epidemiologist Sam Scarpino of Northeastern University in Boston. The new data may also inform public health guidance during outbreaks of seasonal viruses like the flu, he says.

Since fall 2021, the CDC's Traveler-Based Genomic Surveillance program has tracked the global evolution of SARS-CoV-2, the virus responsible for COVID-19, through voluntary nasal swab PCR testing at U.S. international airports. In August, the program picked up one of the first known cases anywhere of the new variant BA.2.86, in a traveler returning from Japan. More than 360,000 U.S. residents have participated in the testing as of September 2023.

The airports participating in the program are San Francisco International Airport, John F. Kennedy International Airport in New York City, Boston Logan International Airport and Dulles International Airport near Washington, D.C. Wastewater and PCR testing "complement each other," Scarpino says.

Participants typically don't get their results, but the program gives out at-home rapid tests for SARS-CoV-2.

The expanded program is "a really smart way" to look for new pathogens reaching the United States through international travel, says Rachel Poretsky, a microbiologist and wastewater surveillance expert at the University of Illinois Chicago. She'd like to see testing at more airports plus bus and train stations. ■

ANTHROPOLOGY

Louse DNA hints at host migration

The parasite's genes can give insights into humans' past

BY JAKE BUEHLER

Head lice have been bugging humans for hundreds of thousands of years, and the insects' genes record the story of their hosts' global voyages.

An analysis of louse DNA suggests that the scalp stowaways rode humans to the Americas at least twice — once from Asia many millennia ago, and again much more recently via European colonists, scientists report November 8 in *PLOS ONE*.

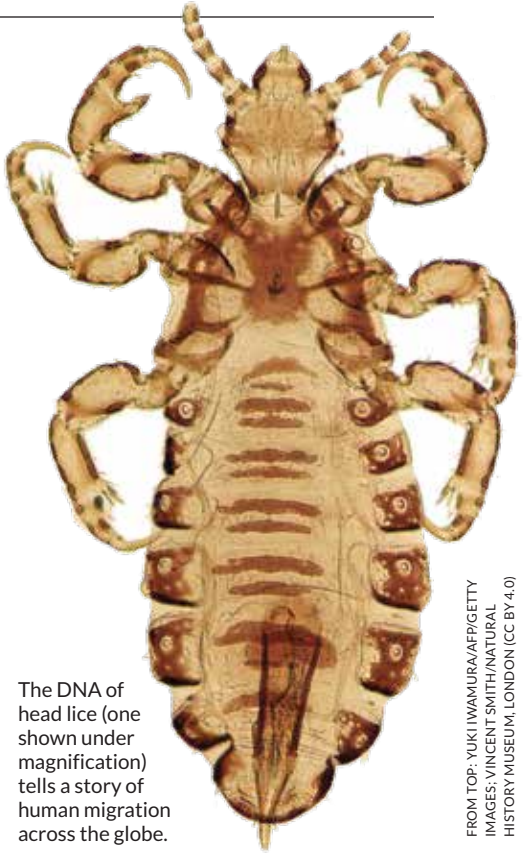
Because head lice (*Pediculus humanus*) can't fly, they are closely tied to the movements of their human hosts, says Marina Ascunce, an evolutionary geneticist at the U.S. Department of Agriculture who is based in Gainesville, Fla.

Ascunce and colleagues compared genes from 274 head lice found on people around the world. The parasites mostly clustered into two genetic groups — one in Europe and North America, and the other in Asia and Central America.

The link between Central American and Asian populations may have resulted from humans crossing a land bridge into the Americas thousands of years ago, the team says. The other group prevalent in North America reflects the more recent colonization of the region by Europeans.

Lice "can help us to see our history," Ascunce says. A closer look at more genes might shed light on how European and Asian lice diverged, and perhaps offer insights into events in human prehistory.

Studying louse evolution could "fast-forward" perspectives on human evolution, says evolutionary biologist Andrew Sweet of Arkansas State University in Jonesboro. Evolutionary patterns might show up in the genes of lice earlier than in humans, because of the lice's quick generations. ■



The DNA of head lice (one shown under magnification) tells a story of human migration across the globe.

FROM TOP: YUKI IWAMURA/AFP/GETTY IMAGES; VINCENT SMITH/NATURAL HISTORY MUSEUM, LONDON (CC BY 4.0)

GENES & CELLS

Human cells might fuel up on phages

Cancer cells that ate bacteria-killing viruses showed growth signs

BY DARREN INCORVAIA

From the nose to the gut, the human body is home to diverse microorganisms. Such rich microbial ecosystems are prime hunting grounds for viruses that infect and kill bacteria. But how these bacteria-killing viruses interact with human cells has remained mysterious.

Previous research has shown that human cells can slurp up these viruses, called phages, when a cell ingests a large amount of the fluid surrounding it. Microbiologist Jeremy Barr and colleagues wanted to know if the ingested viruses have any effect on the cell's immune response. Instead, the researchers found that lab-grown human cancer cells use the viruses as food, the team reports October 26 in *PLOS Biology*.

The finding shows that it's possible for mammalian cells, including potentially noncancerous ones, to use phages as fuel.

The finding upends traditional biological dogma, says Barr, of Monash University in Melbourne, Australia. "You're told that [phages] just do not interact with mammalian cells," he says. "And that's completely false. They do."

Phages are ubiquitous in the human body. Our gut cells ingest up to 30 billion each day, Barr estimates. To test how the viruses interact with mammalian cells, the team grew human and dog cancer cells in an environment flush with T4, a phage that preys on *E. coli*.

Barr and colleagues then used protein-binding antibodies to determine which proteins the cells made in response to the phage. The researchers expected the cells to churn out immune proteins involved in inflammation. Instead, they found that amounts of proteins involved in cell growth increased and amounts of growth-inhibiting proteins decreased. "Cells that had been given phage were actually growing at a faster rate," Barr says. This suggests "they're using the phages as a food source."

Because the cells were grown in a lab and come from established lines of cells used for research, scientists can't yet be sure that cells in the body behave the same way, says immunologist Paul Bollyky of Stanford University. "Cell lines are funny creatures," Bollyky says. "They do things energetically that are probably closer to tumor biology than to normal cell biology, so it can be difficult to extrapolate." Still, he says, "like a lot of good science, this study really raises questions."

Barr next wants to investigate whether noncancerous cells snack on phages. He also plans to examine more phages, including ones that — like T4 — live in our guts and others that are used to treat bacterial infections (SN: 1/15/22, p. 14). "We know they kill the bacterial hosts, but what are they doing to the human host?" he asks. ■

A plunge-diving kingfisher can hit water at speeds of up to 40 kilometers per hour, which risks damaging the head and brain.

ANIMALS

Genes hold clues to kingfisher diving

Genetic tweaks may protect the brain from forceful impacts

BY CLAUDIA LÓPEZ LLOREDA

Genetic tweaks in kingfishers might help cushion the blow when the diving birds plunge beak-first into water to catch fish.

Analysis of the genetic instruction books of kingfishers identified genetic differences between diving and non-diving species. Those changes are in genes related to brain function as well as retina and blood vessel development, which might protect against damage during dives, scientists report October 24 in *Communications Biology*. It's not yet clear how the changes protect the birds.

Diving kingfishers smack into water at speeds of up to 40 kilometers per hour. The amount of force from such impacts could cause concussions in humans, says evolutionary biologist Shannon Hackett of the Field Museum in Chicago. "There has to be something that protects them."

Hackett and colleagues analyzed the genomes of 30 kingfisher species. The plunge divers had evolved the behavior independently rather than from the same ancestor. Perhaps they converged on the same behavior through similar genetic changes. That's what happened among species of birds that lost the ability to fly.

The team found diving-associated changes in 93 kingfisher genes, signaling convergence. One gene that stood out provides instructions for making tau, a protein that normally helps stabilize brain cells and that in people has been linked to concussions and neurodegenerative diseases. The change might help the birds adapt to diving, the team suggests.

The idea that tau mitigates hard impacts in kingfishers is an interesting hypothesis that will take more work to verify, says Tim Sackton, a geneticist at Harvard University.

Hackett agrees. There's a long way to go to understand how genetic changes "turn into what we see in the natural world," she says. "We're just at the beginning." ■

NEUROSCIENCE

Lab rats master a telekinetic task

Moving virtual blocks hints at how the brain imagines places

BY LAURA SANDERS

Like tiny, hairy Yodas raising X-wings from a swamp, rats can lift digital cubes and drop them near a target. But these rats aren't using the Force. Instead, they are using their imagination.

This telekinetic trick, described in the Nov. 3 *Science*, hints at how brains imagine new scenarios and recall past ones.

The research "opens up a lot of exciting possibilities," says neurophysicist Mayank Mehta of UCLA. A deeper understanding of the brain area involved in the feat could help scientists diagnose and treat memory disorders, he says.

Neuroscientist Albert Lee studies how brains mentally time travel by revisiting memories and imagining future scenarios. Those processes are "part of what makes our inner mental lives quite rich and interesting," says Lee, who did the work while at Howard Hughes Medical Institute's Janelia Research Campus in Ashburn, Va.

To dip into this complex subject, Lee and colleagues began with a simple question: Can you be in one place and think about another? "The rat isn't doing anything fancier than that," says Lee, now at Beth Israel Deaconess Medical Center in Boston.

The team trained rats to move on a spherical treadmill in the midst of a 3-D virtual world projected onto a surrounding screen. While the rats poked around their virtual world, electrodes recorded signals from nerve cells in the hippocampus, a brain structure known to hold complex spatial information. This let the team match patterns of brain activity with locations in the virtual world.

Next, the scientists trained the rats to mentally move a cube to a twisty column in the virtual world, using only brain activity patterns in the hippocampus. If the rodents Jedied the cube correctly, they'd get a reward.

The furry apprentices mastered the task. By activating the right patterns of cells in the hippocampus, the rats could concentrate and hold the cube near the column for several seconds as well as virtually transport themselves to the column.

The study provides "strong evidence that rats can use imagination to perform novel, artificial tasks," says neuroscientist Daoyun Ji of Baylor College of Medicine in Houston. "It is likely we humans imagine by activating hippocampal memories too."

Compared with rats, Lee says, "humans can probably control their hippocampus for longer durations with a larger repertoire, and the concepts being encoded in the brain are probably much more complex." ■

PHYSICS

Nitrogen-9 might have made its debut

The elusive atom's lopsided nucleus defies standard definitions

BY ELISE CUTTS

Researchers may have just spotted the elusive, ephemeral nucleus of nitrogen-9 for the first time.

With seven protons and two neutrons, the lopsided atomic nucleus of nitrogen-9 pushes the limits of what can even be considered a nucleus at all. Yet signs of its existence seem to be lurking in years-old data from experiments seeking out a different unusual nucleus, researchers report in the Oct. 27 *Physical Review Letters*.

If follow-up studies can confirm the detection, nitrogen-9 will be the first nucleus spotted with five protons that it cannot stably hold and must expel — until now, the limit was four.

"What are the limits of nuclear existence?" asks Andreas Heinz, a nuclear physicist at Chalmers University of Technology in Gothenburg, Sweden, who was not involved in the study. That's what the study's authors and physicists more generally are trying to understand, he says.

Protons and neutrons, the subatomic particles that make up atomic nuclei, are glued together by the strong nuclear force (SN: 9/10/22, *p.* 4). But the force can't hold together nuclei that have wildly skewed ratios of protons to neutrons. Too many of either particle — especially protons, which repel each other due to their positive charge — and the nuclear bucket starts to overflow.

Beyond this stability point, which physicists call the drip line, nuclei cannot fully bind their particles and must release either protons or neutrons.

"People talk about the drip line as something like the end of the existence of nuclei," says nuclear physicist Marek Płoszajczak of the Grand Accélérateur National d'Ions Lourds in Caen, France, who was not involved with the study.

> "These experiments show that the life of the nucleus extends far beyond the drip line."
>
> MAREK PŁOSZAJCZAK

But nuclei do exist beyond the drip line, if only ephemerally (SN: 11/20/21, *p.* 20). To qualify as a nucleus, protons and neutrons need to hang out together for something like 10^{-22} seconds — a blink so brief that more of these moments fit in a second than seconds fit in the age of the universe. However, that's a somewhat arbitrary definition based mainly on just one previous study, Heinz notes.

Scientists searching for nuclei beyond the drip line are testing that definition. "We're interested in how far you can go before you no longer can consider these things new nuclei," says study coauthor Robert Charity, a nuclear scientist at Washington University in St. Louis.

Finding a nucleus as far beyond the drip line as nitrogen-9 — five protons beyond — was surprising even for Charity and colleagues.

The atoms of any given element each have a fixed number of protons. But the number of neutrons can vary, creating isotopes of the element. Charity's team had been hunting for a different lopsided isotope, oxygen-11, which has three neutrons and eight protons. The team smashed high-energy beams of oxygen-13 nuclei into beryllium targets and measured the decay products of short-lived nuclei produced in the collision.

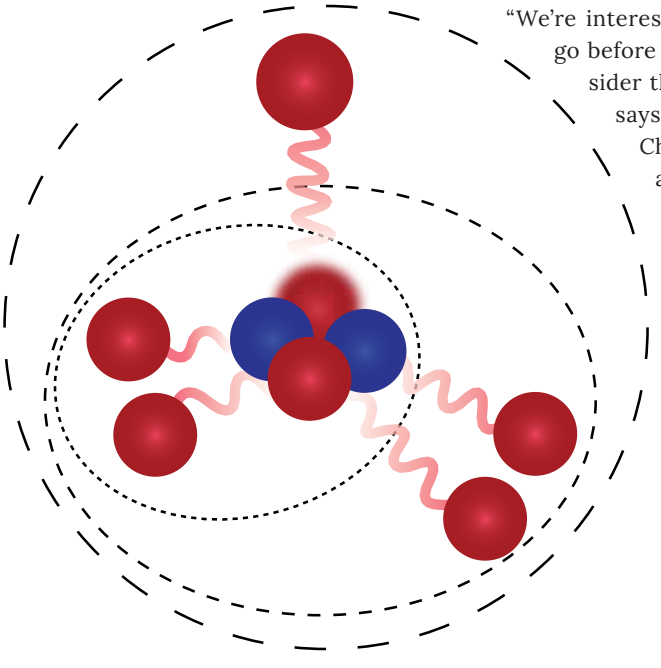
Years after that study, Charity noticed decay products in the data that looked like they could have crumbled away from nitrogen-9 nuclei. His theorist colleagues later confirmed that the decay products could have only come from the isotope. What's more, the data suggest that nitrogen-9 lasts for about 10^{-21} seconds, or about 10 times as long as the minimum cutoff, Charity says.

The statistical strength of the evidence for nitrogen-9 falls just shy of what scientists would consider a discovery. But the team really does have "strong evidence" for nitrogen-9, Heinz says. "For me, this sounds really convincing."

The possible discovery should come as reassuring news to experimentalists looking for other isotopes beyond the drip line, Heinz says.

As for theoretical physicists, the new result should give them a push to improve their models of nuclei beyond the drip line, Płoszajczak says. "These experiments show that the life of the nucleus extends far beyond the drip line."

When it came to nitrogen-9, experiment beat theory to the punch. But better theories could make it possible to start looking for extremely drippy nuclei on purpose, which would, in turn, make it easier to verify theories about how nuclei hold together. When that happens, "we will start to have a kind of a discussion — a talk with nature," Płoszajczak says. "Then, I think the whole field will explode. So we are just at the beginning." ■



T. TIBBITTS

Nitrogen-9's nucleus has two neutrons (blue) and two protons (red) encircled by five protons. As the nucleus decays, it loses the five protons and shrinks (dashed lines).

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SN 10 Scientists to Watch

This year's scientists look to the world and their colleagues

How do we adapt to climate change? Can we fight back against Alzheimer's disease? What will it take to build a more equitable society? The researchers on this year's SN 10: Scientists to Watch list are tackling slices of these and other grand challenges. For the eighth year, *Science News* is recognizing 10 early- and mid-career scientists who have innovative ideas and unique skill sets — and are applying their talents to shape our future and our understanding of ourselves. But they aren't doing it alone. Each credits parents, mentors and colleagues with inspiring their success. Many emphasize the power of collaboration, the value of other perspectives and the importance of mentoring the next generation of scientists. Speaking of the future, if you know someone who belongs on the next SN 10 list, send their name, affiliation and a few sentences about their work to sn10@sciencenews.org.

— Elizabeth Quill, Executive Editor

BLAKE ELIGH/UNIV. OF TORONTO

Lauren Schroeder
PALEOANTHROPOLOGIST
University of Toronto

Human evolution is about so much more than natural selection

Backstory

Lauren Schroeder has loved dinosaurs since age 3 and bones since age 10. During university, she started studying the early evolution of the *Homo* genus and it turned into her Ph.D. Many fossils have taken her breath away, she says, but a 2-million-year-old *Homo habilis* skull holds such a special place in her heart that it's tattooed, opposite a coyote skull, on her inner forearm. "I think I can safely say that I'm doing what I wanted to do," she says.

Schroeder, a paleoanthropologist at the University of Toronto, works to untangle the various processes by which humans have evolved. One such process, natural selection, is adaptive: Changes in an organism's features make it more suited to its environment. But some changes are not selected for, or are even totally random. Despite the existence of these "nonadaptive" processes, paleoanthropology has often focused on adaptation alone. While a Ph.D. student, Schroeder questioned this emphasis. "It was very clear that something was missing," she says.

Standout research

During her Ph.D., Schroeder scanned and analyzed fossil *Homo* skulls dating from 2.8 million years ago until just tens of thousands of years ago. Some features showed a strong adaptive signal; a changing diet likely drove jaw evolution, for instance. But surprisingly, genetic drift, the loss of genetic variation due to the chance disappearance of genes, appeared to be at play in the shape of braincases across the genus, she reported in the *Journal of Human Evolution* in 2017. Such nonadaptive processes may play a bigger role in human evolution than previously realized. "All aspects of Lauren's research have been consequential for the discipline," says biological anthropologist Benjamin Auerbach of the University of Tennessee, Knoxville. "We're witnessing maybe a change in the way we talk about human evolution."

Overcoming obstacles

Schroeder, who grew up in South Africa, remembers noticing early on that most of the paleoanthropological research in her country was conducted by foreign researchers, and the field was "so white." As a Black African woman, "it was such a lonely place, actually, for a long time," she says. Schroeder has struggled to publish papers, received sexist reviews and experienced blatant racism. Some things have improved, she adds, but there is still a long way to go. Schroeder recently secured tenure at the University of Toronto. As the first in her family to attend university, it means a lot to her and her parents. "They don't necessarily get everything I do," she laughs. But "we're in disbelief that I've gotten here." *— Anna Gibbs*

Microscopic machines may one day enter — and help — our brains

Standout research

Deblina Sarkar makes little machines, for which she has big dreams. A nanotechnologist at MIT, she develops ultratiny electronic devices that she hopes will one day enter the brain. Her group's most innovative device so far may be the Cell Rover, a flat antenna that could monitor processes inside cells. For a study published in 2022 in *Nature Communications*, Sarkar and colleagues used magnetic fields to finesse a Cell Rover, roughly the size of a tardigrade, into a mature frog egg cell. The researchers showed that they could make molecules in the nanodevice vibrate at frequencies safe for living cells, and with those vibrations, the device could communicate with the outside world.

Big goal

Sarkar confesses to working day and night on her research. "There is an urgent problem at hand," she says. That problem is Alzheimer's disease, Parkinson's disease and other afflictions that assault the brains of millions of people worldwide. Sarkar hopes her minute machines can someday help detect and reverse these disorders. Machines entering the brain may, for example, spot misfolded proteins that may be early signs of Alzheimer's disease. Cell Rovers could also be paired with nanodevices that harvest energy from and electrically stimulate cells, opening the door for new types of brain electrodes and subcellular pacemakers. Or fleets of remotely controlled devices could replace invasive surgeries — detecting a small tumor growing in the brain, for example, and maybe even killing it. She's essentially establishing a new field of science, at the intersection of nanoelectronics and biology, says collaborator and bioengineering researcher Samir Mitragotri of Harvard University. "There are many opportunities for the future."

Backstory

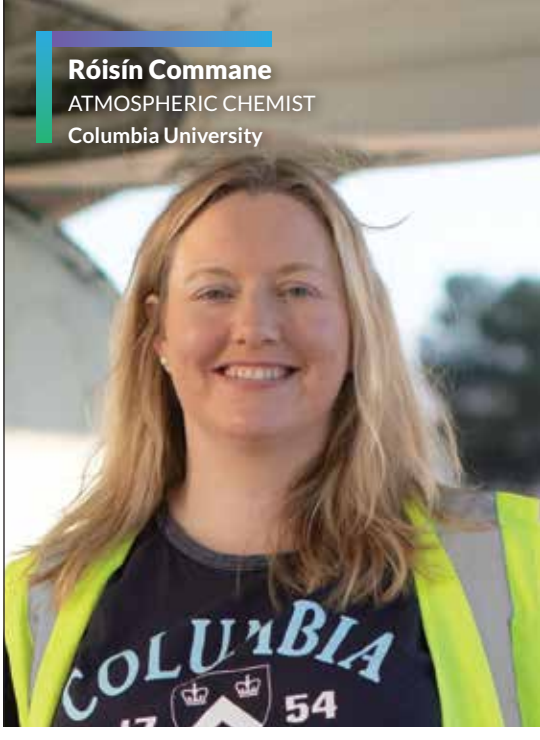
Born in Kolkata, India, Sarkar credits her parents as early inspirations. Her boldness as a researcher comes from her mother, who as a young woman defied social norms by working to fund her own education and speaking out against the dowry system. Meanwhile, Sarkar's father sparked her fascination for engineering. He was always fashioning devices to make home life more convenient, including an electricity-free washing machine and vehicles that could freight hefty loads down local byroads to their house. "That got me very, very interested in science and technology," Sarkar says, "engineering specifically." — *Nikk Ogasa*

Greenhouse gas leaks can't stay hidden for long

Motivation

New York has a greenhouse gas accounting problem. The state broadly tracks its sources of air pollution, from energy production to transportation to waste management, but the books don't always match what's actually in the air. The amount of methane over New York City, for example, is puzzlingly higher than expected. It's a mystery that Róisín Commane is trying to solve.

Part accountant, part sleuth, the atmospheric chemist at Columbia University scours the city from pavement to rooftop looking for unidentified or incorrectly cataloged sources of greenhouse gases. The info could improve our understanding of New York City's emissions and assess how well its reduction efforts are working, Commane says, which could help the city reach its goal of becoming carbon neutral by 2050. "We all have great intentions, but if we can show it's reducing emissions, that's a much more tangible thing."



FROM LEFT: JIMMY DAY/MIT MEDIA LAB; ERINN SPRINGER

Backstory

Commane compares her atmospheric modeling to solving a complicated puzzle. "I've always enjoyed playing with numbers," she says. After studying chemistry and mathematical physics in college, she got a Ph.D. in atmospheric chemistry, learning to build tools that measure atmospheric gases. Atmospheric scientist Steven Wofsy, who advised Commane while she was a research associate at Harvard University, praises her ability to "think about problems holistically."

Her work on Arctic carbon emissions, for example, focuses not just on the summer growing season, like many existing models, but on the winter months too. In warmer years, when the ground freezes later, she has found, the tundra could turn into a net carbon source. That research is "slightly depressing," Commane says. But moving to Columbia in 2018 to start her own lab gave her the opportunity to tackle emissions at their source. "Here, I can do something about it," Commane says.

Standout research

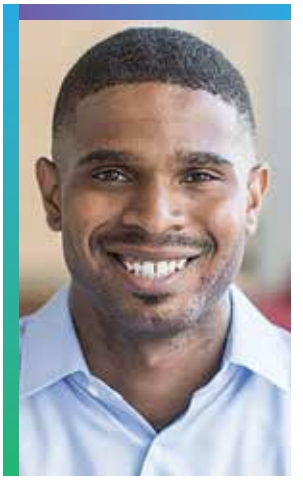
With colleagues at other universities, Commane has developed a network of monitors to sample gases, including carbon dioxide and methane, around New York City and the entire state. The network is helping explain why actual levels of methane in the air above the city are at least three times as high as predictions would suggest. So far, her group has attributed a surprisingly large amount of the excess methane to chimneys and rooftops, likely associated with heating systems. The researchers have also detected localized spikes of methane around certain equipment in now-closed landfills. The largest signals have come from older wastewater treatment plants, Commane says.

On the bright side, refurbished facilities barely produce any methane at all. "The ground truthing that Dr. Commane is doing is really important," says Ellen Burkhard, a senior adviser at the New York State Energy Research and Development Authority, which funds Commane's research. "It's sort of the old adage: You can't manage what you don't measure."
—Jennifer Lu

Lab-made organs are built with tools adapted from Silicon Valley

Backstory

While volunteering at the University of New Mexico's Children's Hospital in Albuquerque, Quinton Smith quickly realized that he could never be a physician. Then an undergrad at the university, Smith was too sad seeing sick kids all the time. But, he thought, "maybe I can help them with science." Smith had picked his major, chemical engineering, because he saw it as "a cooler way to go premed." Though he ultimately landed in the lab instead of at the bedside, he has remained passionate about finding ways to cure what ails people.



Quinton Smith
CHEMICAL ENGINEER
University of California, Irvine

Today, his lab at the University of California, Irvine uses tools often employed in fabricating tiny electronics to craft miniature, lab-grown organs that mimic their real-life counterparts. By combining Silicon Valley tech and stem cell biology, scientists are now "making tissues that look and react and function like human tissues," Smith says. Prodding cells to assemble into these 3-D structures, called organoids, offers new ways to study diseases and test potential treatments.

Standout research

Smith's work began in two dimensions, and with a respect for human induced pluripotent stem cells. These stem cells are formed from body cells that are reprogrammed to an early, embryonic stage that can give rise to any cell type. "It just blew my mind that you can take these cells and turn them into anything," Smith says. During his Ph.D. at Johns Hopkins University, Smith explored how physical and chemical cues can push these stem cells toward becoming blood vessels. Using micropatterning—a technique where researchers stamp proteins on glass slides to help cells attach—he spurred cells to organize into the beginnings of artificial blood vessels. Depending on the pattern, the cells formed 2-D stars, circles or triangles. Since tissue can't grow without them, the ability to make vessels to carry blood or other liquids around the body is the "holy grail" of efforts to build organs in the lab, says biomedical engineer Milica Radisic of the University of Toronto.

While a postdoc at MIT, Smith transitioned to 3-D, with a focus on liver organoids, which have a complex network of bile ducts that can't always be re-created in artificial tissue. To get around the problem, Smith and his team pour a stiff gel around minuscule acupuncture needles to create channels. After the gel solidifies, the researchers seed stem cells inside and douse the cells in chemical cues to coax them to form ducts.

What's next?

Such engineering techniques could help researchers study and pinpoint the root causes behind some liver diseases, such as fatty liver disease, Smith says. But he and his trainees are branching out to explore other tissues and diseases as well.

One of those pursuits is preeclampsia, a disease that affects pregnant people, and disproportionately affects African Americans. People with preeclampsia have an inflamed placenta and constricted blood vessels, and they develop dangerously high blood pressure. Smith plans to examine lab-grown placentas to determine how environmental factors such as physical forces and chemical cues from the organ impact attached blood vessels.
—Erin Garcia de Jesús

COURTESY OF Q. SMITH

How ancient viruses have shaped human history and evolution

Motivation

Smallpox, measles, mumps. These are some of the contagious diseases that European colonists likely brought to the Americas at the turn of the 16th century, prompting the collapse of Indigenous populations. But the exact viruses that caused the millions of deaths remain unknown. Evolutionary virologist Daniel Blanco-Melo seeks to solve that historical puzzle.

Daniel Blanco-Melo
EVOLUTIONARY VIROLOGIST
Fred Hutchinson Cancer Center

Blanco-Melo, of the Fred Hutchinson Cancer Center in Seattle, studies ancient viruses and illuminates how they have shaped human evolution and history. The research holds personal meaning for Blanco-Melo as someone born and raised in Mexico. Through genetic sleuthing, he studies "something that is very dear in my heart," he says, "really understanding, with molecular biology, those historical events."

Backstory

Blanco-Melo's obsession with viruses bloomed in high school with a chance encounter with Matt Ridley's book *Genome*. He'd bought it as a Father's Day gift for his dad but ended up reading it himself. Later, with encouragement from his biology teacher, he enrolled in an undergraduate program in genomics at the National Autonomous University of Mexico, or UNAM, campus in Cuernavaca.

Blanco-Melo had his first encounter with ancient viruses as a Ph.D. student at the Rockefeller University in New York City. His research focused on particular viruses called endogenous retroviruses, remnants of past infectious viruses that have become integrated into a host's genetic instruction book. Amid the genetic remains left behind by an ancient retrovirus called HERV-T that spread among our primate ancestors tens of millions of years ago, he identified one particular gene that stuck around throughout primate history. It encodes a protein that helped the virus enter and infect cells. Studies of cells in a lab dish suggest, over the course of evolution, the virus's own genetic material was used against it. Blanco-Melo hypothesizes that a primate ancestor must have co-opted the viral gene and used the related protein to block entry into cells. "This project not only satisfied my curiosity," he says, "but we were able to push it into a full-blown story."

Collaboration

More recently, Blanco-Melo has teamed up with María Ávila-Arcos, an evolutionary geneticist at UNAM, to study epidemics in the Americas. The researchers extracted and isolated viral DNA from skeletal remains that they dated to between the 15th and 17th centuries. The remains come from mass graves at a colonial hospital and a chapel in what is now Mexico City, and records suggest they belonged to Indigenous people and enslaved Africans who had died in epidemics that occurred during the 1540s and 1570s. From the remains, the team reconstructed the genetic instruction books of two viruses not previously known to be circulating at that time — human parvovirus B19 and a human hepatitis B virus.

The viruses were similar to contemporary African strains and appear to have come from Africa through the transatlantic slave trade. Published in 2021 in the journal *eLife*, the study is "of great scientific and historical interest throughout the world, but especially of interest in the Americas," says Jesse Bloom, a virologist at Fred Hutch who wasn't involved in the work. — *Pratik Pawar*

Don't ignore cooperation as an evolution driver

Backstory

Marjorie Weber has long been drawn to "bizarre and interesting and underappreciated species." As a kid, she liked beetles, roly-polys, earthworms and spiders. But more than individual bugs, Weber, an evolutionary ecologist at the University of Michigan in Ann Arbor, is fascinated by life's richness. How did this vast assortment come to be? Start talking about biodiversity, and she bubbles with questions: Why are there so many different types of flowers? Why are there millions of insect species and relatively few species of sharks? Why did one branch of the tree of life flourish while another withered? "I'm just really passionate about these big biological mysteries," she says.

Since Darwin's time, studies of what drives evolution have focused largely on antagonistic interactions between species, like finches competing for seeds or predator-prey arms races. Yet cooperation appears again and again, Weber says. Her lab looks at how cooperation, particularly between plants and arthropods, drives evolution and biodiversity.

FROM LEFT: COURTESY OF D. BLANCO-MELO; M. WEBER

Standout research

Weber may be best known for her work on extrafloral nectaries. These nectar-filled knuckles bulge from leaves and stems on some plants, leaking sugary snacks that entice ants to stick around and fend off predator attacks. Weber looked at extrafloral nectaries in modern vascular plants and then reconstructed the trait's evolution across ancient species. The trait, she found, was a recipe for evolutionary success. Once the sweet structures evolved in a branch of the plant family tree, that branch quickly accumulated more species.

"Somehow, possessing extrafloral nectaries leads to diversification," says Judith Bronstein, an evolutionary ecologist at the University of Arizona in Tucson. "And that's a fantastic avenue for future research." Weber's work stands out because she's able to braid separate scientific threads into something "completely new and completely different," Bronstein says. "That's how you trailblaze in our field."

Inclusivity in science

Weber is blazing trails elsewhere too. In 2018, she cofounded Project Biodiversify, a program to make biology education not only accurate and compelling, but also "as equitable and inclusive as possible," she says. As a student growing up in Grosse Pointe, Mich., she didn't see examples of women scientists, and she never thought about science as a career option. A biology course with spider scientist Greta Binford at Lewis & Clark College in Portland, Ore., changed that. "Knowing that was a job and watching her do it was just incredibly life-shaping for me," Weber says.

Years later, after Weber had her own lab, she and colleagues decided to investigate how well college biology textbooks represented a diverse set of scientists. The results, reported in *Proceedings of the Royal Society B* in 2020, called out the stark demographic mismatch between scientists featured in textbooks (mostly white men) and the students using them. Weber's team works to bridge that gap by developing resources for teachers that highlight a diverse group of role models in biology. — *Meghan Rosen*

MELANIE GONICK

Clara Sousa-Silva
QUANTUM ASTROCHEMIST
Bard College

Will life in alien atmospheres reveal itself through molecular signatures?

Big goal

Clara Sousa-Silva is looking for aliens, but she is not hunting them. She finds that idea "very distasteful," she says. "I have spent my life…trying to let go of the notion that I have to go somewhere to know it, that I have to touch it to know it's real." A quantum astrochemist at Bard College in Annandale-on-Hudson, N.Y., Sousa-Silva studies how molecules in space interact with light, essential groundwork for figuring out what distant objects are made of. One day, she hopes her work will help identify traces of life in the atmospheres of alien worlds, including worlds humankind will almost certainly never visit.

"Molecules behave on a quantum level, and they interact with light on a quantum level," Sousa-Silva says. "I'm using quantum behavior of molecules — so, chemistry — to study space." Though these quantum interactions play out on tiny scales, they leave traces in starlight's spectrum, the chart of intensity at different wavelengths. Scientists can read spectra like a chemical bar code to identify the molecules the light encountered before reaching Earth.

Standout research

During her Ph.D. at University College London, Sousa-Silva simulated the light spectrum of phosphine. The simple molecule, her absolute favorite, is considered a potential biosignature because it's easily made by life but considered unlikely to form on a lifeless, Earthlike planet. "I know no one else who is so knowledgeable about one molecule — any molecule," says astronomer Adam Burgasser of the University of California, San Diego. So when astronomers thought they might have detected the toxic gas in Venus' atmosphere, they knew who to call. A team including Sousa-Silva announced in 2020 that they'd detected phosphine there — which many interpreted as a possible sign of life on the planet. The detection and its interpretation have since been called into question (SN: 11/21/20, *p.* 16), including by Sousa-Silva herself, but the claim got scientists more interested in the molecule. As interest grew, Sousa-Silva's deep expertise "really put her on the map," Burgasser says.

What's next?

While Sousa-Silva still spends much of her time puzzling out molecular spectra, she has plenty else on her agenda. One of her students is working on a new way to quantify how certain astronomers can be that they've detected a gas — any gas — in a planetary atmosphere based on spectral data. Sousa-Silva also wants to find better ways to talk with the public about the uncertainties of biosignatures. "There's an expectation that if we find aliens, we'll know — we'll be so sure. And that is so deeply unlikely," Sousa-Silva says.

And she is focused on mentorship too. In the long term, she sees her students leading more and more research. But she wouldn't mind leading some "less respectable" science projects. For instance, there's some evidence that will-o'-the-wisps, those bobbing ghost lights from folklore, might be phosphine-powered fireballs. Though alien hunting is still off the table, she says, "I really would like to do some ghost-busting." — *Elise Cutts*

A new cosmic 'ruler' could size up an early epoch of the universe

Big goal

Julian Muñoz has come up with a ruler to measure the early universe. A theoretical physicist, Muñoz studies the distant, dim period in the universe's history known as cosmic dawn. That's when stars first began flickering on, a few hundred million years after the Big Bang, infusing the universe with initial glimmers of starlight and forming the first galaxies. Before the first stars, the universe was cold and dark—as Muñoz describes it, "boring." Then, starlight began to reshape the universe.

"It is a very dramatic epoch," says Muñoz, of the University of Texas at Austin. That epoch is also poorly understood; Muñoz compares it to an uncharted area on early maps of Earth. There, Muñoz says, "there could be dragons." By studying this era, he hopes to reveal the behavior of one dragon of the cosmos, dark matter, the inscrutable substance whose mass binds galaxies.

Standout research

Scientists have a variety of methods to measure distances in the cosmos, but none reach back to the cosmic dawn era. That's where Muñoz's ruler comes in. "He's got an eye for interesting ideas," says theoretical physicist Marc Kamionkowski of Johns Hopkins University, Muñoz's Ph.D. adviser. But the cosmic ruler, "that's probably the most singular idea that he's had."

As the first stars of the cosmic dawn formed, their light heated the surrounding hydrogen gas, causing it to absorb light with a wavelength of 21 centimeters, a number that results from the separation between energy levels in hydrogen atoms. If it can be detected, this absorption signal should have subtle, ring-shaped patterns imprinted in it, Muñoz reported in 2019 in *Physical Review Letters*. Those patterns, the basis of his ruler, result from the differing behavior of dark matter and normal matter during an even earlier period. Though too subtle to pick out by eye from the data, the rings show up in statistical analyses and have radii of half a billion light-years—making for one long measuring stick.

This standard ruler could reveal how fast the universe was expanding during cosmic dawn. That information can tell scientists what the youthful universe was made of, revealing the amount of dark matter, normal matter and dark energy, another hidden piece of the cosmic puzzle.

Backstory

Becoming a physicist, in itself, was uncharted territory for Muñoz. As a child, he liked science. He recalls being amazed by fossilized shark teeth that were millions of years old—perhaps his first experience grappling with such grand timescales. But Muñoz didn't have a scientific role model; his parents didn't finish high school. He focused his attention on video games and coding until a high school physics teacher encouraged his scientific streak. He turned to physics, he says, where "it was possible to channel all this nerdy energy for knowledge." That's what drives Muñoz to explore the questions that swirl around dark corners of the cosmos. "I do it because I think the answers enrich the human experience."

—*Emily Conover*

Preventing the social harms of genomics research

Backstory

For five summers beginning in college at Stanford University, Daphne Martschenko worked at Camp Phoenix. The camp, for youth from low-income backgrounds in the San Francisco Bay Area, focuses on "joyful learning in an outdoor camp environment," she says. The experience ignited her passion for making education more equitable for students, regardless of their race or socioeconomic background. She ultimately pursued a Ph.D. in education, but today her work goes beyond that field. Now a bioethicist at Stanford, Martschenko is interested in how findings from social and behavioral genomics—the study of how genetic differences among individuals influence complex behaviors and social outcomes—affect society at large, including inequity and injustice and how we respond to them.

Motivation

With abundant access to genetic information, researchers can ask new questions about what influences human behavior. But such studies can be prone to bias and can be misinterpreted or co-opted to promote unscientific and even harmful ideas. Today's science tells us that race has no basis in genetics, but genetics has been invoked throughout history to justify slavery, racial discrimination, forced

FROM LEFT: NOLAN ZUNK/THE UNIV. OF TEXAS AT AUSTIN; MAGDALENE COLLEGE, CAMBRIDGE, UNITED KINGDOM

sterilization and more. Martschenko's work focuses on how genomics research can be conducted in a social and ethical way, can include community engagement and can be clearly communicated. She looks at the downstream effects of the research, especially social harms, and develops strategies to prevent those harms. She wants to stop "the unintended consequences of our research from playing out," she says.

Martschenko's Ph.D. work explored how genomics research on cognitive abilities and educational attainment affects how teachers think about their students, and how relevant it is to their teaching. There's a tendency to think of students in certain racial groups as "not having certain abilities," she says. She wanted to "contribute to disrupting those harmful narratives."

Standout research

More recently, Martschenko has helped create a reading list that draws on scientific papers to explore how people think about the relationship between race and genetics. She has built a publicly available repository of open-access FAQs on genomics studies that aims to communicate the context, scope and limitations of studies and so help prevent misinterpretation and misapplication. "The idea of getting out in front of the controversy and explaining things in a clearer way," says bioethicist Steven Joffe of the University of Pennsylvania Perelman School of Medicine, "I think that's the key attribute of her work."

One strategy Martschenko employs is called adversarial collaboration, which invites people with opposing viewpoints to collaborate. Another theme of her work is community engagement. She seeks ways for study participants to be equal partners with researchers. Getting people together, particularly those who haven't been historically included in conversations around how to study genetics and behavior, helps make science more inclusive and equitable, Martschenko says. "We need more marginalized representation in research," she adds, and building trust and access is key. —*Martina G. Efeyini*

EMILY WALKER

Boosting photosynthesis might be a big win amid climate change

Backstory

Berkley Walker didn't plan on becoming a scientist; he wanted to be an entrepreneur. In high school in Portland, Ore., he started a granola bar company, which helped pay for his bachelor's degree in microbiology. After college, Walker worked as a product manager at a company, planning to go to business school and then into biotech. But a class on environmental biophysics during that time changed his trajectory. The course was about using mathematics to model physical systems in nature. "Working that math out to understand how energy and matter exchange within the environment," Walker says—that was all it took. He decided to pursue plant science. "I wanted to have some kind of usefulness to the world," Walker says. "Feeding people is where I settled."

Berkley Walker
PLANT SCIENTIST
Michigan State University

Big goal

Today, at Michigan State University, Walker seeks to understand the details of photosynthesis, with the aim of improving it. It's a surprisingly inefficient process. A leaf converts just about 1 percent of the sun's light into usable energy, Walker says. In part that's because of mistakes in the first step of photosynthesis. The enzyme that captures carbon dioxide molecules and sticks them to sugar often grabs oxygen instead. That error results in a compound that actually inhibits photosynthesis. Photorespiration, a kind of recycling process, gets rid of that compound—but photorespiration requires a lot of energy. Any efficiency gains in photosynthesis or photorespiration could make a big difference in agricultural productivity, he says.

To better understand both processes, Walker came up with an innovative technique to trace carbon in leaves, research published in 2022 in *Nature Plants*. His group was using flux analysis, which reveals how molecules move through the metabolic network. But the team needed a better way to freeze the metabolism of a plant for snapshot views. The problem was, there was no way to spray liquid nitrogen into the instrument chamber that held the leaves. After talking to engineers at the company that makes the instrument, Walker decided to drill a hole in the chamber to insert a nozzle to spray in liquid nitrogen and hit the leaf instantaneously.

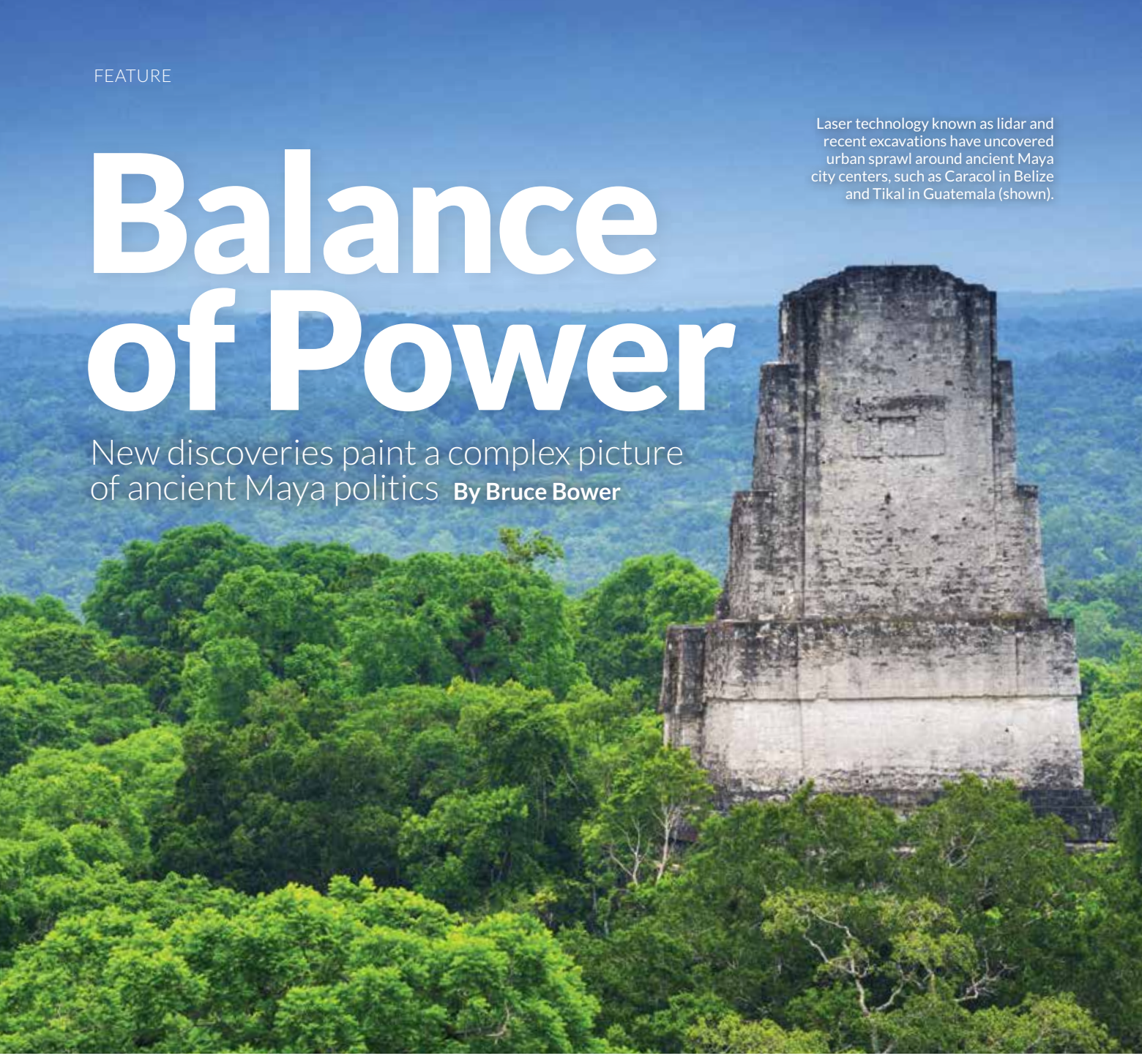
"That's a really critical step," says Xinyu Fu, a postdoc in Walker's lab.

The team found that up to about 40 percent of the carbon-bearing amino acid serine produced during photorespiration gets diverted to be used for something—perhaps protein synthesis. That points to potential trade-offs to be aware of in trying to enhance the processes.

Superpower

Walker's colleagues point to his eagerness to collaborate as one of his strengths, along with his generosity of spirit. Don Ort, a plant scientist at the University of Illinois Urbana-Champaign and Walker's postdoc adviser for nearly three years, says Walker is a committed teacher and colleague. "He's very passionate about what he does. He does it with a very high level of enthusiasm and a very high level of optimism," Ort says. "And it's infectious."

Walker sees plant science as one big community trying to solve two big problems: how to make crops more productive to feed a growing population, and how to do it in a changing climate. And he believes we'll start seeing solutions in the coming decades, whether from his lab or someone else's. —*Aaron Brooks*



Laser technology known as lidar and recent excavations have uncovered urban sprawl around ancient Maya city centers, such as Caracol in Belize and Tikal in Guatemala (shown).

Balance of Power

New discoveries paint a complex picture of ancient Maya politics

By Bruce Bower

Pots with fancifully molded eyes, noses and mouths were one of the tip-offs.

Adrian Chase already had a growing sense that Maya society wasn't quite what it's been traditionally portrayed as: powerful rulers reigning while powerless commoners obeyed — or perhaps lived far enough from seats of power to operate largely on their own. Work by Chase and others had started to create a picture of a more politically complex society.

An archaeologist at the University of Chicago, Chase leads excavations of residential sites in and near the ancient Maya city center of Caracol in what's now Belize. This city once sprawled across valleys, hillsides and hilltops. At its height, Caracol stretched 240 square kilometers, about the size of Milwaukee, before it was abandoned and swallowed by the forest.

Accumulating archaeological evidence had convinced Chase that shared social practices, such as placing pottery and other ritual items in special shrines, bonded groups of farm families into dozens of distinct neighborhoods within Caracol's urban sprawl.

Consider those face-decorated pots. Varying shapes and spacings of molded eyes and other facial features added up to signature ceramic looks at different neighborhood-linked shrines. And those pots were just one element of a range of shrine offerings — including three-legged plates, curved jars with thin necks, and small medicine bottles and paint pots — that

THEPALMER/E+/GETTY IMAGES PLUS

neighborhoods appeared to combine in distinctive ways.

And then there were the teeth. Individuals buried at some neighborhood shrines had either carved jade nuggets implanted in their teeth or their teeth filed in one of two styles. No such dental decorations appeared among the dead interred at other shrines. Various tooth alterations further defined neighborhood-specific shrine practices.

Pottery styles and tooth alterations together formed patterns specific to neighborhoods, Chase says. "There is a community aspect to these finds that reflects tight-knit neighborhoods."

Caracol citizens, including those who lived well beyond downtown temples and pyramids, were not simple farmers growing crops in the service of a king, Chase suspects. Groups of as many as several hundred people had formed farming neighborhoods that built local ritual structures and followed distinctive ceremonial practices, apparently through their own collective efforts.

Neighborhoods, in turn, belonged to administrative districts with ties to royalty and other downtown political big shots. Stone compounds scattered throughout the city — each with their own ceremonial centers and plazas that probably hosted marketplaces and ritual events attended by crowds from nearby neighborhoods — represented districts' bureaucratic service centers.

Neighborhoods and districts formed rungs of a political system in which central rulers sometimes gained power and laid down the law. At other times, royal dynasties crumbled and lower rungs in the political hierarchy assumed primary control.

Chase's findings at Caracol have contributed to a shift in thinking about ancient Maya societies that has intensified over the last decade.

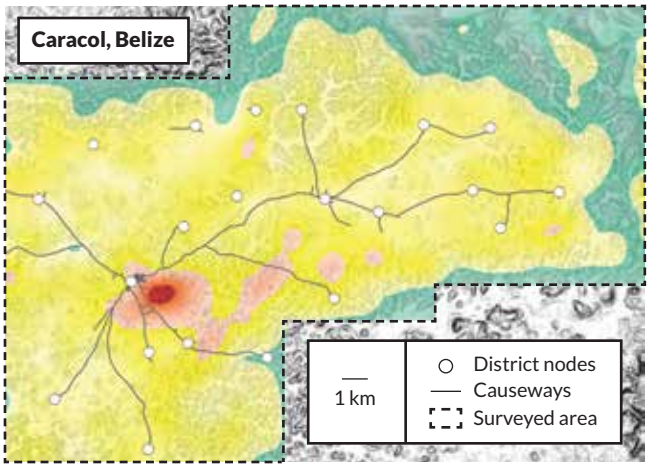
These societies, which originated as early as around 3,000 years ago, came to be known for giant stone pyramids, vast plazas and elite ballcourts discovered at jungle sites across Mesoamerica, a cultural region that extended from central Mexico to much of Central America before Spanish contact in the 1500s. These edifices had long suggested to researchers that Maya rulers wielded absolute power. So did hieroglyphics carved on stone slabs, which described kings' exploits.

But expanded archaeological research, ongoing translations of Maya writings and the rise of airborne laser technology that sees through jungles are revealing a vast urban sprawl around major Maya ceremonial sites. Similarly extensive, low-density settlements have recently been discovered in other tropical areas around the world previously known only for giant ritual structures, such as Cambodia's Angkor Wat temple (*SN: 5/14/16, p. 22*).

Among the Maya, shifting circumstances would have tilted the balance of power. For instance, rural population booms might strengthen the hand of neighborhood-level elites. Military defeats of a royal dynasty could shift power to midlevel, district officials.

"A lot of Mesoamerican settlements probably had nested units of power," Chase says. "There was no simple division between Maya elites and commoners."

A. CHASE



Linked in Causeways linked many administrative centers (district nodes) within Caracol. At its peak of about 100,000 residents, estimated population densities reached over 1,000 people per square kilometer in the city center (dark red; lower densities in pink, yellow then green).

Vaulted ambitions

Laura Gilabert-Sansalvador did not have Mesoamerican politics on her mind in 2013 when she began studying stone palaces at La Blanca, an ancient Maya site in Guatemala. But her project ended up providing insights into not just physical structures, but also power structures.

Working toward a doctorate in architecture, Gilabert-Sansalvador wanted to decipher ancient techniques for erecting roofs on structures ranging from huts to temples.

Large rooms inside La Blanca palaces featured vaulted roofs, a tricky technical feat that Maya stonemasons worked to improve for more than 1,000 years. Inspired by La Blanca's artfully angled room toppers, Gilabert-Sansalvador launched a project to draw, digitize and analyze vaulted buildings throughout the Maya lowlands of southern Mexico and Guatemala.

Vaulted structures featured two horizontal stone walls topped by rows of stones arranged to angle inward and meet at a central row of stones, creating an inverted V- or U-shaped roof.

Because Maya vaults required thick, load-bearing walls, they rarely exceeded 3 meters in width. Long, narrow vaulted structures in urban centers were often connected to form rectangular, oval or L shapes around courtyards. Some sites from the Classic Maya period — which ran from about A.D. 250 to 900 and is considered by many to be the zenith of the Maya civilization — include small numbers of vaulted stone buildings. These structures were much fancier and sturdier than farmers' huts and thus researchers suspect high-ranking officials lived there. Other Classic Maya sites contain a high percentage of vaulted structures that may have served a variety of purposes, including storing important objects, hosting feasts and housing elites.

With her doctorate and a database of measurements for the remains of 200 vaulted stone buildings in hand, Gilabert-Sansalvador arrived at Tulane University's Middle American Research Institute in New Orleans in 2021 as a visiting researcher. There she met Tulane archaeologist Francisco Estrada-Belli, who viewed her

In the urban sprawl of Maya cities, farmers may have lived in thatched-roof huts (similar to the modern one, top). Nobles or local officials may have lived in vaulted stone buildings (one at Tikal, bottom).

architectural expertise as essential for solving a Maya mystery.

Estrada-Belli had spent two decades excavating small structures that had been covered in dirt over time on forest floors at several ancient Maya sites. Some structures retained only plaster floors, consistent with having been farmers' huts made of thatch and wooden poles that had long since decayed. But others were bordered by remains of thick stone and mortar walls, raising questions about who had lived there.

In reviewing aerial images of ancient Maya buildings across southern Mexico and Guatemala, Estrada-Belli had surmised that earth-covered mounds at least 1 meter tall corresponded to the rubble of collapsed stone structures, including those with vaulted roofs, like the ones he had excavated. But he could not be sure.

Gilabert-Sansalvador's database offered an opportunity to evaluate that suspicion with lidar, short for light detection and ranging. In archaeology, airborne lidar technology uses laser pulses to detect remains of ancient structures and objects otherwise hidden by forests and ground cover. Lidar has revealed general features of interconnected Maya cities and extensive rural drainage channels and terraces dating to at least 2,300 years ago (*SN: 10/27/18, p. 11*).

The challenge was to develop a geometric measure of collapsed vaulted structures that lidar could detect.

Welcome to the neighborhoods

In 2021 and 2022, Gilabert-Sansalvador, now at the Polytechnic University of València in Spain, joined Estrada-Belli and three other researchers to review measurements in her database plus measurements of another 251 vaulted structures collected by other excavation teams. Those buildings come from throughout Maya territory, from southern Mexico and Central America to as far north as the Yucatán Peninsula.

Inspecting the entire sample of 451 structures, the researchers found that collapsed vaulted buildings had a much higher volume of rubble, formed taller mounds and had steeper sides than same-sized buildings made of perishable materials, such as thatched-roof huts.

To verify that these mound dimensions spotlight only crumpled stone structures with vaulted roofs, the team examined stone buildings previously identified in excavations and ground surveys at the Classic Maya site of Tikal in Guatemala. Overall, the researchers' method correctly distinguished between remnants of vaulted and nonvaulted structures, such as ballcourts lined by stone walls, ceremonial buildings and inscribed stone monuments, up to 97 percent of the time.

Confident in the method, the team then analyzed 11 lidar datasets that covered Tikal and seven other Classic Maya urban centers, along with several rural territories. Lidar analyses encompassed a total of around 60,000 square kilometers, nearly the area of West Virginia. About 111,000 previously identified structures were analyzed for signs of having been built with vaulted roofs.

A picture emerged of clusters of vaulted stone buildings, typical of ruling elites' houses in major centers. But they were in farming communities as far as five kilometers from the nearest urban core. As lidar images of rural stone compounds accumulated, Estrada-Belli felt increasingly surprised: "We checked our tests many times and concluded that this result was in fact correct."

Small groups of huts, possibly occupied by extended families of farmers and other settlers, encircled shared plazas. Neighborhoods were made up of sets of huts clustered around stone buildings, which may have housed low-level nobles or other elites, the researchers reported in the September *Journal of Archaeological Science*. Sets of neighborhoods, in turn, clustered around large stone structures that may have housed higher-ranking officials, to form administrative districts.

"We now have quantitative measures of ancient Maya neighborhoods, which have been hard to define or identify," Estrada-Belli says.

Urban sprawl managed by low- and midlevel officials flourished despite a lack of horses and wheeled vehicles, Estrada-Belli says. Transportation consisted of walking and river travel.

Raised roads, or causeways, ran from farmsteads, neighborhoods and districts to urban centers, making foot travel easier and pit stops convenient. Public plazas dotting the countryside hosted ritual gatherings and served as marketplaces. Rural elites' duties included mediating local disputes and organizing community projects such as reservoir and causeway construction, Estrada-Belli suspects. In exchange, local officials

BOTH: L. GILABERT-SANSALVADOR

probably collected taxes on market transactions.

Toward the end of the Classic Maya period, from around A.D. 600 to 900, local political authorities lived among many farming communities, Estrada-Belli says.

Any lingering suspicions that Maya farmers played no part in political decisions that affected their daily lives do not hold up, he contends. "We can now talk about one common model of urban organization among the Classic Maya that included the less populated countryside," Estrada-Belli says. Maya political elites directed the construction of stone compounds at prominent locations in interconnected neighborhoods and administrative districts. This highlights the importance of central rulers in forming and running these complex political systems, he suspects.

Even among researchers impressed by the new lidar findings, though, some doubt that multilayered political systems always revolved around a king or elite political power brokers, as proposed by Estrada-Belli.

Some ancient Maya cities featured collective actions by local communities while others emphasized royal edicts, these investigators contend. And the same community could dramatically alter its political system as times and conditions changed.

Political variation across sites fits with archaeological and lidar discoveries over the last two decades that challenge a popular idea that Classic Maya cities collapsed rapidly around A.D. 900, over a span of 50 to 100 years. A group of 15 Maya researchers summarized these recent findings July 24 in the *Proceedings of the National Academy of Sciences*.

Residents of Maya urban centers often found ways, whether through local or centralized decision making, to survive droughts and military defeats previously thought to have been society killers, research now suggests. Major sites suffered population losses over as many as 100 to 200 years before emptying out.

At that point, Maya people who had developed a taste for social and political flexibility established towns and smaller cities elsewhere. Maya culture soldiered on after Classic period cities lost their appeal.

Why urban centers turned into ghost cities over a couple of hundred years, some more quickly than others, is poorly understood. That raises questions about precisely who lived in Estrada-Belli's newly identified Maya stone structures and what they were up to.

Mystery officials

Excavations of those stone structures, guided by the lidar findings, will help to clarify who lived there.

Some occupants of rural vaulted structures may have belonged to noble lineages that served the royal interests, says anthropological archaeologist Andrew Scherer of Brown University in Providence, R.I. Ancient DNA evidence indicates that rulers of a 2,000-year-old nomadic empire in Asia followed a similar strategy, sending members of royal lineages to oversee distant territories.

But Maya rural elites may have acquired wealth and power in local communities without being appointed by a paramount ruler, Scherer cautions. If so, it's not clear who, if anyone, pulled the strings of neighborhood and district officials.

Advances in deciphering Maya writing and ongoing excavations indicate that midlevel authorities wielded considerable power at rural settlements aligned with urban centers such as Tikal, says anthropological archaeologist John Walden of Harvard University. Midlevel elites ran public rituals and feasts, hosted marketplaces and maintained diplomatic ties with their counterparts in nearby communities, Walden concluded in the Spring 2023 issue of *The Mayanist*.

It's an open question whether some vaulted structures served as homes for heads of local kin groups or clans that prioritized their own interests over those of kings and urban big shots, Walden says.

But the new lidar findings underscore a central point, Scherer says. "Authority in some fashion was dispersed on the landscape and not clustered in Maya civic ceremonial centers."

Garden city makeovers

At Caracol, one of the largest Classic Maya cities, authority took chameleon-like turns, Chase says. "Caracol shifted between more collective and more autocratic systems of governance over its 1,500-year life span," he says. "The city experienced great transformations and changes as it grew."

Chase has reconstructed Caracol's wild historical ride using an array of evidence accumulated over the last four decades, including deciphered Maya written records carved on stone slabs, archaeological finds and lidar imagery. His conclusions appear in the 2023 *Research Reports in Belizean Archaeology* and

Excavated pots displaying different types of stylized face decorations (one shown) provided archaeologist Adrian Chase with clues to identifying neighborhoods in the urban sprawl of the Maya city of Caracol.

IMAGE PROVIDED BY THE CARACOL ARCHAEOLOGICAL PROJECT

View from above In this lidar image of the ancient Maya site of Campeche on the Yucatán Peninsula, archaeologists discovered vaulted structures (red outlines), nonvaulted structures (black outlines) and agricultural terraces (green lines).

in a chapter of an upcoming book that he coedited, *Ancient Mesoamerican Population History*. For instance, carved hieroglyphics include dates when specific rulers assumed power and won or lost battles with kings of rival cities. And lidar maps have guided ongoing excavations of farming sites outside Caracol's city core.

Chase's own connection to Caracol began before he could talk. His parents, anthropological archaeologists Diane Chase and Arlen Chase, both at the University of Houston, brought him there every year, starting as an infant, after launching a Caracol fieldwork project in 1985.

As a high school junior steeped in archaeology, Chase helped run a Caracol excavation. Now he oversees multiple excavations and on-site lab investigations of unearthed artifacts.

Caracol started out small too. Around 600 B.C., three villages collectively built reservoirs, causeways and ceremonial sites. Residents of the villages formed a single site that was governed without central rulers for about 700 years. A royal dynasty assumed power in A.D. 331. Successful wars against the nearby cities of Tikal and Naranjo between 553 and 680 sparked a population boom. A minimum of 100,000 people inhabited Caracol at its peak.

Urban and rural areas coalesced into a "garden city," Chase says. He has mapped 373 neighborhoods, each linked to a nearby public space that hosted market and ritual events. In each neighborhood, residents carved agricultural terraces out of adjacent hillsides and constructed small reservoirs. Groups of neighborhoods formed 25 districts, each containing a monumental center with reservoirs, ballcourts or other large structures that provided public services, he reported in the June *Journal of Anthropological Archaeology*.

Chase ended up defining neighborhoods not just by combinations of pottery offerings and dental practices, but also by distances of farmers' huts to the nearest district plaza. Farmers who would have walked similar routes over Caracol's rugged hills to district sites presumably forged ties on those trips, which cultivated feelings of belonging to neighborhoods with common practices, such as leaving certain types of offerings at local shrines, Chase suspects.

Naranjo's military defeat of Caracol in 680 ushered in roughly a century of decentralized government, Chase says. "Faceless administrators" who went unnamed in Maya writings oversaw taxation and the provision of services to urban communities. Policies at that time led to widespread wealth, community-wide ritual ceremonies and relatively equal access to market products and agricultural land.

New rulers who aligned themselves with powerful Maya gods assumed power in 798. These kings instituted autocratic policies and oversaw a sharp rise in wealth disparities. Those developments may have instigated a population exodus from Caracol. By 900, the garden city had been abandoned.

Estrada-Belli suspects a system of Caracol neighborhood and district officials operated out of regularly spaced, elite residences, much like the compounds of vaulted structures his team has identified elsewhere. Plans are in the works to probe lidar data at Caracol for signs of collapsed vaulted structures in or near previously identified neighborhoods, Chase says.

Classic-era sites in the northern Maya lowlands of the Yucatán Peninsula, which generally have drawn less scientific attention than Classic Maya sites to the south, also deserve closer lidar scrutiny. Vaulted structures still stand at some of those centers, including large sites such as Chichén Itzá, Estrada-Belli says.

New excavations guided by lidar discoveries, and lidar analyses informed by the dimensions of excavated buildings, may clarify Classic Maya power structures at sites on the Yucatán Peninsula.

The layering of authority and its reach across ancient Maya urban areas is just beginning to emerge from a forested shroud. ■

Explore more

- Francisco Estrada-Belli *et al*. "Architecture, wealth and status in Classic Maya urbanism revealed by airborne lidar mapping." *Journal of Archaeological Science*. September 2023.

F. ESTRADA-BELLI *ET AL*./*JOURNAL OF ARCHAEOLOGICAL SCIENCE* 2023

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As the capabilities of large language models and other forms of generative artificial intelligence grow, teachers must continue to navigate a changing educational landscape. Instead of regarding this new technology as an obstacle, it is vital to explore how to leverage it as an asset that can inspire creativity while improving student outcomes.

This was the focus of Gabriella Waters' keynote address at the 2023 Middle School Research Teachers Conference, produced by Society for Science, which publishes Science News. Waters is the Director of Research & Operations at the Center for Equitable Artificial Intelligence and Machine Learning Systems at Morgan State University in Baltimore, Md. In her speech, Waters explored the fascinating history of AI. She also shared concrete strategies for educators to incorporate AI ethically and equitably into their instruction—from individualizing study plans to collaboratively workshopping prompts to jump-start inspiration.

This year's conference (shown above) welcomed 75 middle school STEM educators from across the United States for an immersive weekend of peer-led professional development.

For more information: www.societyforscience.org/MS-research-teachers-conference

SCREENTIME

Landscape Explorer transports you back to a more wild West

With the click of a mouse, a new mapping tool shows how places in the American West have changed over the last 70 years.

With just a Web browser, anyone can open Landscape Explorer (landscapeexplorer.org), which will pull up a modern Google map of the United States beside a black-and-white aerial image of the western states circa 1950. A slider button allows for scrolling back and forth between past and present.

You can type a place or address into the search bar, then zoom in or out. Search for "Lake Powell" and watch the Colorado River's red rock canyons of the past turn into a reservoir. Type in "Las Vegas" and see Sin City's sprawling grid of streets disappear into desert arroyos as you swipe back in time.

The free tool is an easy way for anyone with an interest in the American West to peruse the past. But Landscape Explorer also has a loftier purpose: helping government agencies, landowners and conservation professionals make complex decisions about how to manage land.

The powerful visual contrast between the historical snapshot and modern-day satellite imagery "allows us to go from zero to 100" in terms of understanding ecosystem changes, says Scott Morford, an applied spatial ecologist at the University of Montana in Missoula who led the development of Landscape Explorer. The project was supported by Working Lands for Wildlife, a conservation initiative led by the U.S. Department of Agriculture, and other partners. The impetus, Morford says, was to "give us a reference for how rapidly things are changing across biomes that we care about."

Before Landscape Explorer, most collections of historical imagery of large-scale landscapes went back to only the 1980s.

Landscape Explorer provides interactive, side-by-side comparisons of how landscapes looked about 70 years ago compared with today. In southwest Kansas, native prairie (left) has turned into cropland (right).

Finding earlier imagery of large landscapes was expensive and time-consuming. While some previous projects have stitched together historical imagery at small scales to look at how a particular watershed or county has changed, "the real revolution is that we were able to figure out how to do it at scale," Morford says. "We wanted to make something that was universal and accessible" for everyone, not just remote sensing specialists.

Morford and colleagues processed about 170,000 aerial images that were taken by U.S. Army pilots during the Cold War and later digitized. To create a continuous mosaic, the team used specialized software to stitch together images of adjacent patches of land, the researchers explained in a paper published in July in *Remote Sensing in Ecology and Conservation*. The final step was pairing the mosaic with satellite imagery using Google Earth Engine.

Landscape Explorer began as a small project to assess the extent of woody encroachment onto grasslands in western Montana. Due to fire suppression, conifers like western juniper or eastern red cedar are taking over ecosystems that were historically treeless, such as sagebrush steppe and prairies. A monoculture of these water-guzzling trees is bad news for local biodiversity and increases the risk of catastrophic wildfire.

Third-generation Montana rancher Bruce Peterson says that seeing historical and current aerial imagery side by side made him realize how the steady infiltration of trees had devalued his family's livestock pastures. "It's a little bit like losing your hearing or your vision with these trees. They eat away a little of your land at a time, and then by the time you get hearing aids or glasses, you realize it's gotten really out of hand," Peterson says.

Using Landscape Explorer, Peterson and dozens of other landowners involved in the Southwest Montana Sagebrush Partnership have prioritized where to remove invading trees. The group has restored nearly 50,000 acres of treeless rangeland since 2020, according to the Nature Conservancy, a member of the partnership.

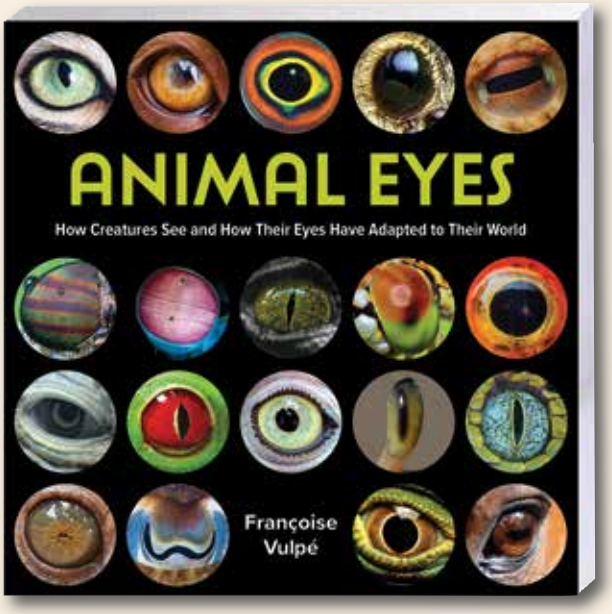
Landscape Explorer also helped the Clark Fork Coalition, a Montana-based nonprofit that protects and restores waterways, to see how urban and industrial development has impacted floodplains. "This tool gives us the power of time travel. It's like a time-lapse showing all that's been lost and where the continued pressure is very real," says Karen Knudsen, the coalition's executive director.

After seeing the successes in Montana, the makers of Landscape Explorer extended the tool to 17 states in the West to show where forests, grasslands or rivers are most at risk of disappearing and where intact habitats can still be preserved.

Since the expanded tool was released in September, researchers have used it to assess glacial retreat in the Pacific Northwest, measure the historical extent of sand dunes in coastal California and pinpoint where wetlands have dried up.

Morford is excited to see all the ways Landscape Explorer can help land managers. "It's going to be used in ways we haven't even thought of yet." — *Brianna Randall*

A unique explanation of how vision works, from insects to mammals to humans



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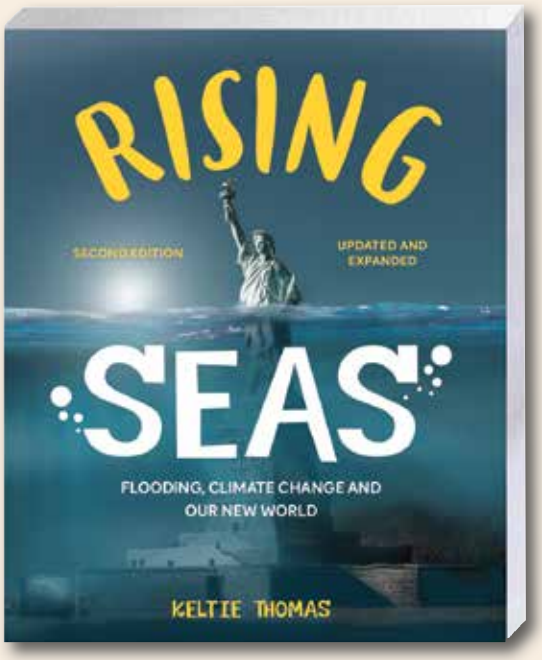

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A storm brewing

Warming ocean waters due to human-caused climate change are spurring more hurricanes to rapidly intensify, ***Carolyn Gramling*** *reported in "Why hurricanes intensify so swiftly"* (SN: 10/7/23 & 10/21/23, p. 10).

The story made reader **Barry Maletzky** wonder why hurricanes take a spiral shape.

A hurricane's spiral form is due to a phenomenon called the Coriolis effect. Earth constantly spins on its axis from west to east. Objects not firmly rooted to the ground, including air currents, airplanes and hurricanes, curve as they travel through the air because they conserve the momentum of the planet's rotation.

Tropical cyclones, such as hurricanes, typically form near the equator, where warm ocean waters and air create the right conditions for the storms to occur. Each cyclone consists of a low-pressure center, known as the eye, which sucks in the surrounding high-pressure air. The Coriolis effect deflects that air slightly to the east as it rushes toward the storm's eye.

At the same time, air from the equator moves toward the poles and is also deflected east by the Coriolis effect. All together, this causes the whole storm system to spin — counterclockwise north of the equator and clockwise south.

Microscopic marvels

A journey through the mysterious world of protists reveals how much we still have left to learn about life on Earth, ***Susan Milius*** *reported in "Charismatic microfauna"* (SN: 10/7/23 & 10/21/23, p. 18).

The story reminded reader **Michael Steinfeld** of the work of scientist, photographer and cinemicroscopist Roman Vishniac.

Famous for his snapshots of Jewish communities in pre-Holocaust Europe, Vishniac spent much of his career zoomed in on the life sciences. At the height of his career in the 1950s through the '70s, he studied, photographed, filmed and wrote about animals, plants and microorganisms, including protists (SN: 9/15/62, p. 172). Vishniac's work on tiny life-forms significantly shaped the field of photomicroscopy.

Reader **Kurt Sroka** shared a self-written poem about microorganisms, entitled "Hierarchy": Without Micro-Beings / Human-Beings couldn't be here / to "dominate" Earth.

Bird brain

Songbirds with complex vocal skills solve problems faster than their less vocally adept peers, ***Darren Incorvaia*** *reported in "Some songbirds excel at brainteasers"* (SN: 10/7/23 & 10/21/23, p. 14).

"The phrase 'bird brain' often gets a bad rap, but science tells us that bird intelligence is far from lacking," **@factfrontier_** wrote on X, formerly known as Twitter. "Take the African grey parrot, for example, capable of understanding the concept of zero — a feat ... shared with humans and a few primates. Then there's the New Caledonian crow, which uses tools to extract insects from tree bark, showing problem-solving skills that rival those of young children.... So, calling someone a 'bird brain' might just be underselling the intricate cognitive abilities that birds possess."

X user **@PhillSher** also remarked on the intelligence of crows: "Crows are exceptionally smart. I once saw a crow pick up a morsel of food, stack it on top of another that was a couple of feet away, then pick up both and fly off."

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Jupiter dazzles in infrared

New infrared shots of Jupiter taken by the James Webb Space Telescope reveal a speedy jet stream encircling the equator at an altitude never imaged before.

Researchers have known about jet streams on Jupiter for more than four decades. The relatively stable winds occur near the planet's main cloud decks, in the troposphere. The newly spotted jet lies 20 to 40 kilometers above, in the stratosphere, and moves at about 500 kilometers per hour, or roughly twice as fast as the jets below, astrophysicist Ricardo Hueso and colleagues report October 19 in *Nature Astronomy*.

In specially filtered JWST images taken about 10 hours apart (one shown above in false color), the researchers noticed bright specks in the white band of clouds around the planet's middle. The movement of the specks let the team identify the jet stream and clock its movement. In these images, cloud brightness indicates altitude, and the reddish arcs at the poles are auroras.

It's not clear what causes the speedy jet. "If you have very intense motions, you need energy to produce those motions," says Hueso, of the University of the Basque Country in Bilbao, Spain. The energy could come from storms below, or the jet might be linked to a band higher in the stratosphere where temperature and wind intensity oscillate over four years or so.

Future observations could help untangle the tricky physics occurring in the atmospheres at planets' equators, Hueso says. "We don't understand it on the Earth at the level that we would like, and we don't understand it on Jupiter." — *Carolyn Wilke*

NASA, ESA, CSA, STScI, R. HUESO/UNIV. OF THE BASQUE COUNTRY, I. DE PATER/UCB, T. FOUCHET/OBSERVATORY OF PARIS, L. FLETCHER/UNIV. OF LEICESTER, M. WONG/UCB, J. DEPASQUALE/STSCI

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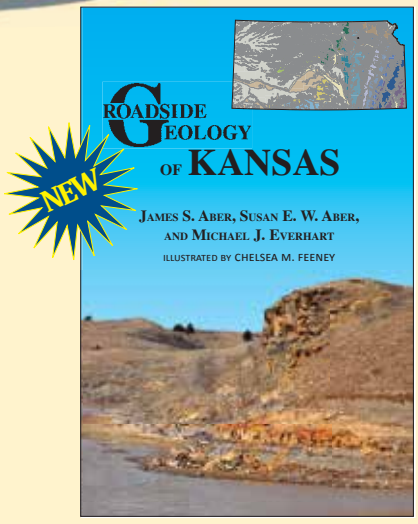

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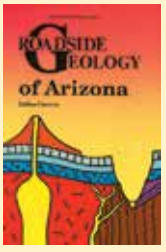

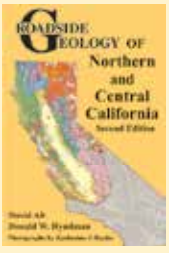

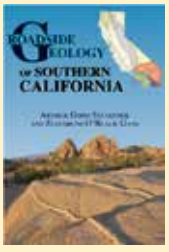

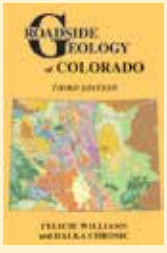

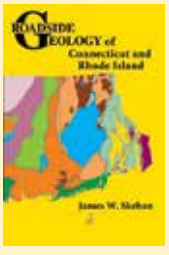

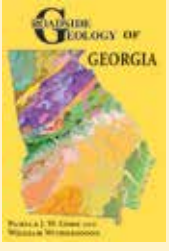

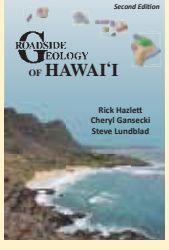

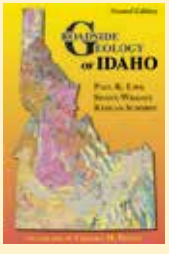

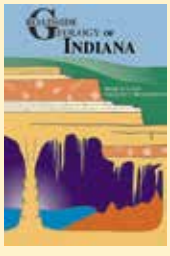

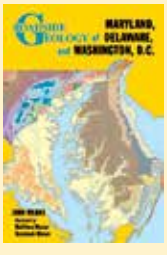

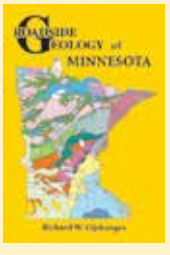

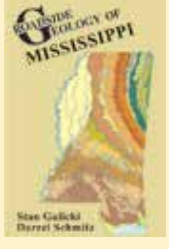

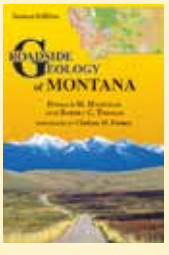

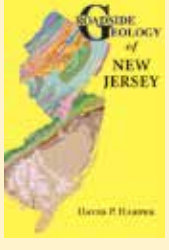

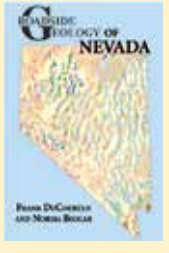

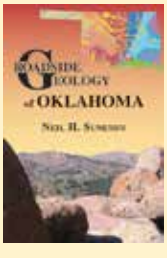

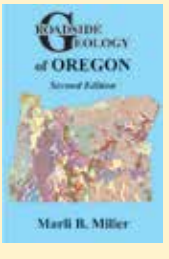

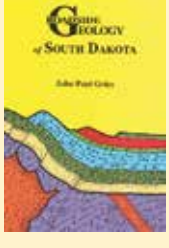

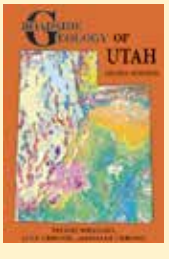

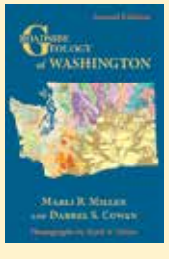

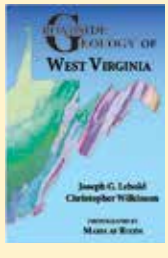

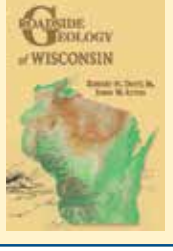

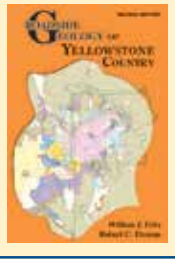

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