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COVER The Andean bear is also known as the spectacled bear for its tan snout markings. *David & Micha Sheldon/ mauritius images GmbH/ Alamy Stock Photo*

FROM TOP: GLENN HARVEY; MATTHEW BERNANKE, NMFS ESA PERMIT NO. 25864; JOSEPH DEPASQUALE, NASA, ESA

Striving to break the global grip of malnutrition

Last year, more than 36 million children under the age of 5 suffered from acute malnutrition worldwide. No child should suffer from lack of sustenance, but natural disasters, poverty and war continue to put the youngest and most vulnerable at risk. Child malnutrition in Sudan is at emergency levels, according to the World Health Organization. And in northern Gaza, up to a quarter of children are malnourished. Children in Afghanistan, Haiti, Nigeria, Yemen and other countries are also afflicted.

Helping children recover from malnutrition isn't a matter of just giving them food. They are far more vulnerable to illness and death even after receiving treatment, and if they survive, they face an increased risk of health challenges throughout their lives. Scientists are trying to figure out why malnutrition hits the body so hard and how to help children recover (Page 22). Recent research finds that prolonged malnutrition weakens the immune system and causes tissue and organ damage, making it difficult to absorb nutrients. Therapeutic food that boosts the gut microbiome may help, as might medications that repair the gut lining. But solutions feel much too far away with so many lives at stake.

Solving an intractable problem is also at the heart of another feature in this issue. Conservation biologist Ximena Velez-Liendo has devoted her life to saving the Andean bears of Bolivia (Page 28). The charismatic creatures were at risk of extinction due to habitat loss and conflicts with humans. She worked with local communities to develop new sources of income, notably beekeeping, to slow the need to clear forests for farming and to help people coexist with bears. Both bears and people are thriving. "Conservation is changing," she says, "from the hands of biologists to the hands of the people."

And in the third feature, we delve into the challenges of assessing the cognitive skills of machines. Over the last few years, generative AI chatbots like ChatGPT have dazzled people with the ability to write computer code, buff up resumes, help with homework and more. Along with these feats have come extravagant claims that the algorithms can think and reason. Finding out if they actually do, it turns out, is complicated (Page 16).

Attempts to test machine intelligence date back to 1950, when famed British mathematician Alan Turing designed the imitation game, in which an interrogator asks questions of a computer and a person. If the interrogator could not tell which answers came from a human, "one will be able to speak of machines thinking without being contradicted," Turing said. He predicted that a computer would win the game by the end of the 20th century; that didn't happen. But interpreting the results of the imitation game and other tests isn't clear-cut. Today's bots can appear to best humans at tests of mathematics, language comprehension and more. Instead of demonstrating superior intellect, however, AI may simply be regurgitating what it learned during training. (I was gratified to read that bots that appeared to have grasped the concept of multiplication had just memorized the answer.) Researchers are now devising new tests that produce less ambiguous results.

This is our summer double issue; we've included more articles to tide you over until the August 10 issue lands in your mailbox. — *Nancy Shute, Editor in Chief*

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Excerpt from the July 6, 1974 issue of *Science News*

50 YEARS AGO

Putting the heat to Helios

Helios, a space probe scheduled to go closer to the sun than any other manmade object ever launched, has successfully survived a ground test that exposed it to temperatures believed to be as high as any it will face during its mission.... During the test, parts of the spacecraft reached — and survived — temperatures up to 700° Fahrenheit. Helios, to be launched in [December], will pass within 28 million miles of the sun.

UPDATE: The Helios mission's study of the sun provided key insights into the solar wind, the star's magnetic field and more. Its success helped pave the way for NASA's Parker Solar Probe, which has been observing the sun's outer atmosphere, or corona, since 2018. Parker has dipped within 5 million miles of the solar surface and will eventually swing within 4 million miles. Such encounters have pinpointed a layer that separates the corona from space and found evidence that snappy magnetic field lines may accelerate the solar wind (*SN: 1/29/22, p. 10*). The probe will next encounter the sun in September.

MYSTERY SOLVED

How a protist stretches its neck really, really far

Origami could be useful for snagging prey.

The single-celled protist *Lacrymaria olor* uses a helix of pleats to unspool a neck-like protrusion up to 1.2 millimeters, 30 times the length of its body, to quickly snap up food, researchers report in the June 7 *Science*. If a person could do the same, their neck would reach about halfway up the Statue of Liberty.

Discovering how the protist accomplishes this feat of stretching could help inspire new robotics, such as tools for microsurgery that can extend and contract inside small body cavities.

Capturing *L. olor*'s neck in action is an exercise in speed. The organism waves its bulbous dome in rapid, snakelike movements as its neck lengthens and retracts. Such quickness and the organism's ability to do it over and over again "sets *Lacrymaria* apart," says biophysicist Eliott Flaum of Stanford University. Other organisms with similar reach move slowly or are unable to reverse any extensions.

L. olor's neck-stretching ability has been known for more than a century, says microbiologist Vittorio Boscaro of the University of British Columbia in Vancouver. "Many times, we notice some crazy feature that we cannot explain, and that's basically where we stop. It's nice that papers are coming out trying to actually explain how the crazy thing [happens].... In this case, the answer is really cool."

The big question was how *L. olor* builds and retracts its neck so quickly. With a combination of still and live microscopic imaging, Flaum and Stanford bioengineer Manu Prakash found that the protist's protrusion is covered in long polymers called microtubules, which give the organism its shape. Layers of microtubules are wrapped around the protrusion in a helix.

Seeing the helical structure made the team wonder, "Is that a spring? Is that a coil? What's happening?" Flaum says.

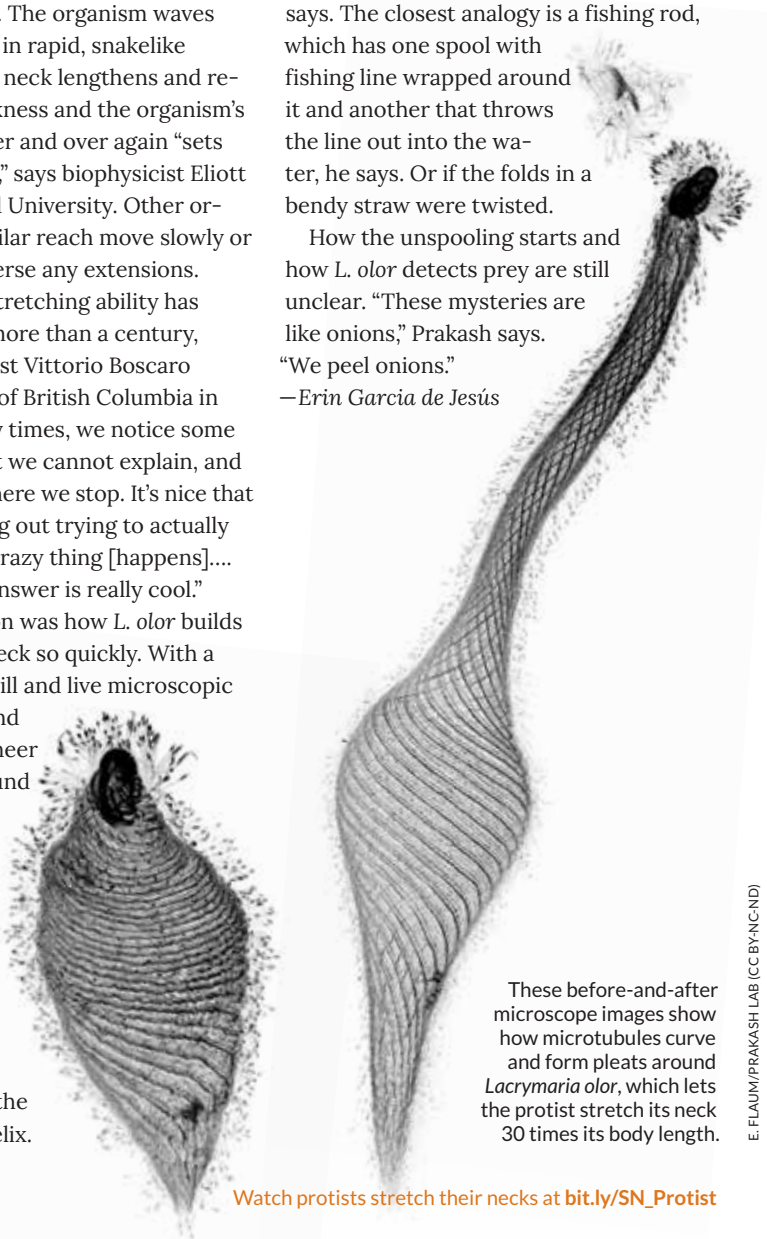
The answer turned out to be neither. On a trip to Japan, Prakash saw chochin lanterns made of pleated paper. "And it just kind of clicked," he says. *L. olor*'s helical microtubules are folded like origami.

Prakash and Flaum tested the idea, folding paper mimics that they dubbed "lacrygami." With paper representation, the team showed that as each curved pleat in *L. olor*'s neck unfolds, the structure rapidly unspools.

There's no known comparison, Prakash says. The closest analogy is a fishing rod, which has one spool with fishing line wrapped around it and another that throws the line out into the water, he says. Or if the folds in a bendy straw were twisted.

How the unspooling starts and how *L. olor* detects prey are still unclear. "These mysteries are like onions," Prakash says. "We peel onions."

—*Erin Garcia de Jesús*



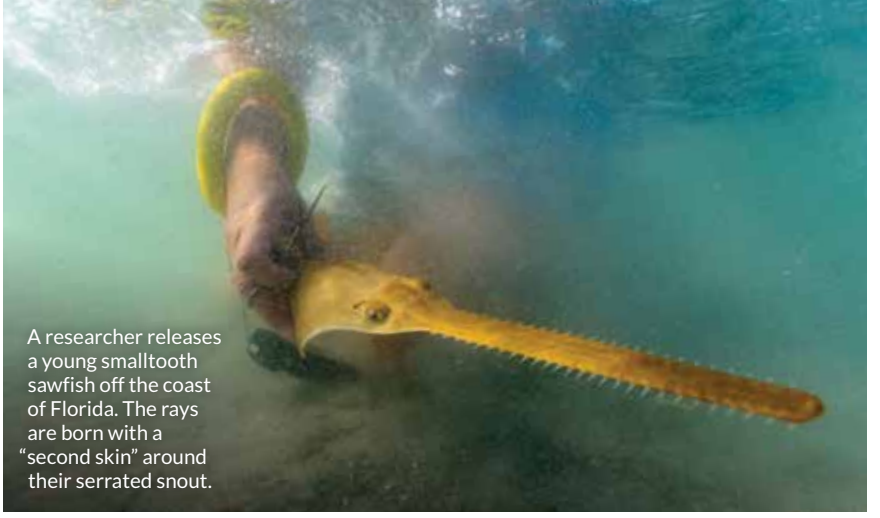
These before-and-after microscope images show how microtubules curve and form pleats around *Lacrymaria olor*, which lets the protist stretch its neck 30 times its body length.

E. FLAUM/PRAKASH LAB (CC BY-NC-ND)

Watch protists stretch their necks at **bit.ly/SN_Protist**

RETHINK

Sawfish scabbards are tougher than they look



A researcher releases a young smalltooth sawfish off the coast of Florida. The rays are born with a "second skin" around their serrated snout.

Smalltooth sawfish, rays that give birth to live young, develop their signature tooth-lined snout while still in the womb. The needle-sharp teeth are encased in a specialized sheath that prevents the rays from cutting up their mother and siblings during gestation and birth. Now, scientists have gotten their first closeup look at this built-in pocket protector.

"It's a cool thing Mother Nature figured out to protect mom from those calcified teeth and protect siblings from sword fighting in the uterus," says fish biologist Gregg Poulakis of the Florida Fish and Wildlife Conservation Commission in Port Charlotte.

The species, *Pristis pectinata*, is found primarily in waters off southern Florida and the western Bahamas. Observations of baby sawfish and lab tests of tissue samples suggest that the sheath is a tough, multilayered "second skin" that sheds within about four days after birth, Poulakis and colleagues report May 28 in *Fishery Bulletin*.

The finding overturns a long-held assumption that the sheath is a fragile, gelatinous membrane. "A lot of the descriptions historically are based on the fact that people have just seen them in pictures," says Dean Grubbs, a fish ecologist at Florida State University's Coastal and Marine Laboratory in St. Teresa. "It's a significant structure … as you would expect it to be if it is going to essentially shield those really sharp points."

The sheath feels like paraffin wax: firm, but with a slight give. "You can't peel it off," Poulakis says. A combination of histology, scanning electron microscopy, micro-CT and elemental analysis revealed the sheath has two tissue layers that resemble an epidermis and a dermis, as well as proteins that look like keratin, reticulin and collagen. This strongly suggests the sheath is a second skin, the researchers say, but they emphasize that more work is needed to confirm the conclusion. —*Natalie van Hoose*

INTRODUCING

'Echidnapus' evokes modern monotremes

In roughly 100-million-year-old rocks in New South Wales, Australia, scientists have unearthed three newfound species of monotremes, a group of egg-laying mammals that today include only the platypus and another Australian oddball, the echidna.

Identified from teeth and jaws, the discoveries double the number of known monotreme species during this brief span in the Cretaceous Period, mammal biologist Timothy Flannery of the Australian Museum in Sydney and colleagues report May 26 in *Alcheringa: An Australasian Journal of Palaeontology*.

One, *Opalios splendens*, earned the nickname "echidnapus" for its mix of features, which are found in modern echidnas and platypuses. Another species, the hamster-sized *Parvopalus clytiei*, is among the smallest known monotremes. And *Dharragarra aurora* may be the closest extinct relative of the modern platypus. —*Carolyn Gramling*

An extinct species of egg-laying mammal had a jaw similar to the modern echidna (shown) and other traits found in the modern platypus.

FIRST

Gauging Earth's spin using quantum entanglement

Earth's rotation has been measured many times, but never like this. In a first, scientists used entangled particles to reveal the rate at which the globe spins. Physicist Haocun Yu of the University of Vienna and colleagues sent pairs of entangled photons, particles of light, through a quantum interferometer. Inside, the photons could traverse loops of optical fiber either clockwise or counterclockwise. Because the two photons were entangled, they took the same path. But rather than picking one direction or the other, the pair took on a strange state called a superposition, traversing a combination of the two paths. Due to Earth rotating underneath, the two paths corresponded to slightly different travel distances. That made the photons' two superposed components slightly out of sync when they exited the labyrinth, causing quantum interference. Measuring that interference implied a rotation speed that agreed with Earth's known rotation rate, the team reports June 14 in *Science Advances*. The feat is a step toward probing how the world of quantum physics interfaces with gravity. —*Emily Conover*

FROM TOP: MATTHEW BERNANKE, NMFS ESA PERMIT NO. 25864; GLOBALP/GETTY IMAGES

EARTH

A famous West Coast fault tells secrets

The most dangerous segment sits offshore of Washington state

These tree stumps protruding from sand and surf in Oregon are the remains of an ancient spruce forest that was likely lowered and buried by a Cascadian mega-earthquake.

BY NIKK OGASA

The most destructive Cascadian earthquakes are likely to slam offshore of Washington state and Vancouver Island, new data reveal.

The Cascadia megathrust is a massive fault that can generate devastating magnitude 9 earthquakes, but its structure has long eluded scientists. Now, data from the most comprehensive survey yet show that the fault is not a single, continuous fracture but comprises at least four segments. The most dangerous segment appears to stretch from off the coast of southern Vancouver Island through Washington state, researchers report in the June 7 *Science Advances*.

The fault "is a huge risk to people living in the Pacific Northwest," says seismologist Edwin Nissen of the University of Victoria in British Columbia. While the segment extending from near Vancouver Island may be the most likely to host the largest quakes, he says, segments farther south along Oregon's coast may be prone to slightly smaller yet more frequent temblors.

Megathrust faults occur where two tectonic plates converge and one plate pushes under the other, or subducts. The plates typically get stuck and periodically slip, releasing earthshaking energy. Such settings have generated the largest temblors in history, including the 2004 Sumatra quake. The Cascadia megathrust, which stretches roughly 1,000 kilometers from British Columbia to northern California, is where the northeast-bound Juan de Fuca Plate slides under the North American Plate.

In the last 10,000 years, 19 quakes around magnitude 9 have rocked Cascadia. The most recent struck in 1700, dropping coastal forests into tidal zones and fomenting tsunamis that reached Japan. The imminent threat of the next Cascadian quake has inspired articles, books and documentaries. And yet, compared with the megathrusts near Japan and New Zealand, the Cascadia fault is poorly understood. That's because it is "eerily quiet in terms of seismicity," Nissen says.

In 2021, marine geophysicist Suzanne Carbotte of Columbia University and colleagues conducted a seismic survey along a 900-kilometer stretch of the subduction zone, towing air guns that blasted sound waves into the seafloor. The waves bounced off of faults and rock layers underground and returned to a receiver array, exposing the structures' positions.

"It's the first time that a regional survey that spans almost the whole subduction zone has been conducted," Carbotte says. "Prior to this, people had looked at individual, small regions."

As the Juan de Fuca Plate grinds under the North American Plate, it splits like a sheet of plywood passing through a row of buzz saws, the data reveal. This segmentation appears to be driven by rigid, irregularly distributed rocks in the North American Plate.

Segmentation is "one way to stop an earthquake," Nissen says. During a quake, a fault will slip at a single underground point and the motion will spread along the fault. If a fault is segmented, then the breaks may limit how far a quake can spread and thus how large it can get.

But the segment extending from Vancouver Island is relatively smooth and descends at a shallow angle beneath the North American Plate, the team found. Those features suggest that a quake originating there would be large and might "propagate much farther to the east, and therefore to the coastline—and people living in Victoria, Seattle, Vancouver—than was previously thought," Nissen says.

The study provides useful information for earthquake forecasting, says geophysicist Mark Petersen of the U.S. Geological Survey in Golden, Colo. Knowing a fault's geometry is crucial for gauging how close future quakes may get to major cities. The agency will update its earthquake hazard model for the Pacific Northwest in 2029. ■

ROB DEGRAFF/FLICKR (CC BY-NC-ND 2.0)

ASTRONOMY

Are black holes neutrino factories?

Growing evidence points to a source of energetic particles

BY MARA JOHNSON-GROH

Supermassive black holes at the hearts of active galaxies may be churning out a lot of the universe's high-energy neutrinos.

Two teams using data from IceCube, the world's premier neutrino observatory located in Antarctica, have independently identified Seyfert galaxies, a common type of active galaxy, as likely high-energy neutrino producers. The findings, reported in the March 8 *Physical Review Letters* and in a paper submitted June 10 to arXiv.org, bolster the view that the cores of these active galaxies could churn out the majority of the nearly massless subatomic particles found streaming across the universe.

"I would put a reasonable bet on them now with the information that I know," says astronomer Andrii Neronov of the Astroparticle and Cosmology Laboratory in Paris, who coauthored the study in *Physical Review Letters*.

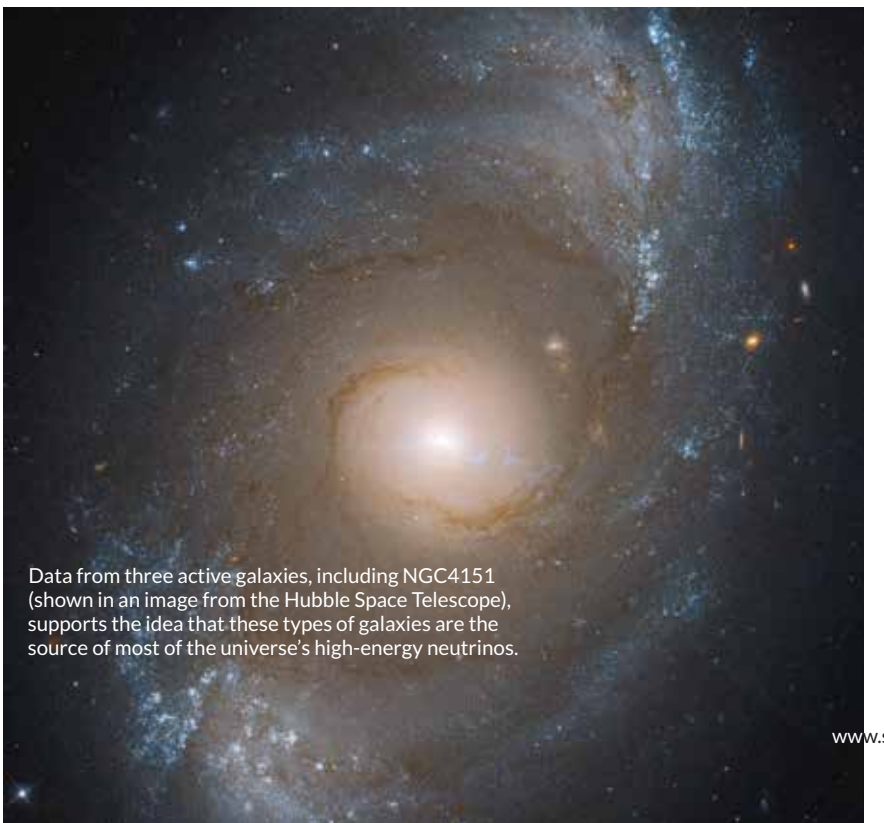
This wasn't the case just a few years ago. When astronomers first identified the galaxy NGC1068 as the likely origin of high-energy neutrinos in 2022, it came as a surprise. Many astronomers at the time didn't think a Seyfert galaxy could produce the particles. Now, with compelling evidence that high-energy neutrinos are coming from NGC1068 and two other Seyfert galaxies, NGC4151 and NGC3079, there's little doubt that these types of active galaxies can produce them.

The new findings add to a flurry of recently published theoretical research that has made headway in tracking down the origins of cosmic high-energy neutrinos. Several studies, including a paper to appear in *Nature Astronomy*, have pinpointed the region around the central supermassive black hole in NGC1068 as the only place in that galaxy where the neutrinos could be produced. If NGC4151 and NGC3079 are confirmed as high-energy neutrino factories, their particles would probably also be produced near their black hole cores.

Previously, scientists have confidently identified only one other significant extragalactic high-energy neutrino emitter: a type of supermassive black hole called a blazar. These cosmic giants spew jets of supercharged material where the particles were thought to be produced. Now, however, some astronomers think maybe it's the black hole itself that's responsible.

"I think that dense cores, not jets, produce neutrinos," says Francis Halzen, a particle physicist at the University of Wisconsin-Madison and the principal investigator of IceCube. "These can be in Seyferts, flat-spectrum radio quasars [types of blazars], or anything else with an obscured black hole."

Kohta Murase, a theoretical physicist at Penn State who has done extensive work to identify the source of NGC1068's high-energy neutrinos, suspects that the black hole hearts of these galaxies are neutrino mills. A promising site is the corona, a very hot region surrounding the black hole, Murase says. "If this is established, it might give us a clue to understanding the physical properties of the corona." ■



JOSEPH DEPASQUALE, NASA, ESA

Data from three active galaxies, including NGC4151 (shown in an image from the Hubble Space Telescope), supports the idea that these types of galaxies are the source of most of the universe's high-energy neutrinos.

ASTRONOMY

For the first time, scientists witness a black hole turning on

Somewhere in the not-too-distant universe, a galaxy is waking up.

Over the last four years or so, astronomers have watched the behemoth black hole at the center of SDSS1335+0728, a galaxy about 300 million light-years from Earth, go from dim and quiet to bright and active. It's the first time this transition has been observed, researchers report June 18 in *Astronomy & Astrophysics*.

The galaxy caught scientists' attention in December 2019, when the Zwicky Transient Facility at Palomar Observatory in California noticed dramatic brightening. Data stretching back 20 years revealed the galaxy hadn't previously been active. Since brightening, SDSS1335+0728 has remained luminous.

The finding could provide insight into the processes powering active galactic nuclei, which occur when supermassive black holes consume enormous amounts of material, becoming bright enough to be seen across the cosmos. — *Adam Mann*

ANTHROPOLOGY

Ancient Maya sacrificed boys

Twins were killed to appease a rain god, a new study suggests

BY BRUCE BOWER

Genetic clues have unveiled a type of ancient Maya ritual child sacrifice that consisted of only young boys, often chosen as closely related pairs that included twins.

The discovery stems from a burial of more than 100 people in an underground chamber at Chichén Itzá, a once dominant Maya city in Mexico's Yucatán Peninsula. Chichén Itzá reached its pinnacle between 800 and 1000 A.D., as many Maya cities in Mexico and Central America fell on hard times or were abandoned.

Twin brothers and other related young boys were ritually sacrificed in Chichén Itzá (a temple at the ancient Maya site, shown).

DNA from 64 of the bodies pegs them as male, challenging an earlier idea that females sacrificed in fertility rites were interred there, archaeogeneticist Rodrigo Barquera and colleagues report June 12 in *Nature*.

The males ranged in age from 3 to 6, based on tooth development. Around one-quarter had a brother or other close relative among those with analyzed DNA. Chemical analyses of diet-related substances in bones found that closely related boys had consumed similar types and proportions of foods, a sign of having grown up in the same households. Related children included two sets of identical twins.

"This is the first evidence of Maya sacrifices involving twins, which were important for Maya [beliefs about the universe]," says Barquera, of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany.

Though reasons for the fatal ritual are unclear, the findings fit with previous suggestions that children were sacrificed to appease the Maya rain deity Chaac and ensure the growth of maize crops, the researchers say.

The team regards the burial chamber as a repurposed cistern for storing water, but archaeologist James Brady of California State University, Los Angeles says it was constructed as an artificial cave. Ancient Maya people created large numbers of artificial caves for a range of spiritual purposes, Brady notes; he examined the chamber in 2017 and 2018.

Barquera and colleagues suspect that closely related boys were chosen for ritual sacrifices as stand-ins for the Hero Twins, powerful mythological figures. A Maya document written in the 1550s, the Popol Vuh, recounts tales of the Hero Twins avenging the murders of their father and uncle (also twins) by underworld gods. After a series of sacrificial deaths, the Hero Twins came back to life to outwit those same deities.

Radiocarbon dating of bones indicates that boys were ritually interred from around 500 to 900 A.D. Whether the ancient Maya placed bodies there one at

GENETICS

DNA bucks horse domestication story

A new timeline may revise the roles that ancient cultures played

BY TINA HESMAN SAEY

Horse power may have revved up about four millennia ago.

Horses were domesticated at least twice, scientists report June 6 in *Nature*. Botai hunter-gatherers in Central Asia may have been the first to domesticate the animals around 5,500 years ago, genetic data suggest. But that attempt didn't stick. Other people north of the Caucasus Mountains tamed horses about 4,200 years ago. Those horses took the equine world by storm, replacing their wild cousins and becoming the modern domestic horse in just a few centuries.

The findings call into question long-held ideas about the when, why and who of horse domestication, says molecular archaeologist Ludovic Orlando of the Centre for Anthropobiology and Genomics of Toulouse in France. For instance, ancient Yamnaya people from southwest Asia have been credited with being the first horseback riders (SN: 4/8/23, *p.* 12).

The Yamnaya hitched up cattle-drawn carts about 5,000 years ago to make homes across Europe and Asia. Along the way, they helped build major Bronze Age cultures in Europe. But that didn't happen on horseback, Orlando and colleagues argue. The timing just doesn't work.

The team analyzed DNA from 475 ancient horses that lived up to 50,000 years ago and 77 modern horses. Combining the analysis with archaeological data established a timeline for domestication.

Scientists knew that domesticated horses galloped off the Russian steppes and spread to other parts of Asia and Europe, eventually replacing wild horses. The new genetic data show that happened about 4,200 years ago. If the Yamnaya and horses migrated together, their genes would have spread at the same time. "You would be literally on their backs," Orlando says. But the horses' genes didn't start spreading until about 800 years after the Yamnaya migrated.

The idea that the Yamnaya weren't horseback riders and horse herders may be "a difficult pill to swallow for a lot [of people]," says archaeozoologist William Taylor of the University of Colorado Boulder. The direct ancestors of modern domestic horses "did not have a presence in Yamnaya culture," he says. This "hard reality" is supported by genetic evidence.

As those horses spread around the world, their generation time fell from

JOHANNES KRAUSE

a time over decades and centuries, or if sacrificed children were buried in pairs or larger sets, is unclear.

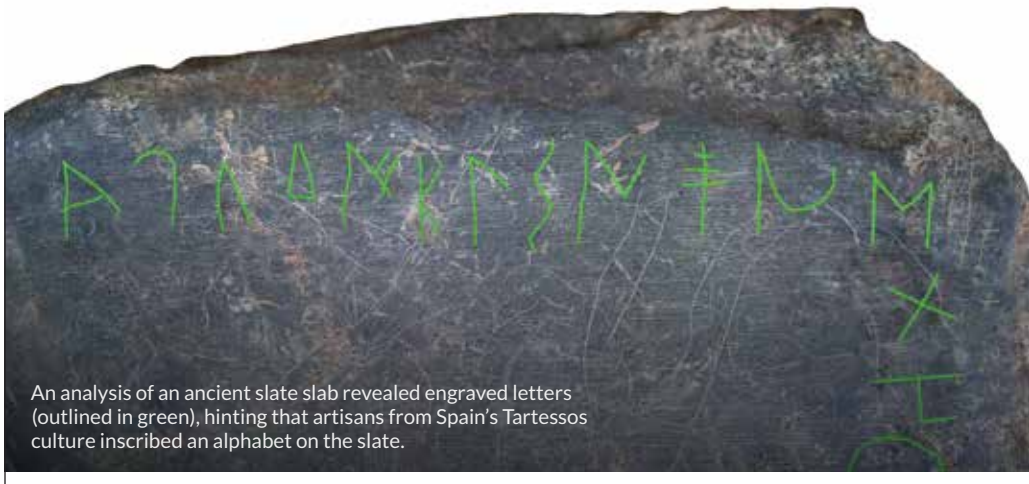
The findings "bring to mind ancestral Yucatec rain invocation ceremonies that are still practiced among traditional Maya communities, especially during times of drought," says Vera Tiesler, a bioarchaeologist at the Autonomous University of Yucatán in Mérida, Mexico. In that context, Barquera's scenario of agriculturally related sacrifices of closely related boys associated with the Hero Twins is plausible. During modern Cha-Chaac rites, boys sit beneath or are tied to an altar adorned with vegetation. The youngsters, no longer ritually sacrificed, imitate sounds of noises linked to first rains, aiming to invoke the cooperation of the rain god Chaac.

The DNA findings at Chichén Itzá fit with emerging evidence that, at least at some ancient Mexican and Central American sites, the sex of the deity to whom sacrifices were made determined the sex of those chosen as offerings, says bioanthropologist Cristina Verdugo of the University of California, Santa Cruz. It's possible that Chaac, a male, motivated sacrifices of young boys at Chichén Itzá. ■

about seven years to four years. And other genetic evidence suggests that closely related horses bred. Taken together, the findings point to people controlling horse breeding to increase numbers and to select for certain traits, clear signs of domestication, Orlando says.

Horses from 5,500 years ago associated with the Botai culture also had a shortened generation time. Past research suggests the Botai milked horses, so this new finding may indicate that they were domesticating the animals, Orlando says. If so, it might be the first—albeit unsuccessful—attempt. The only living relatives of Botai horses are wild Przewalski's horses, which were included in the genetic analysis.

Taylor doesn't buy it. All the available evidence suggests that what happened with Botai horses "was the last hurrah of a hunter-prey relationship … that really didn't have anything meaningful to do with domestication." ■



An analysis of an ancient slate slab revealed engraved letters (outlined in green), hinting that artisans from Spain's Tartessos culture inscribed an alphabet on the slate.

JFIJ/CSIC

ARCHAEOLOGY

Alphabet illuminates a lost civilization

Engraved letters could unravel the writing system of Tartessos

BY JAVIER BARBUZANO

Letters from an ancient alphabet have been discovered in a most unusual way: by someone scrolling through social media.

The inscription, on a slate slab unearthed in southern Spain, is closely linked to the Phoenician alphabet, which influenced later writing systems including Latin, Spanish and English. Researchers hope that the finding will expand their understanding of a pre-Roman civilization's writing system. Until now, only incomplete or poorly dated samples had been found. The Spanish National Research Council announced the discovery in a June 11 press release.

Joan Ferrer i Jané, a software engineer in Barcelona, was browsing X, formerly Twitter, for updates on an archaeological dig at Casas del Turuñuelo. The site dates to the fifth century B.C. and is one of several connected with the Tartessos civilization, which emerged from the cultural exchange between the Iberian Peninsula's Indigenous dwellers and Phoenician settlers who arrived around the ninth century B.C. Tartessos disappeared near the end of the fifth century B.C.

Casas del Turuñuelo features a large building that experts suggest was burned down and buried as part of a ceremonial ritual. The clay used for burial, researchers say, sealed the site, preserving its contents. Excavations earlier this year turned up a slate rock engraved with warriors, geometric shapes, faces and other markings. It appears to have been an artisan's sketching surface, says excavation codirector Esther Rodríguez González of the Archaeological Institute of Mérida in Spain.

The team posted photos highlighting the warriors on X. But Ferrer, who is also a part-time researcher of ancient languages at the University of Barcelona, noticed something more. "My eye went immediately to one symbol," he says. It was the Paleohispanic version of the letter I, which he says can't be mistaken for anything else.

Ferrer contacted the team for more images. He identified 15 symbols and hints of more letters. The bottom of the tablet, potentially containing additional characters, is missing. Ferrer thinks that the slate might have had as many as 32 symbols.

Rodríguez González praises Ferrer's ability to spot symbols that her team missed, especially since they were upside down in the online photos. Ferrer has been invited to study the symbols and examine other slate fragments for missing letters.

This finding provides a clearer picture of the Tartessian writing system and confirms literacy among Casas del Turuñuelo's inhabitants, says José Ángel Zamora López, an expert in the origin of alphabetic writing at the Institute of Mediterranean and Near Eastern Languages and Cultures in Madrid.

Studying the alphabet will be useful for figuring out if a singular writing system was used throughout Tartessos territory or if there were regional variations, Zamora López says. Because different sounds and new symbols were often placed toward the end of alphabet inscriptions, the missing slate piece may be especially interesting. ■

NEUROSCIENCE

Honeybees can 'smell' lung cancer

Disease-related odors spark distinct brain activity patterns

BY MEGHAN ROSEN

Float like a butterfly, sniff out cancer like a bee? Honeybees can detect the subtle scents of lung cancer in the lab—and even the faint aroma of disease that can waft from a patient's breath.

Inspired by the insects' exquisite olfactory abilities, scientists hooked up living bees' brains to electrodes, passed various scents under the insects' antennae and recorded brain activity. "It's very clear—like day and night—whether [a bee] is responding to a chemical or not," says neural engineer Debajit Saha of Michigan State University in East Lansing.

Cancer-related odors sparked distinct brain activity patterns, a kind of neural fingerprint for scent, Saha and colleagues report June 4 in *Biosensors and Bioelectronics*. One day, doctors might be able to use honeybees in cancer clinics as living sensors for early disease detection.

Electronic noses and other types of mechanical odor-sensing equipment exist, but they're not exactly the bee's knees. When it comes to scent, Saha says, "biology has this ability to differentiate between very, very similar mixtures, which no other engineered sensors can do."

Scent is an important part of how many insect species communicate, says chemical ecologist Flora Gouzerh of the French National Research Institute for Sustainable Development in Montpellier. For them, "it's a language," she says.

The idea that animal senses can get a whiff of disease is nothing new; in 1989, doctors reported a case of a border collie and a Doberman pinscher sniffing out their owner's melanoma. More recently, scientists have shown that dogs can detect COVID-19 by smelling people's sweat. A lot of insects probably have similar abilities, Gouzerh says. Ants, for instance, can be trained to pick out the smell of cancer cells grown in a lab dish. But until now, bees' abilities haven't been so clear, she says.

By directly plugging into insects' neurons, scientists can bypass behavioral training, Saha says. Instead of taking weeks to teach a dog to sit when it smells something suspicious, the researchers can get their answer straight from the brain.

Saha's team held honeybees in place with 3-D printed harnesses and wax while the scientists performed bee brain surgery, attaching wires to the region that processes odors. A device delivered puffs of air to the insects' antennae, like a salesperson spritzing scents at a perfume counter.

Each puff could contain a milieu of mingling odors, such as those exhaled by healthy people. Another mixture mimicked the miasma of lung cancer patients' breaths, which contain distinct odors that the human nose can't detect. Using electrical signals from the bees' brains, researchers could distinguish between the two types of synthetic breath at least 93 percent of the time. In another test, the bees could successfully tell the difference between air samples taken above healthy cells in a lab dish and those gathered above two types of cancerous cells.

The team hopes to test bees on breath samples from cancer patients. Though the insects last just a few hours before their brain health wanes and responses become unstable, they work fast, Saha says. With just one bee brain, the team could buzz through over 100 samples, he says. ■

To test whether honeybees can detect cancer, scientists had to first secure the bees in a 3-D printed harness with some wax (blue).

SAHA LAB

PALEONTOLOGY

Ancient great ape had company

Fossils amplify Europe's status as a hotbed of ape evolution

BY BRUCE BOWER

Two lines of ancient apes, including what may be the smallest great ape yet found, lived alongside each other in Europe, fossils discovered in a Bavarian clay pit indicate. It's the first time that different species of great ape, each with a distinctive body style and diet, have been found coexisting outside of Africa, researchers say.

Germany's Hammerschmiede site previously yielded 11.6-million-year-old fossils of *Danuvius guggenmosi*. That creature, categorized as an extinct great ape, gained fame as possibly the oldest known upright walker, a team led by paleontologist Madelaine Böhme of the University of Tübingen in Germany reported in 2019 (SN: 12/7/19, p. 13).

Now Böhme and colleagues report that three fossils found in the *Danuvius* sediment layer come from another great ape, the newly identified *Buronius manfredschmidi*. A partial upper molar and a kneecap found next to each other probably represent a young, sexually immature individual, Böhme says. A partial lower premolar excavated about 25 meters from the other fossils belonged to an adult, the team reports June 7 in *PLOS ONE*.

Based on the size and shape of those fossils, the researchers suspect that *Buronius* weighed about 10 kilograms, making it the smallest known great ape. The ancient ape's weight is on par with modern siamangs, a type of lesser ape.

The few fossils are enough to start piecing together *Buronius*' lifestyle, the team contends. A thin outer layer of tooth enamel would have been suited to a diet of soft foods. Several features of the relatively short, thick fossil kneecap enabled skillful climbing. That suggests that *Buronius* ate leaves and fruits.

Danuvius, which grew to about twice the size of *Buronius*, had thickly enameled teeth that could manage tough foods, such

as mollusks, nuts, roots, underground stems and meat from small animals.

If the team is correct, Hammerschmiede represents the first locale outside Africa to have hosted two Miocene great ape species at the same time. The Miocene Epoch extended from about 23 million to 5 million years ago. Miocene great apes belong to an evolutionary family that includes modern chimps, gorillas, orangutans and humans.

Evidence that *Danuvius* and *Buronius* survived on different resources in the same place "shows that ecosystems in the Miocene of Europe enabled, perhaps even forced, the evolution of diverse ape lineages," Böhme says.

With the addition of *Buronius*, there are now 16 known European ape genera from between 16 million and 6 million years ago that are related to modern great apes, Böhme says. That's more than twice as many as have been found in Africa dating to the same period.

This fossilized kneecap (left) and two partial teeth (right) belonged to an unusually small great ape that lived in Europe nearly 12 million years ago, scientists say.

But a total of only three *Buronius* fossils leaves room for uncertainty about the creature's evolutionary status — or whether it's a separate species at all.

For instance, some features of the two partial teeth resemble those found on fossil teeth from one branch of a group of Eurasian apes called pliopithecoids, says paleoanthropologist Clément Zanolli of the University of Bordeaux in France. Pliopithecoids have no living descendants.

Or the two small partial teeth might have belonged to *Danuvius* infants, says paleoanthropologist Sergio Almécija of the American Museum of Natural History in New York City. The discoveries, he says, "highlight how much we don't know about the evolution of the great ape and human family, and of other primates, during the Miocene in Europe." ■

ANIMALS

Leeches can leap, a new video suggests

The creatures' acrobatics have stirred debate for over a century

BY SUSAN MILIUS

A chance video by a researcher relishing her first big field trip might help resolve an argument that's raged among biologists for more than a century. Can leeches jump?

Yes, at least one kind of leech can, says conservation biologist Mai Fahmy of the American Museum of Natural History and Fordham University in New York City. She has twice filmed tiny land-crawling leeches in Madagascar doing what she sees as jumping as they navigated the rainforest's low-hanging and fallen leaves.

The first time, in 2017, "I came back to New York with what I thought was just a neat little video of a leech doing something it always does," Fahmy says. She had, however, stumbled upon evidence related to what AMNH leech specialist Michael Tessler calls "one of the top two or three most contentious facts about leeches."

That phone video and another one shot in 2023 have opened a new chapter in the contradictory lore of leech locomotion, Fahmy and Tessler report June 20 in *Biotropica*.

In the 1300s, traveling chronicler Ibn Battuta noted that, in Southeast Asia, a "flying leech" lurks on trees and weeds near water "and leaps to the person who happens to pass it." Yet doubters at least as early as 1886 dismissed this as mistaking falling for "flying," if indeed leeches really were able to get up into trees and shrubs to begin with.

"It's surprisingly hard to define *jump*," says Tessler, also of City University of New York's Medgar Evers College. "For us, it was about active propulsion."

Of the hundreds of named leech species, many stay in water. But the jumping debate involves land dwellers. Fahmy and Tessler propose that a jump is "an intentional movement that muscularly propels the organism outward and/or upward." That definition, they say, could apply to vertebrates as well as to squishy legless life.

The species they're applying the definition to, one of Madagascar's *Chtonobdella* leeches, has not been previously proposed as a leaper. In the 2017 video, an upright leech sways, makes a small move toward the edge of a leaf and then goes into the air over the edge.

The question is whether leeches would tumble off after releasing their grip. "What we believe these videos, we hope, pretty obviously show is that this is a forceful movement," Tessler says. For example, the leeches rear back into a "coil" before jumps, as a snake might before launching a strike.

Chris Darling, a senior curator of insects at the Royal Ontario Museum in Toronto, got an early peek at the 2017 video. Darling, who has described a novel jumping motion in fly larvae, sees the leech motion as "a clear jump."

But evolutionary biomechanicist Sheila Patek of Duke University isn't so sure. She sees the leech's movement as "something in between falling, controlled aerial descent and directed launch. I honestly cannot tell whether that's a jump or not."

The new study may not end the debate, but at least the video updates the puzzle for the digital age. ■

M. BÖHME *ET AL*/*PLOS ONE* 2024 (CC BY 4.0)

Watch videos of leeches "leaping" at **bit.ly/SN_Leeches**

HEALTH & MEDICINE

Short space trips may affect health

The finding raises questions about risks to private crews

BY ADAM MANN

Researchers have been studying how spaceflight affects astronaut health since the dawn of the Space Age. Well-known problems include bone loss, heightened cancer risk, vision impairment, weakened immune systems and mental health issues. Yet what's going on at a molecular level hasn't always been clear.

A new project known as the Space Omics and Medical Atlas, or SOMA, is poised to help answer such questions. A suite of 30 papers, published June 11 in various *Nature* journals, represents the largest database for aerospace human biology and medicine published to date.

SOMA is responding to a major shift under way in human spaceflight — the rise of crewed commercial missions such as Axiom's Ax-1 and SpaceX's Inspiration4. The project's datasets include clinical information from these missions as well as those from NASA and JAXA, Japan's space agency.

While professional astronauts employed by government agencies must undergo rigorous health screenings, no such regulations apply to private passengers.

Perhaps the most well-known long-term biomedical NASA study involved identical twins Scott and Mark Kelly (*SN: 5/11/19 & 5/25/19, p. 22*). Researchers looked at how Scott's 340-day stay on the International Space Station affected his physiology, gene expression, immune system and mental reasoning compared with Mark's, who stayed on the ground.

One fascinating finding: Scott Kelly's telomeres grew longer. Telomeres are short stretches of repeating DNA sequences at the end of chromosomes. As cells divide, telomeres get shorter, a process associated with aging. But this didn't mean that Kelly got younger while in space. In fact, he was potentially at risk of developing cancer.

Certain cancers "protect telomere lengths or cause telomere elongation," says bioastronautics researcher Eliah Overbey of the University of Austin in Texas. Kelly's telomeres shrank to their preflight size after he returned to Earth. But the experiment was limited by its tiny sample size. "NASA didn't repeat these sorts of studies on their future crews," Overbey says.

Telomere length and molecular changes related to immune response, DNA repair and stress are data that Overbey and colleagues have collected with SOMA. And the data show that commercial jaunts lasting several days to weeks can induce genetic effects similar to those that astronauts experience during longer missions.

For instance, the telomeres of Inspiration4 passengers lengthened in space but returned to normal on the ground. Overbey's team saw "a pretty dramatic effect," she says. Many other molecular changes followed similar patterns as the twins study, shifting during spaceflight and then returning to baseline back on Earth. What the findings mean for long-term health isn't yet entirely clear.

Overbey's team intends SOMA to become a hub that can help answer questions about how space travel impacts the body on a molecular level and what it means for health. "I view a lot of these datasets as hypothesis-generating machines," she says.

The rising popularity of commercial spaceflight raises a host of ethical issues as long as the health risks to private travelers go unknown. The Federal Aviation Administration, which oversees launch licenses, cannot currently mandate health screenings for private individuals. A long-standing congressional moratorium on new safety regulations for commercial human spaceflight is set to expire in January, but several bills have proposed pushing this date back by up to six years. For now, the FAA suggests that private individuals consult with physicians who are trained in spaceflight issues before flying.

So far, all commercial crews have participated in biomedical research, but there's no guarantee that future crews will allow their health data to be collected.

Lawmakers should figure out health criteria for commercial crews long before the moratorium expires, says philosopher Dana Tulodziecki of Purdue University in West Lafayette, Ind. "There are lots of space ethics efforts that think about really large issues; political systems on other planets and whatnot," Tulodziecki says. "But that's really far in the future, right? This one is already here.... It's really something urgent." ■

Peggy Whitson, a passenger on the Ax-2 mission, spent two weeks aboard the International Space Station in 2023. Short stints in space can spur molecular changes in the body that longer trips do.

NASA

PILLI/GETTY IMAGES PLUS

Millions of people in the United States have reported experiencing long COVID, but there has not been a standard definition for the condition until now.

HEALTH & MEDICINE

Long COVID gets a universal definition

The description may validate millions of people's ongoing struggle

BY TINA HESMAN SAEY

A sweeping new definition of long COVID, announced June 11 by the U.S. National Academies of Sciences, Engineering and Medicine, could help affected people get recognition of their condition and improve diagnosis.

Previous definitions each have had their own set of accepted symptoms, timelines and requirements for proof of infection. The lack of standardization "left many patients in the lurch without clear ability to be recognized for the condition that they had," says Harvey Fineberg, a public health expert who chaired the committee that drafted the definition. "We heard from literally hundreds of people experiencing long COVID about the challenges that they had in being heard, in gaining access to care and obtaining the care they needed."

The National Academies defines long COVID as a medical condition that persists for at least three months after a COVID-19 infection. The condition can strike adults and children and can start weeks or months after seeming recovery from the initial infection. There isn't an upper limit on how long after getting the original illness that long COVID could start.

Long COVID can affect any organ or system in the body. People may have any of more than 200 symptoms, which include difficulty breathing, brain fog, blood clots, dizziness, extreme fatigue, loss of taste or smell, fast heart rate, diabetes and autoimmune diseases such as lupus. Those symptoms can appear alone or in various combinations, can be continuous, get progressively worse or seem to improve and then get worse again.

Because chronic symptoms can affect people who had mild to severe COVID-19 and can even strike people who didn't have any symptoms from their original infection, a past positive test isn't required for diagnosis.

For now, there are no tests that reliably diagnose long COVID. That means that no one knows exactly how many people have it, though a recent survey found that more than 17 percent of adults in the United States have experienced the condition. Some people have eventually recovered.

> "We're very mindful that the definition is only good as far as science can take us at this time."
>
> HARVEY FINEBERG

The National Academies calls for continued research to find diagnostic tools. It also calls for revision of the definition in no more than three years and possibly sooner if new science warrants it. "We're very mindful that the definition is only good as far as science can take us at this time," says Fineberg, who is president of the Gordon and Betty Moore Foundation, which funds scientific research.

Anyone with lingering effects from COVID-19 should fall under the broad umbrella erected by the new definition. That means some people who have long-term health problems caused by a different infectious disease or other cause might be mistakenly diagnosed with long COVID, Fineberg admits.

Still, this big-tent approach is essential for health equity, says committee member Monica Verduzco-Gutierrez, a physical medicine and rehabilitation physician at the University of Texas Health Science Center at San Antonio. The committee wanted to make sure that people who don't have access to COVID-19 testing — because tests weren't available early on and free testing has now ended — or who got a false-negative test or had asymptomatic infections could still be included.

Having the gravitas of the National Academies behind the definition "will be seen by patients and patients' advocates as legitimizing the illness," says Ziyad Al-Aly, head of research at VA St. Louis Health Care System.

Some people have dismissed the condition as being a mental health disorder, but plenty of research has established that there are widespread changes in the body, Verduzco-Gutierrez says. The definition "makes it clear that long COVID is a physical health condition."

Patients can take the definition to their doctors to bolster their claims, says Daria Oller, a New Jersey–based physical therapist who has had long COVID since 2020. Early on, Oller had no name for what she was experiencing and encountered skepticism from medical professionals. Though the definition may be refined, starting out broad, she says, will allow people whose symptoms don't "fit into a nice little package" to have their condition recognized. ■

HEALTH & MEDICINE

Gen X cancer rates are rising

The uptick could be bad news for Millennials and Gen Z

BY TINA HESMAN SAEY

Generation X is outdoing baby boomers, but not in a good way.

Per capita, people born between 1965 and 1980 are getting cancer more often than their parents' and grandparents' generations, researchers report in the June *JAMA Network Open*.

The forecast doesn't look good for Gen Xers, who are starting to reach ages when cancers most often appear, says Philip Rosenberg, a biostatistician at the U.S. National Cancer Institute in Rockville, Md. If the trend continues, Millennials (1981–1996) and younger generations might also experience more cancer than their elders, Rosenberg and his NCI colleague Adalberto Miranda-Filho warn.

Rosenberg, who describes himself as a boomer, wanted to see whether his generation (1946–1964) was better off than his parents' Greatest (1908–1927) and Silent (1928–1945) generations. And whether his Millennial and Gen Z (1997–2012) children might be better off still.

"You hope to see things get better when it comes to health metrics, life expectancy [and] cancer rates," Rosenberg says.

He and Miranda-Filho gathered data from 3.8 million people in the United States diagnosed with various invasive cancers. The scientists compared generational differences in diagnoses and projected Gen X's rate at age 60.

Compared with baby boomers, Gen X women have projected increases in thyroid, kidney, rectal, uterine, colon, pancreatic and ovarian cancers, as well as leukemia and non-Hodgkin's lymphoma. Gen X men have forecasted rises in thyroid, kidney, rectal, colon and prostate cancers.

There were some bright spots, though. Gen X women have decreases in lung and cervical cancers, while Gen X men have less lung, liver and gallbladder cancers and non-Hodgkin's lymphoma. But combining data on all the cancers painted a bleak picture because the gaining cancers numerically overtook falling ones.

Hispanic women have one of the largest increases in overall rate of cancer: 35 percent. They went from 598 cancers diagnosed per 100,000 person-years in the Silent and Boomer generations to 806 diagnoses per 100,000 person-years in Gen X. The rate is presented as the number of new cases you would expect if you watched 100,000 people for a year.

All racial and ethnic groups included in the study experienced increases in cancer diagnoses except for Asian and Pacific Islander men, for whom cancer rates fell from 562 cancers diagnosed per 100,000 person-years in the Silent and boomer generations to 519 cancers per 100,000 person-years for Gen Xers, a decrease of 7.7 percent. Non-Hispanic Black men in Gen X had the highest overall cancer rate, at 1,561 cases per 100,000 person-years. That's up about 12 percent from the Boomer and Silent generations.

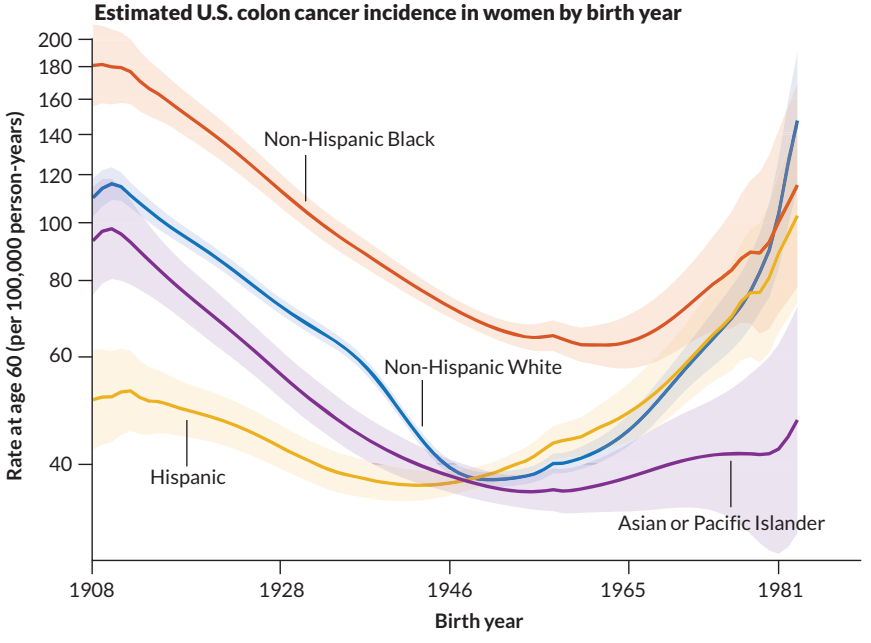
Increases in many cancers, including colorectal cancers in people under 50 and kidney and thyroid cancers, have previously been noted, says epidemiologist Ahmedin Jemal of the American Cancer Society in Atlanta. And the jump is not limited to the United States. Other high-income countries have reported similar increases.

Some of the increase may be due to better screening and early detection, says cancer epidemiologist Corinne Joshu of the Johns Hopkins Bloomberg School of Public Health. Many of the cancers on the rise among Gen Xers are linked to obesity, lack of exercise, eating a lot of red meat and other lifestyle factors. But changing behavior is difficult. "The healthy choices are not the easy choices to make in our society," she says. "We do not see it easier and more affordable to eat healthier."

Joshu notes that drops in lung cancer were driven by policies banning smoking indoors and taxes that made cigarettes too expensive for young people. Taking something away that isn't good for health may be easier than making positive lifestyle changes accessible and affordable for everyone, she says.

"We could move the needle on that, but it takes societal effort and for people to come together and say, 'This is … worth changing,'" Joshu says. "That presumably would lead to not only a decrease in cancer, but a decrease in [other] major causes of death." ■

A generational thing Gen X women (1965–1980) at age 60 are expected to be diagnosed with colon cancer more often than baby boomers (1946–1964) were at that age. The graph shows the person-year cancer rate (on a logarithmic scale) for 60-year-old women by their birth year.



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HEALTH & MEDICINE

Sex may influence pain pathways

Male and female cells respond differently to the same signals

BY CLAIRE YUAN

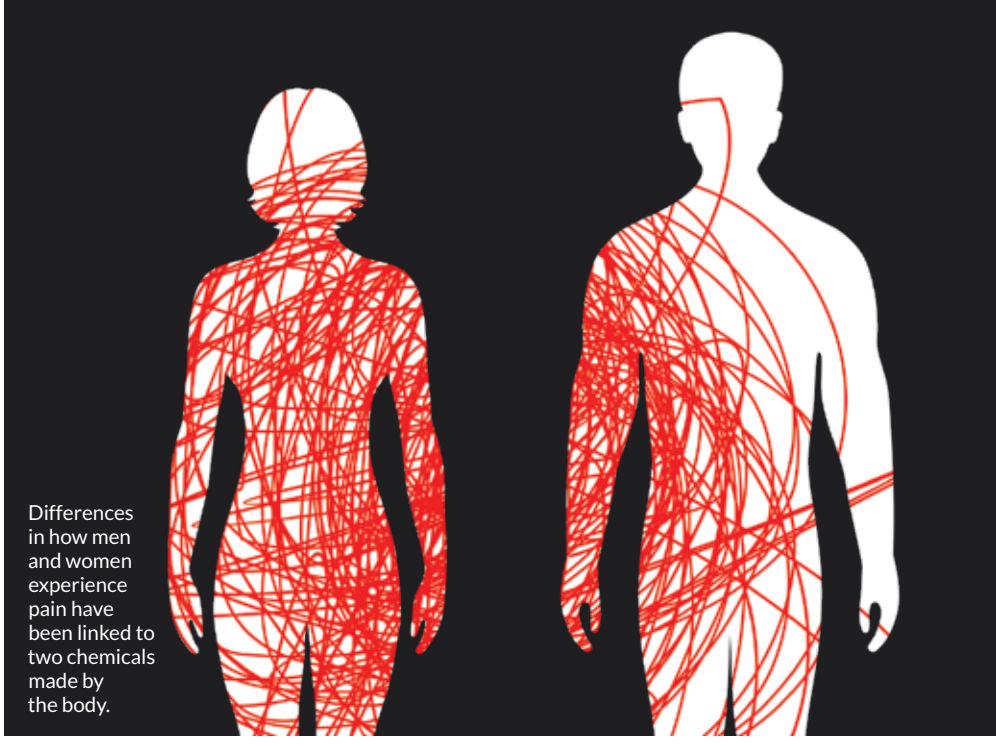
Men and women experience pain differently, and until now, scientists didn't know why. Differences in male and female nerve cells may be part of the answer, new research suggests.

Pain-sensing nerve cells from male and female animal tissues responded differently to the same sensitizing substances, researchers report June 3 in *Brain*. The results suggest that at the cellular level, pain is produced differently between the sexes.

The results might allow researchers "to come up with drugs that would be specific to treat female patients or male patients," says Katherine Martucci, a neuroscientist who studies chronic pain at Duke University School of Medicine. "There's no debate about it. They're seeing these differences in the cells."

Some types of chronic and acute pain appear more often in men or women, but it's unclear why. For instance, about 50 million adults in the United States have a chronic pain condition. About 50 percent of chronic pain conditions (such as rheumatoid arthritis and migraines) are more prevalent in women, while 20 percent (such as gout) are more prevalent in men. Similar disparities exist for acute conditions.

These differences prompted pain researcher Frank Porreca of the University of Arizona Health Sciences in Tucson and colleagues to study nociceptors, nerve cells that can act like alarms for the body. The pain sensors of these cells, which are found in skin, organs and elsewhere, can detect potentially dangerous stimuli and send signals to the brain, which then interprets the information as pain. In some cases, the nerve cells can become more sensitive to outside stimulation, registering even gentle sensations — like a shirt rubbing sunburned skin — as pain.



Differences in how men and women experience pain have been linked to two chemicals made by the body.

T. TIBBITTS

Using tissue from mice, monkeys and humans, the researchers studied the effects of two substances that can sensitize nerve cells to pain: a hormone called prolactin and the neurotransmitter orexin B. In the presence of sensitizing substances, nerve cells have a lower threshold of when they send electrical signals to the brain that something is wrong. Across all three species, exposure to prolactin made nerve cells from females more active compared with those from males. Orexin B had the opposite effect, boosting the activity of nerve cells from males.

This finding suggests that there are differences between men and women even at the first step in the pain pathway, says study coauthor Harrison Stratton, a neuroscientist at the University of Pittsburgh.

If the driving forces that produce pain differ between sexes, then pain medicines could be tailored for males or females, Porreca says. This could mean blocking sensitivity to prolactin in females and to orexin B in males. The two substances have already been widely studied for their involvement in other body processes, such as lactation and sleep. Some orexin blockers approved by the U.S. Food and Drug Administration to treat insomnia could be repurposed for pain. And Porreca and colleagues previously discovered a prolactin-blocking antibody, which could hold promise for treating a variety of conditions from female pain to infertility.

Typically, discoveries about pain in mice do not translate cleanly to humans. But since the particular pain pathway tested in the study seems to operate similarly across mice, monkeys and humans, future drugs targeting orexin B and prolactin could turn out to be a good way to manage pain following further research and testing, Martucci says. "It's giving us a really good vision for how to move forward."

But Richard Miller, a pharmacologist at Northwestern University Feinberg School of Medicine in Chicago, notes that while the study finds differences between the sexes, pain is often caused by a confluence of many other potential factors. That means there may be many other substances that would have shown similar results, he says, calling into question whether prolactin and orexin B are uniquely important targets. ■

50 million
Adults in the United States with chronic pain

50 percent
The share of conditions that are more prevalent in women

20 percent
The share of conditions that are more prevalent in men

ACING IT

AI performs well on cognitive benchmarks, but how do we know if it really understands? **By Ananya**

*Illustration by **Glenn Harvey***

"Sparks of artificial general intelligence," "near-human levels of comprehension," "top-tier reasoning capacities." All of these phrases have been used to describe large language models, which drive generative AI chatbots like ChatGPT. Since that bot arrived on the scene in late 2022, it seems as if every new generative AI is the next, best iteration — not just producing humanlike content but also approaching near-human cognition (*SN: 12/16/23 & 12/30/23, p. 20*). But what can we really say about any LLM's ability to reason and understand?

In the AI community, there is no consensus on the definition of machine "intelligence," nor on how to define the various cognitive capabilities often attributed to LLMs. Such high-level claims about understanding are often based on benchmark datasets, which use many instances of a specific task (say answering questions) to assess aggregate performance (usually based on a metric like accuracy).

Consider, for example, Massive Multitask Language Understanding, or MMLU, a popular benchmark for assessing the knowledge acquired by LLMs. MMLU includes some 16,000 multiple-choice questions covering 57 topics, including anatomy, geography, world history and law. Benchmarks such as BIG-bench (the BIG stands for Beyond the Imitation Game) consist of a more varied collection of tasks. Discrete Reasoning Over Paragraphs, or DROP, claims to test reading comprehension and reasoning. WinoGrande and HellaSwag purport to test commonsense reasoning. Models are pitted against each other on these benchmarks, as well as against humans, and models sometimes perform better than humans.

But "AI surpassing humans on a benchmark that is named after a general ability is not the same as AI surpassing humans on that general ability," computer scientist Melanie Mitchell pointed out in a May edition of her Substack newsletter.

These evaluations don't necessarily deliver all that they claim, and they might not be a good match for today's AI. One study posted earlier this year at arXiv.org tested 11 LLMs and found that just changing the order of the multiple-choice answers in a benchmark like MMLU can affect performance.

Still, industry leaders tend to conflate impressive performance on the tasks LLMs are trained to do, like engaging in conversation or summarizing text, with higher-level cognitive capabilities like understanding, knowledge and reasoning, which are hard to define and harder to evaluate. But for LLMs, generating content is not dependent on understanding it, researchers reported in a study presented in May in Vienna at the International Conference on Learning Representations. When the researchers asked GPT-4 and other AI models to answer questions based on AI-generated text or images, they frequently couldn't answer correctly.

Nouha Dziri, a research scientist studying language models at the Allen Institute for AI in Seattle and coauthor on that study, calls that "a paradox compared to how humans actually operate." For humans, she says, "understanding is a prerequisite for the ability to generate the correct text."

What's more, as Mitchell and colleagues note in a paper in *Science* last year, benchmark performance is often reported with aggregate metrics that "obfuscate key information about where systems tend to succeed or fail." Any desire to look deeper is thwarted because specific details of performance aren't made publicly available.

Researchers are now imagining how better assessments might be designed. "In practice, it's hard to do good evaluations," says Yanai Elazar, also working on language models at the Allen Institute. "It's an active research area that many people are working on and making better."

Why benchmarks don't always work

Aside from transparency and inflated claims, there are underlying issues with benchmark evaluations.

One of the challenges is that benchmarks are good for only a certain amount of time. There's a concern that today's LLMs have been trained on the testing data from the very benchmarks intended to evaluate them. The benchmark datasets are available online, and the training data for LLMs are typically scraped from the entire Web. For instance, a technical report from OpenAI, which developed ChatGPT, acknowledged that portions of benchmark datasets including BIG-bench and DROP were part of GPT-4's training data. There's some evidence that GPT-3.5, which powers the free version of ChatGPT, has encountered the MMLU benchmark dataset.

But much of the training data is not disclosed. "There's no way to prove or disprove it, outside of the company just purely releasing the training datasets," says Erik Arakelyan of the University of Copenhagen, who studies natural language understanding.

Today's LLMs might also rely on shortcuts to arrive at the correct answers without performing the cognitive task being evaluated. "The problem often comes when there are things in the data that you haven't thought about necessarily, and basically the model can cheat," Elazar says. For instance, a study reported in 2019 found evidence of such statistical

associations in the Winograd Schema Challenge dataset, a commonsense reasoning benchmark that predates WinoGrande.

The Winograd Schema Challenge, or WSC, was proposed in 2011 as a test for intelligent behavior of a system. Though many people are familiar with the Turing test as a way to evaluate intelligence, researchers had begun to propose modifications and alternatives that weren't as subjective and didn't require the AI to engage in deception to pass the test.

Instead of a free-form conversation, WSC features pairs of sentences that mention two entities and use a pronoun to refer to one of the entities. Here's an example pair:

Sentence 1: In the storm, the tree fell down and crashed through the roof of my house. Now, I have to get it removed.

Sentence 2: In the storm, the tree fell down and crashed through the roof of my house. Now, I have to get it repaired.

A language model scores correctly if it can successfully match the pronoun ("it") to the right entity ("the roof" or "the tree"). The sentences usually differ by a special word ("removed" or "repaired") that when exchanged changes the answer. Presumably only a model that relies on commonsense world knowledge and not linguistic clues could provide the correct answers.

But it turns out that in WSC, there are statistical associations that offer clues. Consider the example above. Large language models, trained on huge amounts of text, would have encountered many more examples of a roof being repaired than a tree being repaired. A model might select the statistically more likely word among the two options rather than rely on any kind of commonsense reasoning.

In a study reported in 2021, Elazar and colleagues gave nonsensical modifications of WSC sentences to RoBERTa, an LLM that has scored more than 80 percent on the WSC benchmark in some cases. The model got it right at least 60 percent of the time even though humans wouldn't be expected to answer correctly. Since random guessing couldn't yield more than a 50 percent score, spurious associations must have been giving away the answer.

To be good measures of progress, benchmark datasets cannot be static. They must be adapted alongside state-of-the-art models and rid of any specious shortcuts, Elazar and other evaluation researchers say. In 2019, after the WSC shortcuts had come to light, another group of researchers released the now commonly used WinoGrande as a harder commonsense benchmark. The benchmark dataset has more than 43,000 sentences with an accompanying algorithm that can filter out sentences with spurious associations.

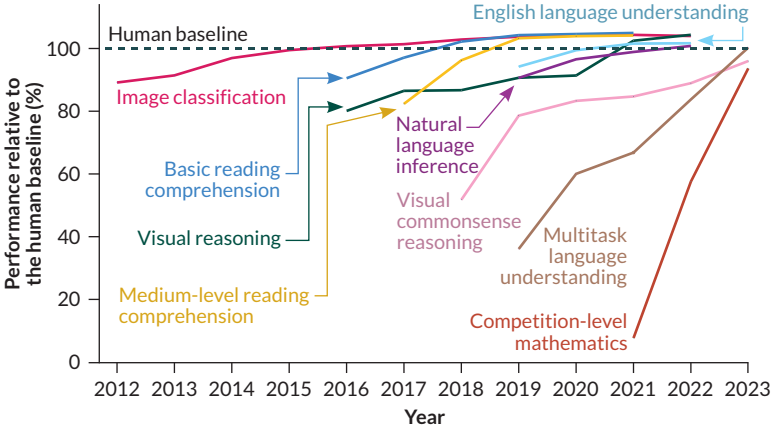
For some researchers, the fact that LLMs are passing benchmarks so easily simply means that more comprehensive benchmarks need developing. For instance, researchers might turn to a collection of varied benchmark tasks that tackle different facets of common sense such as conceptual understanding or the ability to plan future scenarios. "The challenge is how do we come up with a more adversarial, more challenging task that will tell us the true capabilities of these language models," Dziri says. "If the model is scoring 100 percent on them, it might give us a false illusion about their capabilities."

But others are more skeptical that models performing great on the benchmarks necessarily possesses the cognitive abilities in question. If a model tests well on a dataset, it just tells us that it performs well on that particular dataset and nothing more, Elazar says. Even though WSC and WinoGrande are considered tests for common sense, they just test for pronoun identification. HellaSwag, another commonsense benchmark, tests how well a model can pick the most probable ending for a given scenario.

While these individual tasks might require common sense or understanding if constructed correctly, they still don't make up the entirety of what it means to have common sense or to understand. Other forms of commonsense reasoning, involving social interactions or comparing quantities, have been poorly explored.

Superior skills? In recent years, AI has started to outperform humans on tests of image classification, language understanding, reading comprehension and more (skills that surpass the human baseline in the graph below). But some experts warn that current benchmarks are not up to the job of evaluating an AI model's understanding and reasoning. SOURCE: ARTIFICIAL INTELLIGENCE INDEX REPORT 2024

AI performance on select tasks based on existing benchmarks



C. CHANG

A different approach to testing

Systematically digging into the mechanisms required for understanding may offer more insight than benchmark tests, Arakelyan says. That might mean testing AI's underlying grasp of concepts using what are called counterfactual tasks. In these cases, the model is presented with a twist on a commonplace rule that it is unlikely to have encountered in training, say an alphabet with some of the letters mixed up, and asked to solve problems using the new rule. Other approaches include analyzing the AI's ability to generalize from simple to more complex problems or directly probing under what circumstances AI fails. There might also be ways to test for commonsense reasoning, for example, by ruling out unrelated mechanisms like memorization, pattern-matching and shortcuts.

In a study reported in March, Arakelyan and colleagues tested if six LLMs that have scored highly on language understanding benchmarks and thus are said to understand the overall meaning of a sentence can also understand a slightly paraphrased but logically equivalent version of the same sentence.

Language understanding is typically evaluated using a task called natural language inference. The LLM is presented with a premise and hypothesis and asked to choose if the premise is implied by, contradicts or is neutral toward the hypothesis. But as the models become bigger, trained on more and more data, more carefully crafted evaluations are required to determine whether the models are relying on shortcuts that, say, focus on single words or sets of words, Arakelyan says.

To try to get a better sense of language understanding, the team compared how a model answered the standard test with how it answered when given the same premise sentence but with slightly paraphrased hypothesis sentences. A model with true language understanding, the researchers say, would make the same decisions as long as the slight alteration preserves the original meaning and logical relationships. For instance, the premise sentence "There were beads of perspiration on his brow" implies the hypothesis "Sweat built up upon his face" as well as the slightly altered "The sweat had built up on his face."

The team used a separate LLM, called flan-t5-xl and released by Google, to come up with variations of hypothesis sentences from three popular English natural language inference datasets. The LLMs under testing had encountered one of the datasets during training but not the other two. First, the team tested the models on the original datasets and picked only those sentences that the models classified correctly to be paraphrased. This ensured that any performance difference could be attributed to the sentence variations. On top of that, the researchers fed the original hypothesis sentences and their variations to language models identical to ones tested and capable of evaluating if the pairs were equivalent in meaning. Only those deemed equal by both the model and human evaluators were used to test language understanding.

But for a sizable number of sentences, the models tested changed their decision, sometimes even switching from "implies" to "contradicts." When the researchers used sentences that did not appear in the training data, the LLMs changed as many as 58 percent of their decisions. "This essentially means that models are very finicky when understanding meaning," Arakelyan says. This type of framework, unlike benchmark datasets, can better reveal whether a model has true understanding or whether it is relying on clues like the distribution of the words.

How to evaluate step by step

Tracking an LLM's step-by-step process is another way to systematically assess whether it uses reasoning and understanding to arrive at an answer. In one approach, Dziri's team tested the ability of LLMs including GPT-4, GPT-3.5 and GPT-3 (a predecessor of both) to carry out multidigit multiplication. A model has to break down such a task into sub-steps that researchers can examine individually.

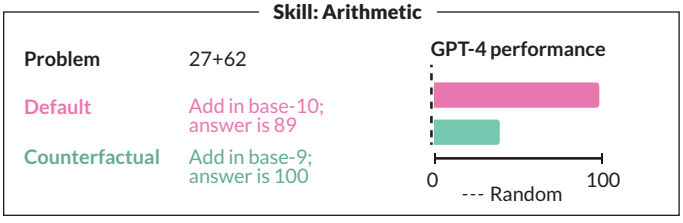
After giving the LLMs a problem, like 7 x 29, the researchers checked the answers at each sub-step — after single-digit multiplication, after carrying over and after summation. While the models were perfect at multiplication of single and two-digit numbers, accuracy deteriorated as the number of digits increased. For multiplication problems with four- and five-digit numbers, the models hardly got any answers right. Lower-digit problems "can be easily memorized," Dziri says, but the LLMs' performance "starts degrading when we increase the complexity."

Perhaps the models hadn't encountered enough examples in the training data to learn how to solve more complex multiplication problems. With that idea, Dziri and colleagues further fine-tuned GPT-3 by training it on almost all the multiplication problems up to four-digits by two-digits, as well as providing step-by-step instructions on how to solve all the multiplication problems up to three-digits by two-digits. The team reserved 20 percent of multiplication problems for testing.

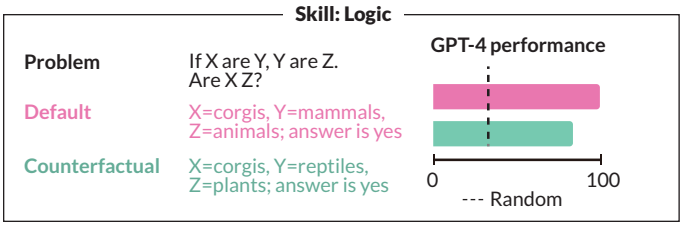
> "Models are very finicky when understanding meaning."
>
> **ERIK ARAKELYAN**

Counterfactual testing

One way to assess AI's grasp of concepts is to use counterfactual tasks, which add a twist on a common rule that the AI is unlikely to have seen in training. Researchers recently presented GPT-4 with several such problems. A couple examples are shown here.



In a test of numerical reasoning, GPT-4 had to add 27 + 62; in the counterfactual version of the task, it had to solve the same problem using a base-9 numerical system. The model scored higher than chance (represented by the dashed line) in both tasks but did far better on the default (pink bar) versus counterfactual (green) version.



In a test of logical reasoning, GPT-4 had to solve a logic problem that depended on factually accurate information. In the counterfactual task, the logic problem required the AI to assume inaccurate information to solve the problem rather than rely on its training. SOURCE: Z. WU *ET AL*/ARXIV.ORG 2024

Without access to the models' original training data and process, the researchers don't know how the models might be tackling the task, Dziri says. "We have this simple assumption that if we humans follow this algorithm, it should be quite intuitive for the model to follow it, because it's been trained on human language and human reasoning tasks."

For humans, carrying out five- or six-digit multiplication is fairly straightforward. The underlying approach is no different from multiplying fewer digits. But though the model performed with near-perfect accuracy on examples it had encountered during training, it stumbled on unseen examples. These results indicate that the model was unable to learn the underlying reasoning needed for multidigit multiplication and apply these steps to new examples.

Surprisingly, when the researchers investigated the models' answers at each sub-step, they found that even when the final answers were right, the underlying calculations and reasoning — the answers at each sub-step — could be completely wrong. This confirms that the model sometimes relies on memorization, Dziri says. Though the answer might be right, it doesn't say anything about the LLM's ability to generalize to harder problems of the same nature — a key part of true understanding or reasoning.

New tests of generative AI will be hard

Even though interest in such nuanced evaluations is gaining steam, it's challenging to create rigorous tests because of the sheer scale of data and training, plus the proprietary nature of LLMs.

For instance, trying to rule out memorization may require checking millions of data points in huge training datasets to see if the LLM has encountered the example before. It's harder still when training data aren't available for scrutiny. "We have to make lots of assumptions, and we have to pick our task very carefully," Dziri says. Sometimes researchers trying to do an evaluation can't get access to the training methodology or a version of the model itself (let alone the most updated version).

The cost of computation is another constraint. For instance, Dziri and colleagues found that including five-digit by five-digit multiplication problems in their fine-tuning of GPT-3 would require about 8.1 billion question-and-answer examples, costing a total of over $12 million.

In truth, a perfect AI evaluation might never exist. The more language models improve, the harder tests will have to get to provide any meaningful assessment. The testers will always have to be on their toes. And it's likely even the latest, greatest tests will uncover only some specific aspects of AI's capabilities, rather than assessing anything akin to general intelligence.

For now, researchers are hoping at least for more consistency and transparency in evaluations. "Mapping the model's ability to human understanding of a cognitive capability is already a vague statement," Arakelyan says. Only evaluation practices that are well thought out and can be critically examined will help us understand what's actually going on inside AI. ■

Explore more

- Fernando Martínez-Plumed *et al.* "Research community dynamics behind popular AI benchmarks." *Nature Machine Intelligence.* May 17, 2021.

Ananya is a freelance science journalist and translator based in Bangalore, India.

C. CHANG

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SURVIVING CHILDHOOD MALNUTRITION

Inflammation and gut problems can persist after recovery. New treatments may repair damage

By Tina Hesman Saey

MOHAMMED ABED/AFP VIA GETTY IMAGES

In Rafah in the southern part of the Gaza Strip, children wait for food in February amid the Israel-Hamas war. Up to 9 percent of children under the age of 5 in southern Gaza are malnourished. Malnutrition's effects on the body don't end when food arrives, research shows.

Denise Potvin, a nurse working in Rafah, a city in the south of the Gaza Strip, has been seeing something new recently: malnutrition among young children. Before the current Israel-Hamas war, there weren't cases of malnutrition, Potvin says. "Now we are seeing cases."

As of June 6, 32 people there, including at least 28 children, have died of malnutrition. In southern Gaza, up to 9 percent of children under age 5 are malnourished, according to the World Health Organization. In northern Gaza, the fraction is greater — up to a quarter of children are malnourished (two to three standard deviations below the average weight-for-height score for their age) and up to 4 percent are severely malnourished (more than three standard deviations below average). The international Integrated Food Security Phase Classification partnership warned in a report in March that famine is imminent in northern Gaza, and the rest of Gaza is also at risk.

36 million

The number of young children experiencing malnutrition globally

The children of Gaza are not alone. In Sudan, up to 2.5 million people could die of malnutrition by the end of September if ongoing fighting there continues, the Clingendael Institute, a Dutch think tank, warned in May. Kids in Afghanistan, the Democratic Republic of Congo, Haiti, Nigeria, Pakistan, Yemen and other countries are also experiencing malnutrition as a result of conflict, poverty, natural disasters and other factors that leave them suddenly without food. Those abrupt disruptions can lead to acute malnutrition and wasting, and — if the situation becomes prolonged — chronic malnutrition, stunting and even death.

Worldwide last year, an estimated 36.4 million children under the age of 5 were acutely malnourished, with 9.8 million of them suffering severe malnutrition, according to the 2024 Global Report on Food Crises. In 2022, about 148 million children had stunting (being too short for their age) and 45 million had wasting (too thin for their height), with more than 13 million with severe wasting. Nearly half of deaths of young children, especially of children in low- and middle-income countries, are linked to undernutrition.

Even for children who get treatment, malnutrition can lead to a lifetime of consequences. Those include an elevated chance of dying in the year or so after recovery, stunted growth and a reduced ability to achieve their full intellectual capacity, even as adults.

Recent research offers insight into the physiological factors that lead to long-term problems

and provides hope that new treatments might heal the lingering damage that can torment survivors of malnutrition.

A weakened immune system

A body suffering from malnutrition must expend energy on essentials like keeping the heart and lungs functioning. To do so, the body cuts back in other important areas, says Indi Trehan, a pediatrician at the University of Washington in Seattle. "Some of the things that it's not going to spend its energy on very much is growing taller, which is part of the jobs of kids' bodies," he says. "It's not going to spend a lot of energy on developing neurons and brain connections," healing cuts and scrapes, or keeping up body temperature.

With malnutrition, "you're really hitting a population for the long term."

INDI TREHAN

One of the most serious cutbacks is in the immune system, Trehan says. "The immune system will start to fall apart," leaving malnourished people susceptible to dying from infections that well-nourished people can more easily get over.

For instance, in a review of studies of malnutrition, researchers found that young kids who were moderately underweight for their age are twice as likely to die of pneumonia as children at healthy weights.

In Rafah, Potvin, who works with the international medical humanitarian organization Doctors Without Borders, also known by its French abbreviation MSF, is watching the reinforcing dynamic between malnutrition and the immune system play out.

"You see everybody living in tents, overcrowded situations, situations with lack of access to proper water and hygiene and sanitation," she says. Those conditions can increase the risk of malnourished children catching infectious diseases that can, in turn, make malnutrition worse. In the MSF clinics in Rafah, Potvin says, "we're seeing a lot of respiratory tract infections, diarrheal illnesses and different skin conditions."

Death even after treatment

Globally, only a fraction of children with severe acute malnutrition get lifesaving treatment, which typically includes an energy-dense, nutrient-rich ready-to-use therapeutic food. About 1 in 5 children hospitalized for severe malnutrition will die before being discharged, says Gerard Bryan Gonzales, a public health nutritionist at Ghent University in Belgium.

Fixing malnutrition isn't as simple as giving a child food. Even after leaving a hospital and returning home, children are prone to dying. A paper published in 2018 in *PLOS ONE* that reviewed multiple studies found that up to 10 percent of severely malnourished young children die in the six months to two years after leaving the hospital. The true figure may be even higher, because up to 45 percent of kids dropped out of the reviewed studies, so their fates couldn't be determined, researchers reported.

In a study of severely malnourished children under age 5 in Kenya, Gonzales and colleagues found that about 10 percent of kids, 177 out of 1,704, landed back in the hospital within a year of being discharged.

It's unclear why so many children die after being treated for malnutrition, says James Njunge, a biochemist at the KEMRI-Wellcome Trust Research Programme in Kilifi, Kenya. What is known is that by the time children are malnourished, a complex cascade has started in the body that may not be completely reversible.

Njunge and colleagues are studying the blood and waste of children who died from severe malnutrition after leaving the hospital. From this research spanning multiple countries, the team hopes to learn whether certain proteins, hormones, nutrients, gut microbes or other factors can explain the children's deaths.

Both inflammation and damaged metabolism were associated with death in severely malnourished children in Kenya and Malawi who also had infections or other health problems, Njunge and colleagues reported in *Science Advances* in 2022. But there's another conflicting factor. Some families may take their children home before they're fully recovered, against medical advice, Njunge says, perhaps because the parents need to care for other children or return to work.

Persistent inflammation

Even when kids do recover and have caught up with their peers for weight, bouts of malnutrition can cause internal damage that may linger for years. Recent work suggests that some malnourished children have "very, very aggressive" inflammation against either active infections or bits of bacteria that may leak out of their guts, Njunge says.

"The inflammatory response is supposed to be a good thing to protect you from these pathogens," he says, but when it is too strong, it can damage tissues and organs. In addition, inflammation can impair how the body absorbs and uses nutrients, he says. "All those factors can lead to organ damage and that's what eventually leads to mortality."

Compared with well-nourished preschoolers in their communities, 264 severely malnourished

children in Zimbabwe and Zambia still had signs of high inflammation in their blood about a year after being released from the hospital, Jonathan Sturgeon, a pediatrician at Queen Mary University of London, and colleagues reported February 28 in *Science Translational Medicine*.

"The fact that [inflammation] continued for at least a year after discharge was quite a surprise," Sturgeon says.

And the inflammation isn't just apparent in the children's blood. It's also in their guts, Sturgeon says. People's intestinal walls have tiny, fingerlike structures called villi. These little fingers increase the amount of surface area that can absorb nutrients from food. But in children with severe malnutrition, the villi "become quite blunted, quite flat, quite thin, quite friable," Sturgeon says. Those changes "mirror some of the inflammatory bowel changes you see in children from the West with inflammatory bowel disease."

That type of change to the villi could mean even after malnourishment ends, children may have lingering trouble absorbing the nutrients needed to grow and develop properly, perhaps setting these kids up for a lifetime of health problems.

Sturgeon and colleagues have been testing drugs that may repair the gut lining in malnourished children. A molecule called teduglutide reduced markers of inflammation in young children being treated for severe malnutrition in Zambia and Zimbabwe, the team found. The compound, which is used to treat short bowel syndrome, also restored growth of villi, the researchers reported April 17 in *Nature Communications*.

The promise of new treatments

Other researchers are also developing new treatments to help with the lasting consequences of malnutrition.

Children with malnutrition often have underdeveloped gut microbiomes, says Jeffrey Gordon, a microbiome researcher at Washington University School of Medicine in St. Louis (SN: 4/2/16, *p.* 6). In most children, the rise and fall of certain types of gut bacteria follows a predictable developmental pattern. But that pattern is disturbed in kids with malnutrition.

In those kids, "there are features of the microbial community that appear younger or more immature than you would expect based on the chronological age," Gordon says. Those disturbances can affect development of the gut and immune system, perhaps causing kids to have lasting digestive issues and immune system problems, he says.

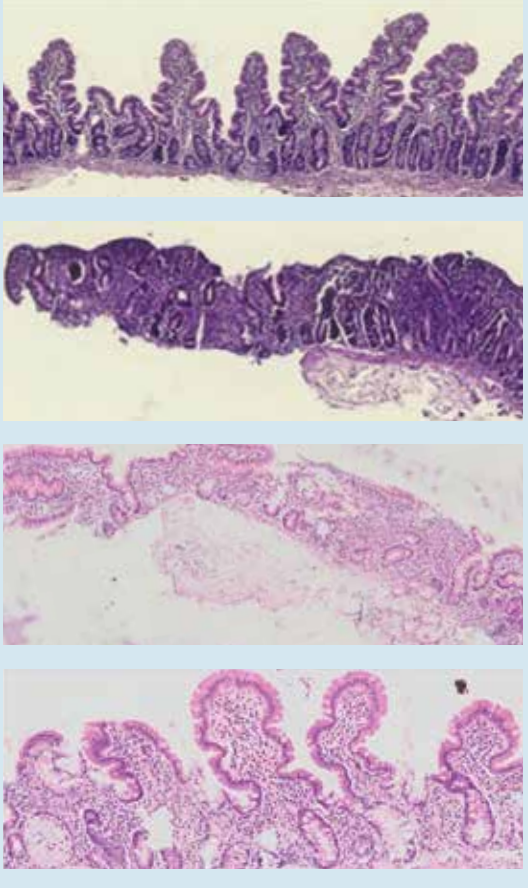
DAN KITWOOD/GETTY IMAGES

A Doctors Without Borders worker measures the mid-upper arm circumference of a child in a refugee camp in Chad. That measurement, along with a child's height and weight, are used to gauge the severity of malnutrition.

Gordon and colleagues developed a therapeutic food that fosters gut microbe growth. It's a mix of chickpea, soybean and peanut flours, mashed green banana, plus sugar and soybean oil (SN: 7/3/21 & 7/17/21, p. 7). The researchers tested the microbe-fostering food against a standard therapeutic food composed of rice, lentil and milk powder with sugar and soybean oil. The experimental food helped toddlers gain weight faster even though it has fewer calories, Gordon's team reported in the *New England Journal of Medicine* in 2021.

The toddlers gained weight due to the presence of two strains of *Prevotella copri* bacteria, which broke down molecules in the microbe-nourishing food, the researchers reported March 19 in *Nature Microbiology*. Knowing how microbes and specific molecules within food work together may help researchers design even better therapeutic foods to treat or even prevent malnutrition, Gordon says.

Repairing the gut Fingerlike extensions, called villi (top image), on the walls of the intestines help the body absorb nutrients. But malnutrition blunts the growth of villi (second image). In some children with severe malnutrition, the villi are nearly absent even after standard therapy (third image). But adding the compound teduglutide to treatment may help restore the growth of these structures (bottom image).



B. AMADI ET AL/EBIOMEDICINE 2017, K. CHANDWE ET AL/NATURE COMMUNICATIONS 2024

A global effort

Because so many children die from malnutrition, few studies have been able to determine the consequences of childhood starvation on adults. What researchers do know is that severe malnutrition or exposure to famine in childhood is associated with an increased risk of high blood pressure, cardiovascular disease and metabolic problems such as diabetes, Gonzales and colleagues reported in *BMJ Global Health* in 2021.

Part of the problem may be the high fat content of the diets that are traditionally used to treat malnutrition, Gonzales says. "It might stress the system too much [so] that the body has this long-term persistent dysregulation," he says. Right now, treatment strategies focus on keeping children from dying in the next year. "We're trying ways now to really study whether we are giving children what they really need," Gonzales says. "Are we treating them in a way that they don't only survive, but they are also thriving?"

It's a time-sensitive question, Trehan says. If young children don't get proper nutrition while their brains are developing, "you're not going to catch up no matter how good your schools and your rehab and things like that are after the fact."

People who survive severe malnutrition in childhood may be a bit shorter than if they'd gotten enough food to grow to their genetic potential, Trehan says. That's probably not a big deal. But stunting can be an indicator of missed intellectual development. "We want … smart kids who can then do good in school and then get good jobs and then help their societies develop," he says. With malnutrition, "you're really hitting a population for the long term."

In a study in Congo, people who had been severely malnourished as children were less likely as adults to report doing well in school, had less education and lower self-esteem than peers in their communities who were never malnourished, researchers reported in 2020 in *PLOS ONE*.

It's not just the people who suffered food shortages that pay the price, Gonzales says. When chronic health problems arise in formerly malnourished people, health systems around the world can become stressed, especially as people migrate from one place to another. A health issue in one part of the world has ripple effects. Malnutrition, he says, "is a global problem that requires global solutions. ■

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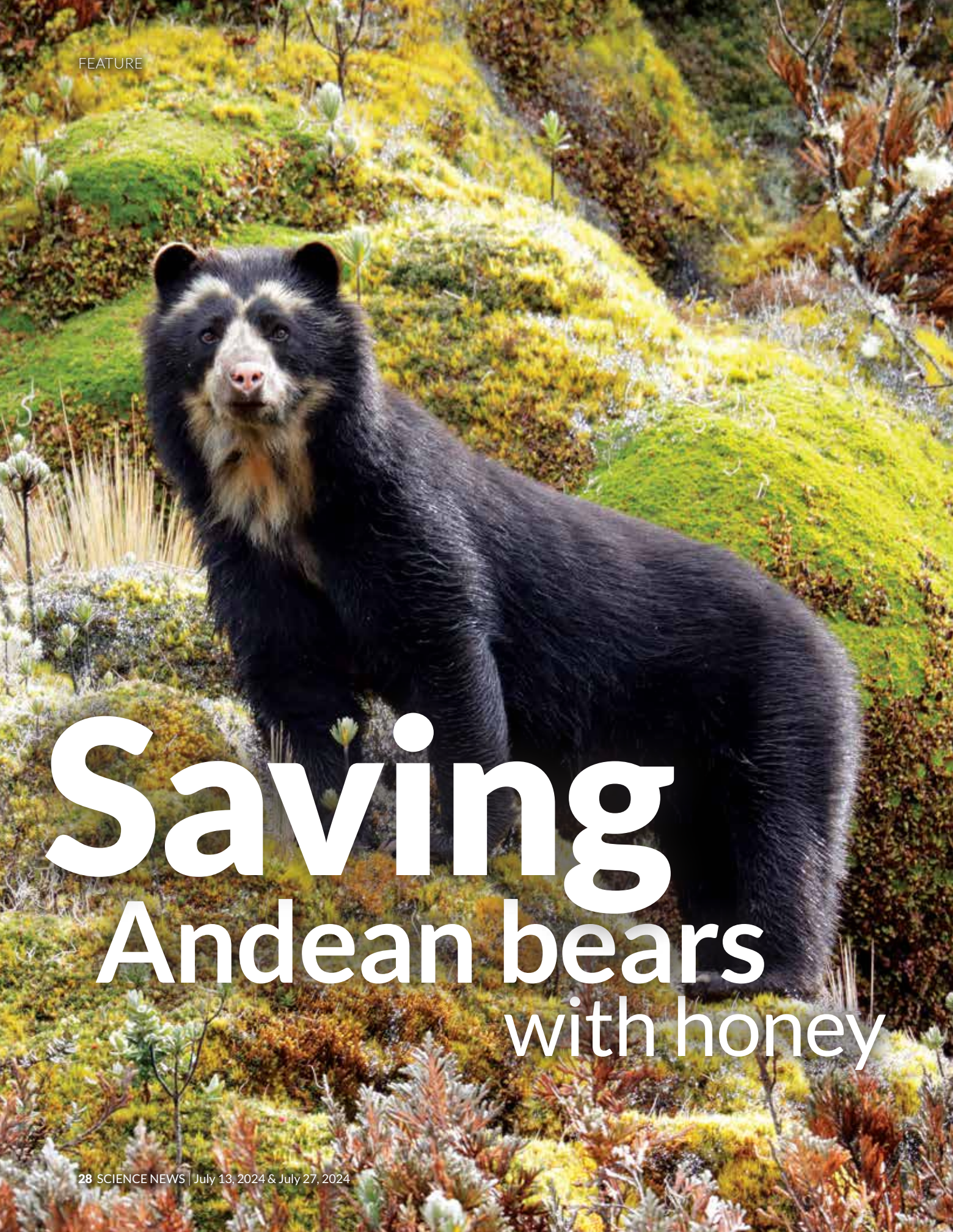

Saving Andean bears with honey

By training beekeepers, Ximena Velez-Liendo is helping rural communities and bears coexist

By Brianna Randall

In 1998, at the age of 22, conservation biologist Ximena Velez-Liendo came face-to-face with South America's largest carnivore on her first day of field research in Bolivia. Her life changed forever when she turned around to see "this beautiful, amazing bear coming out of the forest," Velez-Liendo says. "It was like love at first sight." She thought in that moment: "If I can do anything for you, I'll do it."

Also known as spectacled bears, Andean bears (*Tremarctos ornatus*) are easily recognized by the ring of pale fur that often encircles one or both eyes. Bolivia is home to about 3,000 adult bears, or roughly one-third of the world's total Andean bear population, whose range arcs through five countries along the western edge of South America. Listed as vulnerable by the International Union for Conservation of Nature, or IUCN, the species suffers mainly from habitat loss and conflicts with humans, who sometimes kill the bears in retaliation when bears raid crops or hunt livestock.

But while the bears can look intimidating (adults weigh up to 200 kilograms), Velez-Liendo says they prefer to grind through plants rather than meat with their powerful jaw muscles. Though Andean bears belong to the order Carnivora and are "absolutely capable" of hunting meat, they have, like many other bears, an omnivorous diet.

When Velez-Liendo first committed to helping the bears, no one knew how many lived in her home country of Bolivia or where they roamed. She answered those questions with a countrywide assessment that estimated the population and identified where the bears can access food, shelter and water. Her analyses also pinpointed Bolivia's southern dry forests as the place where the bears face the biggest threats from humans. So she decided to put her data into action: Velez-Liendo started asking locals how she could help them protect this keystone species.

Velez-Liendo is a "renowned Andean bear expert" and an award-winning conservationist, says John Hechtel, president of the International Association for Bear Research and Management. Velez-Liendo is a cochair of the IUCN's Andean Bear Expert Team, a research associate at the University of Oxford's Wildlife Conservation Research Unit, a conservation fellow at Chester Zoo in Cheshire, England, and director of the Andean Carnivore Conservation Program in Bolivia. In addition to her strong skills as a biologist and spatial analyst, she also "genuinely cares about the well-being of the environment … and the local people," Hechtel says, which makes her "a really effective advocate for new, creative approaches to bear conservation."

Thanks to Velez-Liendo's work, Andean bears went from nearly extinct in the southernmost part of their range to healthy and recovering. Her population and habitat assessments now inform global, regional and local efforts to conserve Bolivia's bears.

From gorillas to bears

Velez-Liendo always knew she wanted to work with animals. Her earliest memories are of playing in the lowland forests near her village in southeastern Bolivia as a child — "in bare feet," she says, "just poking insects or crossing the river." When her family moved to Oruro, a city in the highlands at just over 3,700 meters elevation, she took to chasing reptiles, continuing to foster her "appreciation of nature," she says.

She planned to attend veterinary school until a friend introduced her to biology as a career path. While earning her undergraduate degree from Universidad Mayor de San Simón in Cochabamba, Velez-Liendo had her heart set on studying gorillas in Rwanda — until that fateful day she met her first bear in Carrasco National Park.

She decided to learn geographic analysis and mapping skills and, as part of her master's research at the University of Leicester in England, she used these tools to analyze what was causing deforestation around the national park. She linked habitat destruction in the region to a boom in coca cultivation following the closing of mines in the highlands along with the completion of a new road connecting the cities of Cochabamba and Santa Cruz.

Velez-Liendo then spent almost three years traveling the eastern slope of the Bolivian Andes to produce the first — and still only — national assessment of Andean bears as part of her Ph.D. in biology at the University of Antwerp in Belgium. This meant knocking on doors in rural communities,

UNSUNG CHARACTERS

This article is part of a *Science News* series highlighting people of science — past and present — who we believe should be better known. Watch for more of these stories, and send your ideas to editors@sciencenews.org

Where the bears are

The Andean bear of South America ranges from Venezuela to Bolivia (yellow marks the range). Some reports suggest the species may also live in northern Argentina.

OPPOSITE PAGE: © JUAN CARLOS VINDAS/MOMENT/GETTY IMAGES PLUS; MAP: IUCN

Top left: Ximena Velez-Liendo explains to the community of San Lorencito how protecting the Andean bear (depicted in the artwork) benefits farmers and the forest ecosystem. Top right: Patricia Sanchez of the Andean Carnivore Conservation Program holds up freshly harvested honeycomb beside beekeeper Isidro Aguirre. Bottom: Beekeepers learn how to replace queen bees.

asking people if they had seen any bears, then verifying anecdotal evidence in the field. At each spot where a sighting was reported, she searched for bear signs, particularly looking for flowering plants that had been munched by the charismatic mammals. She then identified the best places to invest in protecting or restoring bear habitat by relying on habitat, landscape connectivity and human-expansion analyses.

In Bolivia, a maximum population of 3,165 adult bears occupy 13 key chunks of habitat covering 21,113 square kilometers, according to two studies published by Velez-Liendo in the journal *Ursus* in 2013 and 2014.

She zeroed in on the dry forested valleys of Tarija, a region in southern Bolivia that borders Argentina, as the best habitat for bears outside protected parks. Only 6 percent of the Andes' original dry forest is left, scattered in a few patches in Ecuador, Peru and Bolivia. It's home to monkeys, foxes, birds and a half-dozen wild cat species, along with the Andean bear. But the forest has been heavily used by people, Velez-Liendo says, and the IUCN was considering listing the bears in Tarija as extinct.

In 2016, Velez-Liendo received a small grant from the Chester Zoo to set up camera traps to see if any bears were still in Tarija. At first, "the forest was just empty," she says. Then in February 2017, a photo of a mother and cub sparked hope.

The same day that photo was taken, Velez-Liendo found out she was short-listed for the Whitley Awards, prestigious prizes from the Whitley Fund for Nature that are known among conservationists as the "Green Oscars." She was one of seven winners in 2017, which gave her 35,000 British pounds (about $45,000 at the rate in May 2017) in project funding as well as conservation training. This was her "golden ticket" to launch the Andean Carnivore Conservation

ALL: ANDEAN CARNIVORE CONSERVATION PROGRAM

Program, she says, and focus on helping people coexist with bears and other carnivores.

Helping with honey

Though Tarija's forests were promising bear habitat, they were also a hot spot for conflicts between people and bears. Local villagers showed Velez-Liendo bear skins hanging in their living rooms, describing how bears were a threat to their livestock and crops. When another community in Tarija showed her a stack of brand-new bee boxes that people didn't know how to use, she had a thought: Could selling honey help save bears?

Training farmers as beekeepers was catching on in other parts of Bolivia as an eco-friendly way to provide reliable income for rural landowners who might otherwise turn to clearing more forest. Velez-Liendo asked Patricia Sanchez, an economist who had experience teaching beekeeping in Bolivia's highlands, to join the Andean Carnivore Conservation Program in 2017. The program covers 70 percent of the cost of new equipment and trains locals on how to care for hives, extract honey and market it for sale.

The program also supports other types of nature-friendly agricultural practices, like fencing livestock and pruning fruit trees so they don't attract bears. In exchange, community members agree to protect the forest and not harm Andean bears. Velez-Liendo also trains locals on how to collect data and help monitor the ecosystem. In 2023, more than 100 families were enrolled in the program.

"If people don't see the value of protecting an animal, protecting an ecosystem … then they're not going to do it," Velez-Liendo says.

The sale of Valle de Osos–branded honey locally provides beekeeping families with income. Sanchez, who visits each of the participating communities at least twice per month, notes that the beekeeping efforts are an economic development opportunity that can support young people who want to stay in their communities instead of leaving to find a job in the city.

Today, more than 60 Andean bears wander through Tarija's forests, a remarkable increase over the five bears documented in 2017. By reducing the retaliatory killing of bears, "we managed to basically save this bear population from extinction," Velez-Liendo says. Having more bears benefits the entire ecosystem in Tarija, since the bears spread the seeds that help forests thrive.

Velez-Liendo's goal is to replicate the Tarija model in the Chuquisaca and Cochabamba regions to the north. Engaging more rural communities can provide "stepping stones" of habitat to connect isolated bear populations, she says.

A 'bear-ologist' who works with people

Ximena Velez-Liendo spotted her first Andean bear in 1998 during a research trip in Carrasco National Park in Bolivia.

CAROLA AZURDUY

Velez-Liendo says all of the bear biologists she knows in Bolivia are women, notable in a country where it's rare to see a woman driving a car. She jokes that pursuing Andean bears over Bolivia's rugged terrain "is not for the faint of heart." Her mentor at the beginning of her career and beyond was Susanna Paisley, the first biologist to put a radio collar on an Andean bear in the wild. Paisley, based in Canterbury, England, says that one of Velez-Liendo's most impressive achievements is the trust she's cultivated among people in southern Bolivia's agricultural communities. Healthy ecosystems are now associated with more economic security in that region, particularly in the face of persistent droughts and climate change.

"There's a lot of obstacles to this kind of work," Paisley says. Many remote parts of Bolivia have no infrastructure and "a lot of machismo," which requires determination to get results. "You've got to be a maverick." She calls Velez-Liendo "a force of nature" with an experimental and collaborative approach.

Velez-Liendo says one of her biggest personal challenges was moving from being a "bear-ologist" who wasn't all that interested in working with people to realizing that people are the solution for saving the animals she loves. "Conservation comes from … the communities that live with this biodiversity," she says. "I think that's how conservation is changing: from the hands of biologists to the hands of people."

The Andean Carnivore Conservation Program recently received a three-year grant from the Chester Zoo. Now that she can take a breather from fundraising to keep the project going, Velez-Liendo plans to focus on publishing results from Tarija. She also wants to write an educational book to help a wider audience understand the bears.

"There are so many things bears can teach us, and the first one is to take life easy," she says. "Just avoid confrontation … and sleep well." ■

Explore more

- Vincenzo Penteriani and Mario Melletti (eds.) *Bears of the World*, Cambridge Univ., 2020.

Brianna Randall is a freelance writer based in Missoula, Mont.

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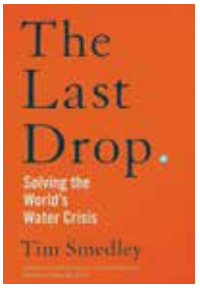

The Last Drop
Tim Smedley
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BOOKSHELF

The world has water problems. This book has solutions

A journalist and a farmer visit three fields with different styles of cultivation — conventional, organic and no-till — to bury cotton underwear in each. Though this sounds like the beginning of a bad joke, it's actually a test of soil health. Healthy soil that produces robust crops holds plenty of water and teems with life that will feast on the undies. This scene is just one of many in U.K.-based journalist Tim Smedley's book *The Last Drop*.

The book provides an exhaustively reported primer on the world's water problems and dives into potential fixes, including agricultural remedies, policy changes, tech innovations and at-home solutions like rainwater harvesting.

"The world isn't running out of water — people are," Smedley writes. He travels to the Hoover Dam in the American Southwest to see the low water levels at Lake Mead. He visits the Middle East, stopping by Jordan's Karameh Dam, where the impounded water has become too saline for irrigation. Closer to home, he tours Europe's largest artificial lake, northern England's Kielder Water, which was constructed during the late 1970s in anticipation of a water demand that petered out within about a decade of completion. It's the southern half of the country that has become water-stressed.

Such megaprojects highlight how "water crises are usually caused by all-too-human mismanagement, not climate," Smedley writes. But climate change is certainly making things worse, he adds: "As climate change bites, precipitation patterns change." For instance, the warmer atmosphere holds more water vapor, a greenhouse gas that exacerbates warming and fuels massive storms that unleash devastating floods.

Flooding can make water pollution worse. Runoff from storms carries extra nitrogen and phosphorus from farms. A "poonami" of livestock-sourced manure, which contains those elements, contaminates freshwater supplies, as do fertilizers. Some agrochemicals, Smedley writes, have been tied to increases in pediatric cancer cases.

Changes to farming practices, just some of the solutions Smedley explores, could mitigate pollution, water scarcity and potentially flooding all at once. No-till agriculture results in root systems, webs of fungi and burrowing bugs that maintain a spongy soil that sucks up water. Because they hold more water, these fields can better weather dry spells. Their soil structure helps them resist erosion, minimizing runoff. They also need far less fertilizer because fungi and other microbes, in conjunction with cover crops planted between growing seasons, maintain and return nutrients to the soil. England's water woes — shortages are an issue despite the reputation for heavy rainfall — could be solved through no-till farming alone, Smedley's reporting reveals.

As for the interred underwear, after a couple months, Smedley and the farmer unearthed dusty, holey pants from the organic field, whereas the conventional farm produced dirty-yet-wearable ones. The no-till field, unplowed for decades, turned up a "bedraggled mess" of soil, fungal residue and purple patches, along with a millipede that leaped from the scraps and scurried away.

Smedley packs his book with sometimes funny, often serious insights that people can apply to their lives. Most of the "water footprint" of people in the Western world, for example, comes not from tap water used for bathing, cooking and cleaning, but from the water that goes into making the products we consume. Depending on where and how it's grown, and the specifics of the calculations, tossing a browned avocado can waste 273 liters of water. A single steak can cost 2,000 liters. "If you're wearing a T-shirt made from cotton grown in Egypt," Smedley writes, "you are, in a sense, wearing water from Egypt." Given all the water we waste, Smedley notes, small changes can make a big difference. "The 'last drop' doesn't mean waiting for the water to run out," he explains. "It means valuing every last drop as precious." — *Alka Tripathy-Lang*

BOOKSHELF

The Air They Breathe
Debra Hendrickson
A pediatrician in Reno, Nev., draws on her patients' experiences to explain why the health impacts of climate change are particularly harmful to children. *Simon & Schuster, $27.99*

Meet the Neighbors
Brandon Keim
The animals around us have richer inner lives than most people realize, this book explains. Should that reality change how we treat our animal neighbors? *W.W. Norton & Co., $29.99*

Sharks Don't Sink
Jasmin Graham
A Black marine biologist and co-founder of Minorities in Shark Sciences charts her unconventional career path from academic to independent ("rogue") scientist. *Pantheon, $28*

Bite
Bill Schutt
In this ode to teeth, a zoologist convincingly argues that the origin of pearly whites was one of the most pivotal events in the evolution of vertebrates. *Algonquin Books, $31*

Origin Story
Howard Markel
This latest book on Charles Darwin zeroes in on a crucial two-year period in the naturalist's life, which covers the writing, publication and response to *On the Origin of Species*. *W.W. Norton & Co., $35*

FROM REGENERON ISEF TO THE INTERNATIONAL SPACE STATION

NASA astronaut Jeanette Epps, currently aboard the International Space Station, spoke virtually with attendees at the 2024 Regeneron International Science and Engineering Fair (ISEF), the world's largest pre-collegiate STEM competition. This year, ISEF, a program of Society for Science, welcomed nearly 2,000 finalists from 67 countries, regions and territories.

Epps answered questions from finalists on topics ranging from how to conduct research in orbit to what it's like living in space.

Epps commended the ISEF finalists for their hard work: "I applaud every one of you for rolling up your sleeves, working hard and producing graduate-level research. I look forward to seeing what you do in the future, and I look forward to seeing who applies for the Astronaut Corps."

Watch the full conversation

JUNE 1, 2024

Sounds like trouble

Exposing zebra finch eggs and hatchlings to traffic noise can lead to lifelong reductions in health and reproduction, ***Jonathan Lambert*** *reported in "Traffic noise harms bird eggs"* (SN: 6/1/24, p. 9). Reader **Gary Wilson** asked how noise pollution affects humans.

Noise pollution can harm humans' physical and mental health. Prolonged exposure to common loud noises, such as construction and powered lawn mowers, can induce hearing damage and loss. The cacophony of everyday transportation and traffic within cities can increase stress, disrupt sleep and hormone levels, impair cognition and up the risk for heart disease, heart failure and stroke.

People exposed to noise pollution during pregnancy may have an increased risk of developing gestational diabetes, gestational hypertension and preeclampsia, some studies suggest. A study published in May in *JAMA Network Open* also found that children and adolescents living in the United Kingdom in areas with high traffic noise have an elevated risk of anxiety.

One in a melon

Captive beluga whales warp their forehead fat, called melons, into distinct shapes when they're around other belugas, ***Elizabeth Anne Brown*** *reported in "Belugas may communicate via 'melons'"* (SN: 6/1/24, p. 9). Reader **Jim Sobek** wondered whether changing the shape of the melon helps the belugas better hear each other during "conversations" by boosting or focusing sounds that they produce and receive.

Belugas and other toothed whales typically hear through their lower jaws and inner ears, so the melon is unlikely to play a role in receiving sounds, says **Malin Lilley**, a comparative psychologist at Texas A&M University–Central Texas in Killeen.

But toothed whales are known to use their melons to transmit and direct echolocation clicks and other vocalizations into the environment. So it's possible that belugas warp their forehead blobs to alter the acoustic properties of their vocalizations, says animal behaviorist **Justin Richard** of the University of Rhode Island in Kingston. However, the visual aspect of the behavior seems key to belugas' social interactions, since the animals change their melon shapes primarily when other belugas can see them, **Richard** says. Studying the potential auditory components of this unique beluga behavior is an important next step in understanding its role in the whales' banter.

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What's the human speed limit?

When athletes compete in the 2024 Summer Olympics in Paris later this month, a few world records will undoubtedly fall. But some of the Olympics' speediest events haven't picked up the pace in more than a decade. Records are made to be broken, but how much faster we can go on land or sea is an open question.

On land, records in the 100-meter dash (top graph) have been in place since 2009 for men and 1988 for women. Jamaican sprinter Usain Bolt ran the race in 9.58 seconds with a top speed of nearly 40 kilometers per hour (SN: 12/05/09, p. 26). Meanwhile, the women's record is held by American sprinter Florence Griffith Joyner, who ran the distance in 10.49 seconds.

Based on human gait and muscle strength, research suggests that people might be able to run as fast as about 60 km/h. That's 100 meters in 5.625 seconds. But the realities of sprinting speed largely depend on technique, says Ross Miller, a biomechanist at the University of Maryland in College Park.

"A sprint should be as hard as you can every step," Miller says. "Maximum, instantaneous effort all the time." Top speed depends on how little time our feet need to be on the ground while still applying the force necessary to propel us forward.

It's possible no one has yet run at maximum speed because no one has come along with that physical ability, Miller says. Or because the right person hasn't had access to the training, "or just [hasn't] put it all together yet in the perfect race."

It's much harder for humans to go fast in water (bottom graph). In the 50-meter freestyle, the men's record belongs to César Cielo Filho, a swimmer from Brazil who swam the pool's length in 20.91 seconds in 2009 — just under one-quarter of Bolt's record-setting average running speed. In 2023, Swedish swimmer Sarah Sjöström swam the race in 23.61 seconds to earn the women's record.

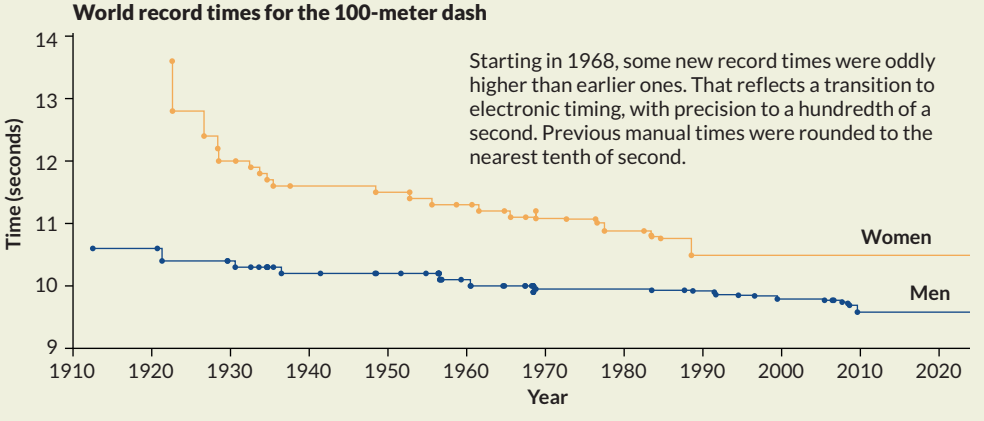
Swimming is slower than running largely because water is far denser than air, says Timothy Wei, a fluid dynamicist at Northwestern University in Evanston, Ill. But also, "we all have this bowling ball between our shoulders. And this thing creates a huge amount of drag."

For swimming speed, it's unknown how much room there is for growth. Swimming with the body parallel to the water's surface can help eliminate drag on our less-than-ideal frames. Superfast freestyle swimmers also raise their elbows as high as possible above the water, plunging their arms dramatically close to perpendicular with the water to pull themselves forward.

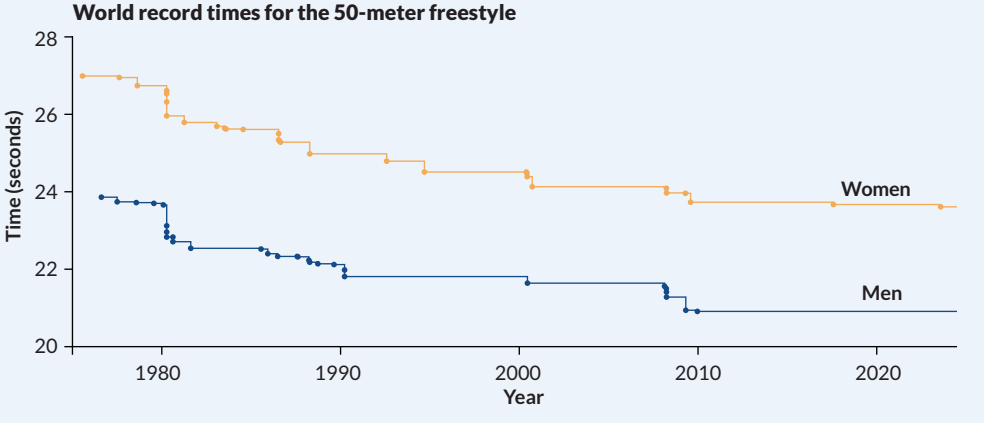
"If you get your technique right, and you can get your stroke rate as high as possible," Wei says, "that combination is what's going to get you to go as fast as you can."

— *Erin Garcia de Jesús*

Speedier runs Times for the 100-meter dash have dropped by about a second for men since recordkeeping began in 1912. Women are running the race about three seconds faster since the first record in 1922. Though Florence Griffith Joyner is the current women's record holder, the record is in doubt. Winds over 2 meters per second disqualify new records. The wind gauge registered 0, but other races that day had logged winds.
SOURCE: WORLD ATHLETICS



Faster swims World record times for men and women in the 50-meter freestyle have gone down by about three seconds since recordkeeping began in the 1970s. A wave of new records came in 2008 and 2009, when a new swimsuit line from Speedo entered pools. The expensive fabric compressed swimmers' bodies and also made them more buoyant, giving swimmers a speed advantage. The suits were banned from competition in 2010. SOURCE: WORLD AQUATICS



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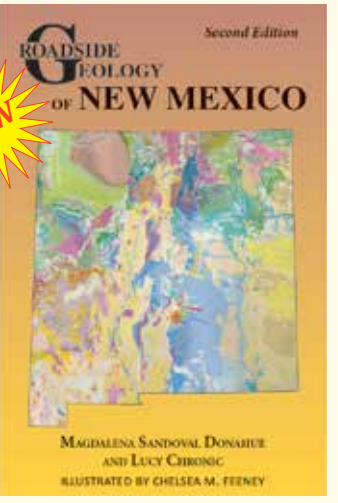

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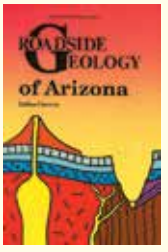

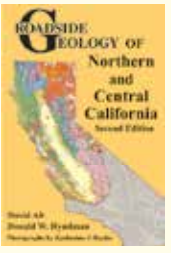

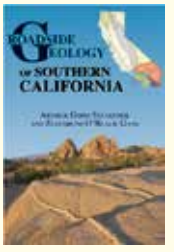

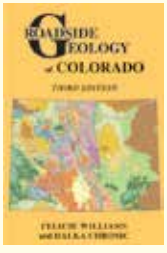

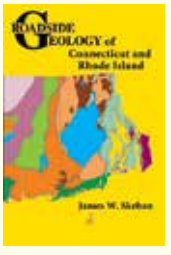

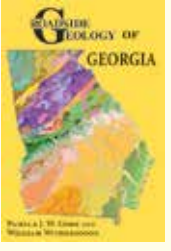

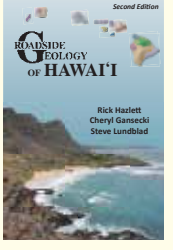

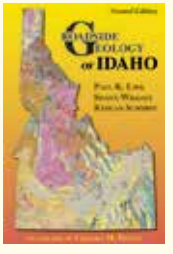

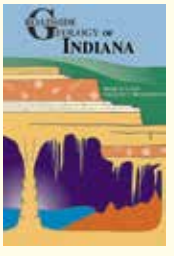

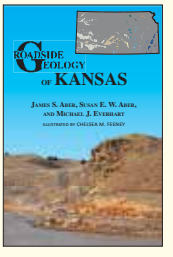

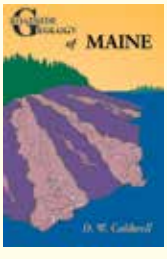

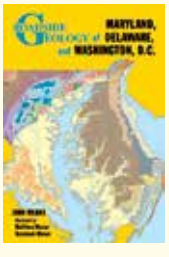

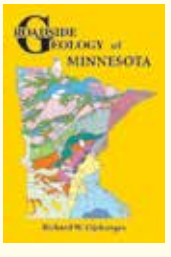

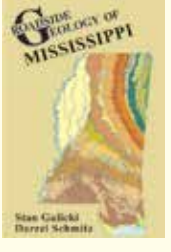

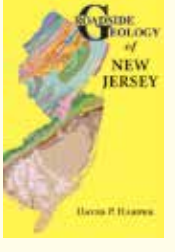

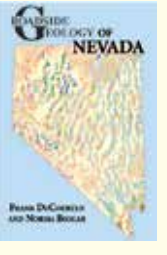

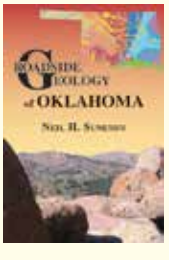

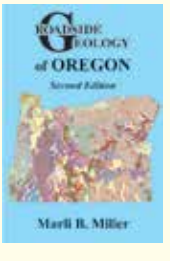

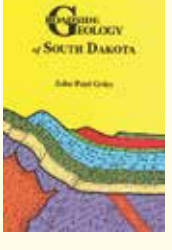

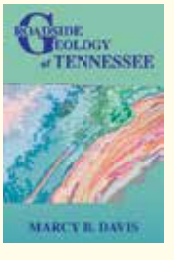

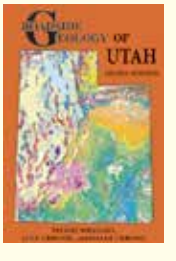

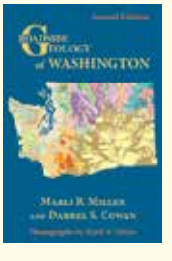

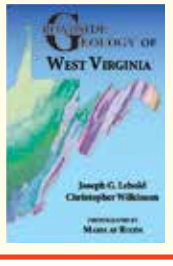

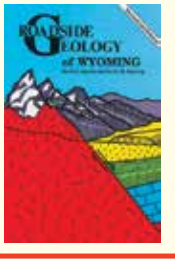

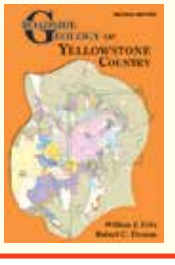

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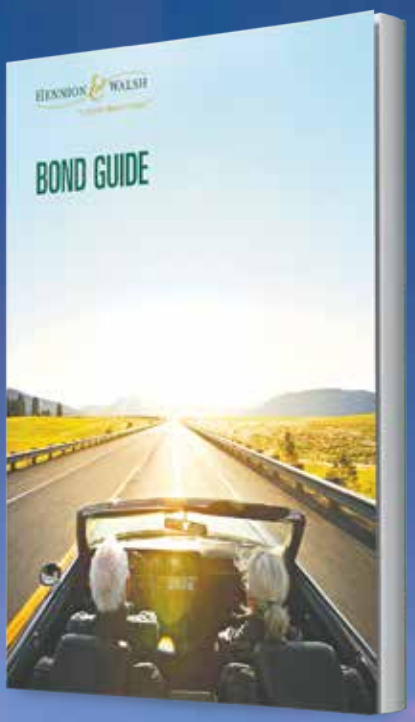

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