Stonehenge's Scottish Heart | Saving Crocs From Toxic Toads

ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ SEPTEMBER 7, 2024 & SEPTEMBER 21, 2024

TRACKING DOWN TRICKY TWISTERS

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★★★★★

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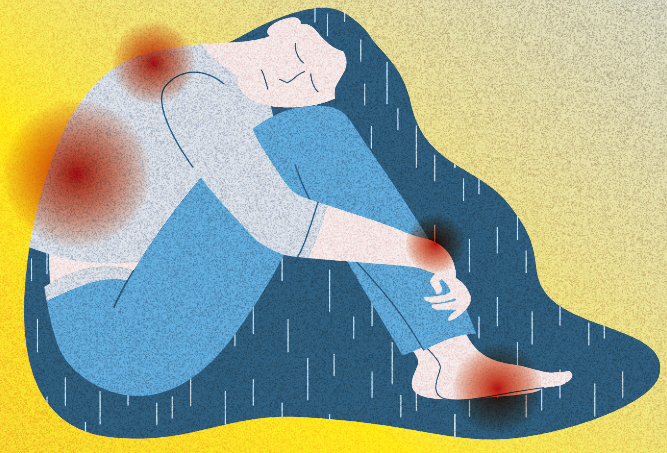

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Departments

COVER Hard-to-track twisters can form along rows of storms, like the one shown hovering over a field in Oklahoma. *Roger Hill/Science Source*

When pain really is in your head

People have been trying to relieve the misery of pain for a very long time. Opium use in Egypt was recorded by 1300 B.C., as was the use of coca plant leaves in pre-Inca cultures. Zaps from electric fish were used to treat headaches and arthritis in antiquity. The first reference to acupuncture in a Chinese medical text was in 300 B.C.

Many centuries later, scientists are still laboring to treat chronic pain, with limited success. That stalemate leaves patients and doctors feeling helpless.

As we report in this issue, researchers are now getting a better handle on the complexities of chronic pain, including the brain's role in amplifying or maintaining pain, and people's perceptions. As freelance science journalist Cassandra Willyard reports, scientists are pursuing possibilities ranging from new medications to a tiny injectable electrode to forms of cognitive behavioral therapy designed to help patients grasp that chronic pain is sometimes a misfiring signal from the brain that can be managed (Page 18). Rather than one-size-fits-all, these treatments will be tailored to the patient, and will likely include multiple treatments to better address the complexities of chronic pain.

Even as our options for medicines evolve, the changing climate may affect their safety. For instance, some medications can make it harder for people to deal with extreme heat. Research suggests that people taking antipsychotics or cardiovascular drugs are more likely to be hospitalized for heat-related illness, staff writer Erin Garcia de Jesús reports (Page 9). I was intrigued to learn that blood thinners and beta blockers, two very common heart medications, can reduce the amount of blood in the skin that otherwise helps people cool off. That's no reason to stop taking the meds, the scientists say. But it's good to keep the risks in mind, especially after another summer when temperatures hit record highs.

Access to treatments for infectious disease is perhaps an even more urgent challenge. The virus formerly known as monkeypox is once again causing a global health emergency, affecting people in at least 12 African countries. A new variant of mpox may be fueling the spread. There are vaccines and treatments, senior writer Tina Hesman Saey reports, but these drugs are not available in many countries (Page 6).

And finally, a story of getting crocodiles to take their medicine: Freshwater crocs in Australia are being trained to avoid eating poisonous cane toads. The toads are an invasive species, introduced by people in the 1930s to combat sugarcane pests. Evidently the toads are tempting snacks (Page 16). As the amphibians have made their way across the continent, freshwater crocodile populations have plummeted.

Enter humans. Conservation scientists collaborated with an Australian Indigenous group who see freshwater crocs as important players in their dreamtime stories. The team collected dead cane toads, removed the toxin and replaced it with lithium chloride, which prompts nausea. Crocodiles that dined on nauseating toads were much less likely to eat the live, deadly versions.

In Aboriginal art and stories, the crocodiles symbolize strength, stealth and survival instincts. And now humans are helping these revered beings learn a new survival skill. — *Nancy Shute, Editor in Chief*

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- Approximately 10 million people die from cancer each year. It is estimated that a **1% reduction** in mortality from cancer has a value of nearly **$500 billion**. Further, **a cure for cancer would be worth about $50 trillion**.[1]

- The pharmaceutical industry spends roughly $280 billion on R&D and $80 billion with contract research organizations (CROs)[2], businesses that specialize in conducting clinical trials. The average cost of bringing a drug to market (including drug failures) is now $2.6 billion.[3] McKinsey suggests that the annual incremental value of doing business in space for pharmaceutical companies is $2.8 to $4.2 billion and companies that develop just one novel oncology drug through space-based R&D could obtain **an average net present value of $1.2 billion**.[2] By providing seamless access to a microgravity environment, which increases returns from innovation, improves the success rate for compounds in development and cuts development timelines, the Sierra Space value proposition is momentous.

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https://www.sciencedaily.com/releases/2006/04/060426174214.htm. One percent reduction in cancer mortality would be worth nearly $500 billion", Kevin Murphy & Robert Topel of the University of Chicago Graduate School of Business as published in the Journal of Political Economy (April 2006)
The potential of microgravity: How companies across sectors can venture into space, McKinsey LLP; Carsten Hirschberg, Ireen Kulish, Ilan Rozenkopf, and Tobias Sodoge (June 2022) McKinsey Industry Life Sciences

Excerpt from the September 7, 1974 issue of *Science News*

50 YEARS AGO

Toxic surprises

In the United States alone, more than 29 billion pounds of plastic are produced each year. An estimated 2.5 million workers are engaged in mass producing them.... Many of these chemicals used to make plastics are so toxic that they affect workers' health. Earlier this year, 15 vinyl chloride workers died from a rare, chemically induced liver cancer.

UPDATE: Vinyl chloride is a primary ingredient in PVC, a non-carcinogenic plastic commonly used for water pipes, IV bags and many other products. Safety standards for vinyl chloride were set in 1975. Today, U.S. workers' exposure levels are tightly regulated. But the chemical may soon be on the chopping block. In July, the U.S. Environmental Protection Agency proposed a review of vinyl chloride's safety and environmental data, which could result in a ban. The proposal follows a train derailment in Ohio in 2023 that exposed a nearby community to vinyl chloride and other chemicals. It's too soon to know what the exposure means for residents' cancer risk.

A NASA spacecraft took this image of Earth while in orbit around the moon. Scientists have proposed building a life-preserving biobank near the lunar south pole.

GSFC/NASA, ASU

FUTUROLOGY

Scientists want to store animal cells on the moon

As more and more species near extinction, scientists have been collecting samples from animals, plants and other creatures and storing them in biobanks across the globe. But climate change, environmental disasters and wars threaten these Noah's arks. Now, a team of researchers is brainstorming an out-of-this-world solution: building one of these vaults on the moon.

A biobank in a permanently shadowed region at the moon's south pole could be far more stable than those on Earth. This part of the moon usually remains around –196° Celsius, perfect for storing most animal cells long-term, marine biologist Mary Hagedorn and colleagues report July 31 in *BioScience*.

"It's very good to have as many plans as possible, especially when it comes to saving our biodiversity and life on Earth," says Hagedorn, of the Smithsonian National Zoo and Conservation Biology Institute in Washington, D.C.

Hagedorn and colleagues were inspired by the Svalbard Global Seed Vault in Norway, which takes advantage of below-zero Arctic temperatures to preserve millions of seeds from around the world.

In 2017, thawing permafrost threatened to flood the vault, underscoring the need for a backup plan. A different team has proposed building a lunar ark in lava tubes that run beneath the moon's surface (SN: 1/21/17, p. 5). But that design requires a solar-powered cooling system; any loss of power and the samples would be destroyed. In the moon's forever-frozen shadowed regions, a lunar vault wouldn't need energy or constant human maintenance, Hagedorn's team says.

Given the shadowy south pole's low temperatures, a vault there could store animal fibroblasts, "one of the most powerful cells that we have today," Hagedorn says. Scientists can transform fibroblasts into stem cells, "and then those stem cells can be used for cloning," she says. The cells could be valuable for regenerating populations of threatened or extinct species and for building ecosystems in future human colonies on the moon or Mars.

The proposal has its share of hurdles. For instance, the moon's permanently dark regions aren't immune from temperature swings, says lunar scientist Benjamin Greenhagen of the Johns Hopkins University Applied Physics Laboratory in Laurel, Md. "They are still cold but perhaps not always cold enough for this project without some level of thermal management."

Hagedorn and colleagues are also figuring out how to protect cells from the harsh environment in outer space. The team is designing radiation-proof containers that could be tested on a future moon mission.

— Gennaro Tomma

INTRODUCING

This spider calls extinct sloths' burrows home

Deep in the unyielding darkness of a Brazilian cave, a pale, blind, spiny beast carefully feels its way across rust-colored rocks. Meet *Paleotoca diminas*, a spider new to science.

The species, shown below and described in the September *Taxonomy*, makes its home in unusual subterranean lairs: the long-abandoned burrows of extinct megafauna, such as giant ground sloths or giant armadillos, researchers say.

Arachnologist Igor Cizauskas of the Biodiversity Research Support Organization in São Paulo and colleagues found the *P. diminas* spiders in iron-rich caves in the Brazilian state of Minas Gerais. About 2 millimeters long, the spiders are a desaturated yellow, lack eyes and have prickly legs. They also sport specialized hairs that some arachnids use to sense vibrations through the air, an alternative to sight.

Careful examinations of the spiders' physical features suggest the species is a type of long-spinneret ground spider. But certain characteristics of the genitalia and legs indicate the newfound spiders represent a previously unknown genus, which the researchers have dubbed *Paleotoca*.

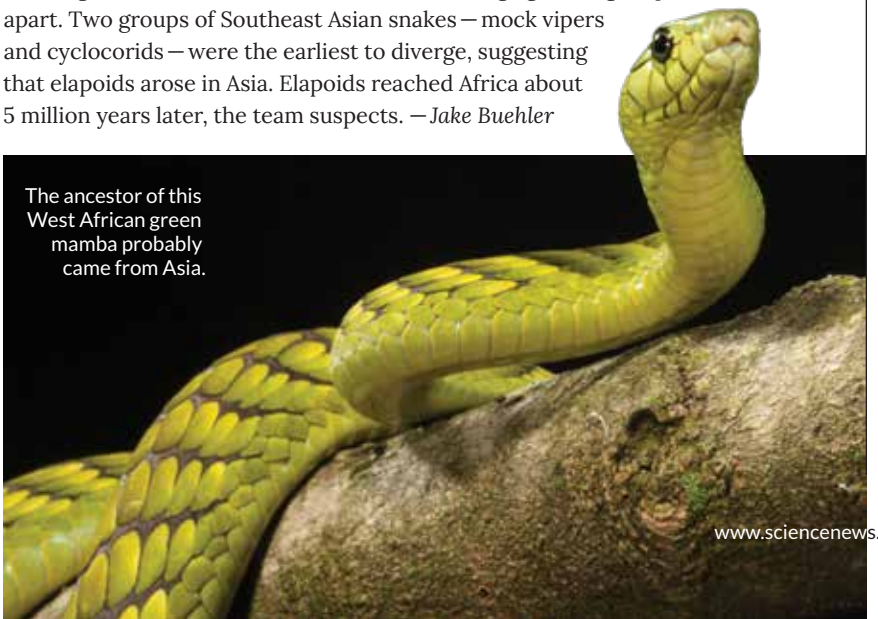
The name means "old house," a nod to the peculiar variety of cave that the spiders call home — a paleoburrow. Long gouges in the walls of the cave in which the spiders were found indicate a giant ground sloth excavated the burrow, the team says. — *Jake Buehler*

RETHINK

Snake superfamily gets a new origin story

The ancestors of cobras, mambas and related snakes first emerged in Asia roughly 35 million years ago, evolutionary biologist Jeff Weinell of the American Museum of Natural History in New York City and colleagues report in the August *Royal Society Open Science*. The Elapoidea superfamily, which includes over 700 snake species, was previously thought to have evolved in Africa 25 million years ago.

Using genetic data from over 400 species, the scientists built evolutionary trees showing how the snakes are related and how long ago lineages split apart. Two groups of Southeast Asian snakes — mock vipers and cyclocorids — were the earliest to diverge, suggesting that elapoids arose in Asia. Elapoids reached Africa about 5 million years later, the team suspects. — *Jake Buehler*



The ancestor of this West African green mamba probably came from Asia.

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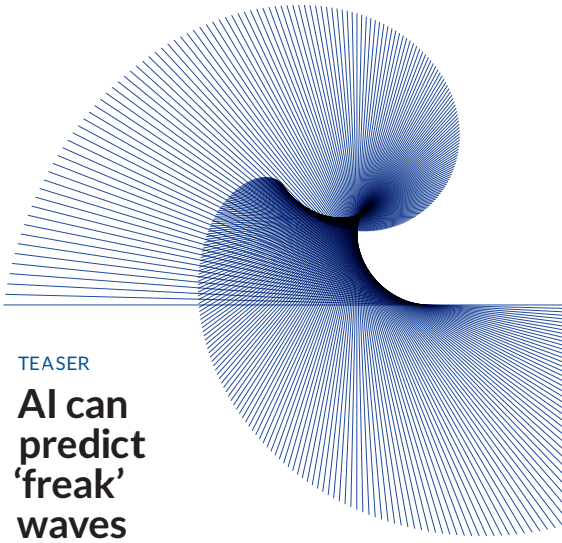


TEASER

AI can predict 'freak' waves

Rogue waves rise out of the blue to ambush hapless ships and beachgoers. Now, a new artificial intelligence model can predict most of these surprising swells up to five minutes in advance, mechanical engineers report July 18 in *Scientific Reports*.

Cresting more than twice as high as surrounding waves, rogue waves may form where converging swells raise a single, amplified wave or where ocean currents compress swells into powerful billows. Certain wave patterns may precede these sudden surges, but no effective forecasting algorithm had yet been developed. Such a tool could be lifesaving: Eyewitness accounts indicate that from 2011 to 2018, rogue waves killed 386 people and sank 24 ships.

Using roughly 16 million data points collected at half-hour intervals by a network of 172 ocean buoys, Thomas Breunung and Balakumar Balachandran of the University of Maryland in College Park trained an AI program to distinguish wave patterns that preceded rogue waves. Thousands of rogue waves were captured in the data. The program predicted 3 in 4 wave arrivals at buoys one minute in advance. At five minutes in advance, about 7 in 10 waves were predicted.

Notably, the program anticipated rogue waves roughly as well at locations where it had received no training data. "If you want to predict rogue waves at a new location, all you need to do is put your buoy [there] and you can use this [program] without training," Breunung says. — *Nikk Ogasa*

HEALTH & MEDICINE

Mpox virus sparks a global emergency

A worsening outbreak across Africa alarms world health officials

A health care worker swabs a person's rash to test for mpox. The virus is rapidly spreading across Africa, including in several countries that have never before reported mpox cases.

KATSON MALIRO/WHO

BY TINA HESMAN SAEY

For the second time, the World Health Organization has declared that mpox is a global health emergency.

The sometimes-deadly virus, formerly called monkeypox, causes rashes, fevers, muscle aches and other symptoms. In 2022, global spread of mpox led to the first emergency declaration (*SN: 8/13/22, p. 6*). That version of the virus, called clade II, is still causing a small number of cases around the world.

As clade II cases declined globally, a new version, clade I, emerged in Congo and caused mpox cases there to rise. Nevertheless, the first mpox emergency ended in 2023. Now, an even newer variant called clade Ib has spread to previously unaffected countries in Africa and reported cases have surged beyond levels seen in 2022 or 2023.

As a result, last month, the Africa Centres for Disease Control and Prevention declared a public health emergency of continental security. And a WHO emergency committee found evidence that mpox is again a global emergency, committee chair Dimie Ogoina said August 14 in a news conference.

Following the committee's advice, WHO declared that the outbreak is a public health emergency of international concern. "It's clear that a coordinated international response is needed to stop these outbreaks and save lives," said WHO Director-General Tedros Adhanom Ghebreyesus.

The next day, Sweden's public health agency announced a case of mpox linked with travel to Africa. The person was infected with clade I, the first time that version of the virus has been diagnosed outside the African continent.

In Africa, mpox is spreading rapidly in at least 12 countries, the Africa CDC reports. This year alone, there have been more than 18,000 cases and over 500 deaths.

Mpox usually spreads through physical contact with animals or with an infected person, their clothing, bedding or other objects. Children seem to be particularly vulnerable to the virus. As of late May, kids age 15 and younger made up two-thirds of reported cases and more than 80 percent of reported deaths this year in Congo. More than 5,000 children had been infected and more than 300 had died.

Among adults, clade Ib is spreading through heterosexual sex. (The 2022 clade II outbreak affected mostly men who have sex with men.) That may put pregnant women and babies at risk, said Ogoina, who is an infectious disease physician at the Niger Delta University Teaching Hospital in Okolobiri, Nigeria.

More than 100 clade Ib cases have popped up in countries that had never before recorded mpox cases, including Burundi, Kenya, Rwanda and Uganda. Evidence suggests that mpox is spreading among communities in Congo and Burundi, while the other countries have so far reported only isolated cases. Clade Ib appears to cause more severe illness and may be more transmissible than clade II.

Vaccines will be deployed, but supplies are limited and experts warn that the full scope of the outbreak is not known. Increasing surveillance will be important to understand how the disease is spreading and who would benefit most from vaccination, WHO epidemiologist Maria Van Kerkhove said during the news conference. Getting the word out to affected communities and talking with them about ways to stay safe may also help contain the outbreak, she said. "There are a lot of interventions that can be utilized in country, in communities, to prevent transmission."

But there are still many things scientists don't fully understand about mpox, including which animals serve as a reservoir and whether there is a real difference in the severity and transmissibility between clades.

One thing is clear: The world can no longer ignore mpox's spread in Africa, Ogoina said. "Mpox, originating in Africa, was neglected there, and later caused a global outbreak in 2022. It is time to act decisively to prevent history from repeating itself." ■

ENVIRONMENT

Half the world may not have safe water

A new model-based estimate more than doubles the official count

BY CLAIRE YUAN

Half the world may lack a basic human right: access to clean water.

Of the roughly 8 billion people on Earth, about 4.4 billion don't have access to safely managed drinking water, researchers report in the Aug. 16 *Science*. The estimate, based on computer simulations of data from low- and middle-income countries, is more than double the figure calculated by the World Health Organization.

4.4 billion
The estimated number of people without access to clean water

"The number of people whose basic human right to safe drinking water is not being met may therefore be significantly underestimated," says environmental microbiologist Esther Greenwood of Eawag, an aquatic research institute in Dübendorf, Switzerland.

That is partly because it can be difficult to collect data on the number of people using safely managed water services, especially in regions with limited technology. The incomplete information creates challenges for international efforts to broaden access to clean water. The new work aims to help fill holes, Greenwood says.

Using a computer simulation that integrates environmental data with survey data from nearly 65,000 households around the world, Greenwood and colleagues generated maps for 135 countries showing areas that probably had safely managed drinking water services in 2020. Comparing those maps with population data from UNICEF, the team estimated how many people didn't have reliable access to clean drinking water.

Regions with the lowest access to clean water include sub-Saharan Africa, South Asia and East Asia, the team found. The most common limiting factors include bacterial and chemical contamination as well as insufficient infrastructure. For instance, approximately 650 million people in sub-Saharan Africa don't have drinking water services in or near their homes, the researchers found.

High-income countries were not included in the analysis, but the team acknowledges that some populations in these countries also probably have inadequate access to safe drinking water.

The new estimate may not replace the WHO's official count of 2 billion people, which is based on country-provided data rather than surveys and simulations, says water solutions researcher Gregory Pierce of UCLA. "It's pretty unlikely that those who are producing the official estimates are going to be OK with just using these methods, because there's a lot more projection involved in them."

Still, Pierce says he hopes the new estimate spurs further investment in efforts to make clean water more accessible, which the United Nations classifies as a human right.

"We've been investing in [such efforts] for quite some time as a global community, but we've never actually stepped up the order of magnitude," Pierce says. "So hopefully this would lead to what's needed to close the gap." ■

PALEONTOLOGY

Dinosaur killer's origin revealed

The destructive asteroid hailed from beyond Jupiter

BY CAROLYN GRAMLING

Earth's most famous killer asteroid came from the outer reaches of the solar system, researchers report in the Aug. 16 *Science*.

About 66 million years ago, an asteroid slammed into the sea off Mexico's Yucatán Peninsula, forming the Chicxulub crater. Many scientists point to that event as the most likely trigger of the mass extinction that killed off all the nonbird dinosaurs.

The impact left geochemical fingerprints in a thin layer of rock found in multiple countries around the globe. Now, chemical analyses of those rock layers, which mark the boundary between the Cretaceous and Paleogene periods (known as the K-Pg boundary), are helping to create a forensic profile of the killer asteroid.

Geochemist Mario Fischer-Gödde of the University of Cologne in Germany and colleagues measured five forms of ruthenium in the K-Pg rock layers, as well as in five impact craters that occurred between 36 million and 470 million years ago and in some Earth-based ores for comparison.

The asteroid that slammed into Earth (illustrated) some 66 million years ago and likely triggered a mass extinction event came from the outer solar system.

MARK GARLICK

Ruthenium is rare in Earth's crust but abundant in space rocks. However, the relative abundance varies depending on where the space rocks originate.

The ruthenium signatures from K-Pg rocks from around the world were indistinguishable from one another, tying them all to the same event, the team found. And that event was definitely extraterrestrial, not from volcanic eruptions that have also been implicated in the dinosaurs' demise. The analysis revealed that the Chicxulub impactor was carbonaceous—originating in an ancient asteroid belt beyond Jupiter. The non-Chicxulub impactors were siliceous, originating from the asteroid belt between Mars and Jupiter. ■

HEALTH & MEDICINE

Blood tests help spot Alzheimer's

The technology is improving, but many questions remain

BY LAURA SANDERS

Blood tests that measure levels of key proteins may indicate whether a person has signs of Alzheimer's disease. But there are not yet guidelines to help doctors interpret results.

Alzheimer's disease is hard to diagnose. But proteins in the blood might provide clarity.

A series of recent findings, presented in Philadelphia at the annual Alzheimer's Association International Conference and in research papers, raises the possibility of a simple blood draw to help doctors figure out if a person's cognitive problems are caused by Alzheimer's — or something else.

Decades ago, the only definitive way to get a diagnosis was an autopsy. Since then, scientists have figured out how to see the disease in living people. Spinal taps reveal levels of key proteins associated with the disease. And brain scans can illuminate the characteristic plaques and tangles that mar the brain in a person with Alzheimer's disease. But spinal taps and brain scans are expensive and uncomfortable. A blood draw would lower barriers to diagnosis even further.

That matters, because while Alzheimer's has no cure, an easier, faster way to spot the disease could give people more time to discuss therapy options, including newly available drugs that lower levels of amyloid, the sticky protein that accumulates in the brain in Alzheimer's. Those drugs can come with serious side effects, but when used early in the disease, can moderately slow a person's cognitive decline.

"It's an exciting moment," says neuropathologist Eliezer Masliah of the National Institute on Aging in Bethesda, Md. "It's an explosive moment" that has the potential to help reshape the diagnosis and treatment of the nearly 7 million people with Alzheimer's in the United States, and millions more worldwide, he says.

Blood tests for Alzheimer's are available to consumers, but many questions surround the technology, Masliah cautions. "We're at an early stage right now," he says. If past Alzheimer's research is any indication, the answers won't be simple or quick.

For now, it's clear that the landscape is changing quickly. Here's what we know so far about blood tests for Alzheimer's disease.

Do blood tests work better than other ways to detect Alzheimer's?

Without brain scans or cerebrospinal fluid tests, doctors aren't so great at diagnosing Alzheimer's disease. In a Swedish study, primary care doctors who examined 1,213 people without those tests both correctly identified and ruled out Alzheimer's only 61 percent of the time, scientists reported July 28 at the meeting and in a paper published that day in JAMA.

"It's not that we think primary care physicians do not do a good job. They do," says Oskar Hansson, a dementia researcher and neurologist at Lund University and Skåne University Hospital in Malmö, Sweden. "It's that the tools they have today are not good enough." Even dementia specialists didn't do a whole lot better: They were right 73 percent of the time.

But a blood test could help get that accuracy up. One that measured two ratios of amyloid and tau, a protein that has long been known to form tangles in the brains of people with Alzheimer's, was 91 percent accurate, the team reported.

The study is one of the first to evaluate how a blood test works in a real-world setting, says neurologist Stephen Salloway of Warren Alpert Medical School of Brown University in Providence, R.I.

The results also hold promise for getting people a diagnosis much more quickly. Right now, a person who goes to their doctor with memory or thinking problems can spend months or even years waiting for appointments and tests that yield an Alzheimer's diagnosis. By the time they are diagnosed, their symptoms may be too advanced to benefit from new treatments.

What do the tests measure?

Blood contains a lot of potential markers for Alzheimer's disease, and scientists are studying many of them. But one marker in particular has garnered attention lately: a protein called p-tau217.

"I think it's fairly settled now that p-tau217 is really an exquisite biomarker of amyloid plaques," says JAMA study coauthor Suzanne Schindler, a neurologist and dementia specialist at Washington University School of Medicine in St. Louis.

Like any protein, tau is made of a string of amino acids, some of which can be decorated with chemical tags. That "p" and "217" in p-tau217 mean that the 217th amino acid in the tau protein is decorated with a phosphate group — a modification called phosphorylation.

Some blood tests measure the level of p-tau217. Others measure ratios of different versions of tau and amyloid, which indicate the amount of amyloid plaques in the brain. The ratios also correlate well with disease markers in cerebrospinal fluid.

ANDREW BROOKES/IMAGE SOURCE/GETTY IMAGES PLUS

Will Alzheimer's blood tests be the final word on a diagnosis?

No. Blood tests provide one piece of the overall clinical picture of a person. There are lots of reasons a person might be experiencing cognitive trouble, such as drug side effects or trouble sleeping.

"It's important not to attribute all symptoms to Alzheimer's disease because someone has a positive test," Schindler says. "I can't cure their Alzheimer's disease, but I can stop medications that are causing problems, or I can diagnose their sleep apnea, or I can do other things that are helpful."

Are blood tests available now?

Yes, and people are using them, Masliah says. But the Alzheimer's blood tests are not necessarily thoroughly tested for accuracy.

In a head-to-head comparison of six commercially available tests, the tests that used p-tau217 more accurately identified signs of Alzheimer's disease, Schindler and colleagues found. That work was presented July 30 at the Alzheimer's meeting and in a paper posted on medRxiv.org.

No Alzheimer's blood test is approved by the U.S. Food and Drug Administration. Salloway points out that FDA approval isn't necessary for use, though it may inspire confidence in the results. Schindler says she wouldn't be surprised if FDA approval were to happen next year for one or more of these tests.

What's next for Alzheimer's blood tests?

There are still many unknowns, including whether these tests work well for diverse populations across the world. Another missing piece is the standardization of these tests, which is needed to establish guidelines that would help doctors know when to use the tests and how to interpret the results.

"Without that it would be the wild west. You can interpret the results any way you want," Masliah says. "That would not help anybody."

Guidelines, similar to what exists for cholesterol levels, would need to be developed before these tests are widely useful, Masliah says. ■

HEALTH & MEDICINE

Some drugs make it hard to cool off

Studying how extreme heat reacts with medicines is a tough task

BY ERIN GARCIA DE JESÚS

As global temperatures continue breaking records this year, its important to think about how to stay safe in extreme heat. A growing body of evidence suggests that the pills in your medicine cabinet may factor into how much heat your body can handle.

When outdoor temperatures sizzle, the body jumps into action to keep internal temps under control. Blood rushes to the surface of the skin to release heat and sweat pours out, cooling the body as it evaporates. If these methods fail, people can develop headache, dizziness and confusion. In severe cases, people might become delirious or go into organ failure.

Chronic health conditions can add an extra one-two punch when it comes to regulating body temperature. Some conditions affect physiological cooling, and the medications that treat those diseases might also interfere with cooling. Older people are especially vulnerable to these effects because they face higher rates of some chronic conditions and because the body's cooling ability decreases with age.

"Hotter weather brought on by climate change represents a serious health risk," says thermal physiologist Jericho Wee of the National University of Singapore's Yong Loo Lin School of Medicine.

Scientists don't have a solid understanding of which medicines pose the greatest threat and how. Some drugs might interfere with sweat and blood flow, while others may influence the body's fluid levels. But researchers have some clues.

For example, epidemiologist Soko Setoguchi of Rutgers University in Newark, N.J., and colleagues examined medical records of nearly 10,000 Medicare recipients age 65 and older. Antipsychotics and cardiovascular drugs were linked with heat-related hospitalization, the team reported in 2020 in *PLOS ONE*. Even in the absence of heat waves, some of these drugs were linked with a higher risk of hospitalization for heat-related illness.

Chlorpromazine, a drug commonly used to treat schizophrenia, can impair the body's internal thermostat, suppress sweating and divert blood flow away from the skin, leading to an increase in body temperature, Wee says. Risperidone and fluphenazine, also used to treat schizophrenia, may alter brain chemistry in ways that make the body less likely to recognize when it is dehydrated and overheating, a 2021 case report of a 47-year-old man hospitalized for heat illness suggests.

When it comes to treatments for heart disease, blood thinners and beta blockers can reduce the amount of blood that rushes to the skin to help release heat. And diuretics, which treat fluid retention caused by heart failure, can lead to dehydration in extreme heat, Wee says.

There's no solid evidence to suggest that people should stop taking or reduce doses of these medications in extreme heat, Setoguchi says. Instead, people should talk to their doctors about ways to avoid heat and learn what to do in cases of heat stress.

Effects of extreme heat on myriad other drugs are unknown. Researchers can make assumptions about how a drug might impact the body's response to heat based on what's known about how the drug works, but how that plays out in the real world is still unclear.

Finding answers is difficult, says physiologist Jason Lee of the Yong Loo Lin School of Medicine. It's unethical to run randomized clinical trials that stop treatment for patients who depend on medications. And heat waves can't be randomized.

Case studies can help, especially those that follow many patients and compare when each patient takes the drug versus when they don't, Setoguchi says. So can studies that follow people taking different drugs for the same disease. Still, disease severity varies among people, which can cloud how researchers interpret results.

To predict who might face the most danger in extreme heat, consider everything together, Setoguchi says, from the disease to the medication a patient is taking. ■

ARCHAEOLOGY

Stonehenge's roots extend to Scotland

The landmark's centerpiece was thought to be from Wales

BY BRUCE BOWER

Stonehenge has a hard Scottish heart.

The ancient site's central stone, a large slab known as the Altar Stone, was transported at least 750 kilometers from northeastern Scotland to southern England, say geoscientist Anthony Clarke of Curtin University in Perth, Australia, and colleagues.

An analysis of the age and chemical makeup of three types of mineral grains in two Altar Stone fragments identified a close match to corresponding measures for a Scottish rock formation known as the Orcadian Basin, the team reports in the Aug. 15 *Nature*. Using the same measures, the researchers ruled out other rock formations in Great Britain and Ireland as sources for the Altar Stone.

The sandstone slab sits within a semicircular arc of smaller stones, known as bluestones. Most of the bluestones have been chemically traced to a rock source in western Wales, about 225 kilometers west of Stonehenge (SN: 3/13/21, p. 12). The new study challenges a long-standing assumption that the Altar Stone, due to its position near the bluestone arc, also has Welsh roots.

A combination of estimated ages for the three minerals in the Altar Stone, which range from several hundred million to 3 billion years old, provided a gauge for identifying the most likely source for the Stonehenge stone. Decay of small amounts of radioactive elements in crystallized minerals — such as the breakdown of uranium into lead in zircon crystals — occurs at known rates, which enabled the team to calculate the age estimates.

Transporting the six-metric-ton Altar Stone from Scotland to southern England's Salisbury Plain would have presented a daunting challenge. How much of a challenge may have depended on the precise location the stone came from, which has yet to be established, coauthor Nick Pearce, a geochemist at Aberystwyth University in Wales, said August 13 at a news conference.

The Orcadian Basin extends from northeastern Scotland to the Orkney Islands off Scotland's northern coast. If the Altar Stone came from an island, a water transport makes more sense than a strictly overland route, Pearce said. Perhaps a ship sailed down England's east coast before the stone was lugged about 160 kilometers to Stonehenge from the English Channel.

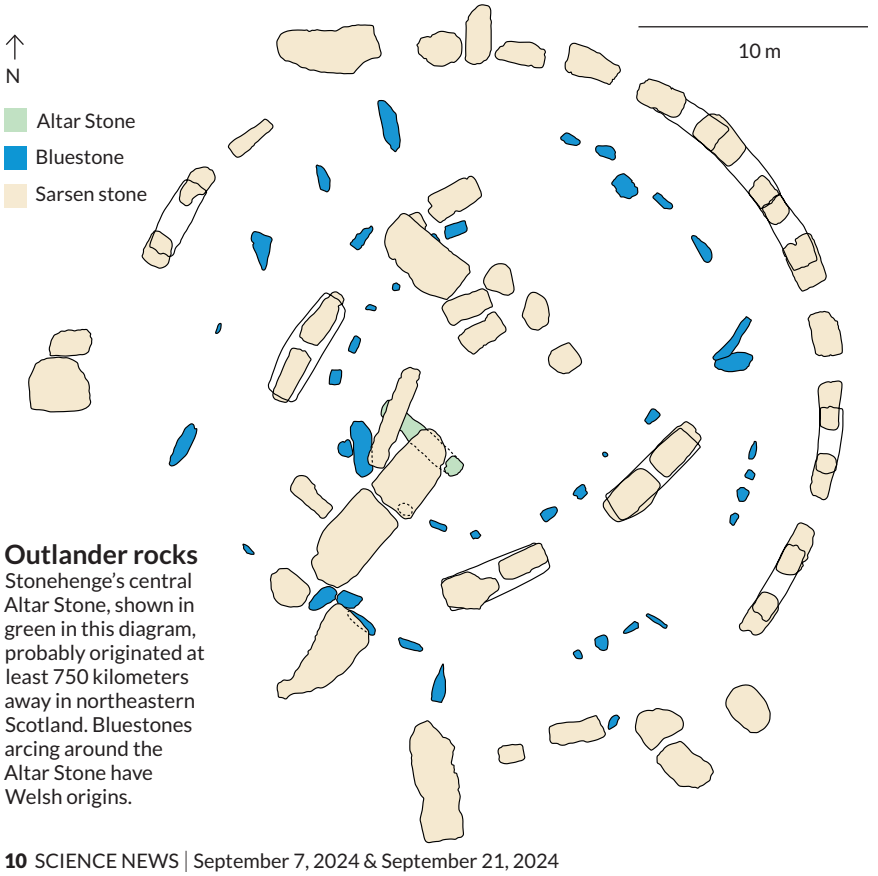
It also is unclear when the Altar Stone arrived at Stonehenge. Construction began around 5,000 years ago. Initially, the site served as a cemetery, with changes and additions occurring over the next two millennia. The Altar Stone may have been placed among the bluestones during a second construction phase between 2620 B.C. and 2480 B.C., the researchers suspect.

A Scottish source for the Altar Stone adds to evidence of long-distance connections, including shared pottery styles and house plans, among Late Neolithic groups that inhabited the British Isles during Stonehenge's construction phases, says archaeologist Alasdair Whittle of Cardiff University in Wales. Diet-related chemical signatures in excavated bones have suggested that some Late Neolithic domestic animals in southern England came from the north, possibly Scotland, Whittle says.

"This was an age of heroic feats of shared labor, movement and assembly, into which an Altar Stone from northeastern Scotland would perfectly well fit in," Whittle says.

A Scottish origin for the Altar Stone also highlights an intriguing architectural link, says archaeologist Joshua Pollard of the University of Southampton in England. Unlike other stones at Stonehenge, the Altar Stone lies on its side — a detail found in nearly 100 ancient stone circles in Aberdeenshire, Scotland. In each of those cases, a ring of standing stones surrounds a slab laid on its side in the ring's southwestern or southern arc.

Researchers do not know whether the Altar Stone originally stood upright. Broken in two, it has sunk into the grass and has two large collapsed stones resting on top of it. ■



Outlander rocks
Stonehenge's central Altar Stone, shown in green in this diagram, probably originated at least 750 kilometers away in northeastern Scotland. Bluestones arcing around the Altar Stone have Welsh origins.

A.J.I. CLARKE *ET AL*/*NATURE* 2024

ANTHROPOLOGY

Why is this mummy 'screaming'?

An ancient Egyptian mummy dubbed the Screaming Woman (shown at right) might have had her open-mouth expression fixed in place when she died about 3,500 years ago. Sudden muscular stiffening associated with violent deaths under extreme physical and emotional stress, known as cadaveric spasm, could explain the silent scream, scientists report August 1 in *Frontiers in Medicine*.

The woman's cause of death remains unknown, so a cadaveric spasm can't be confirmed as the reason for the look. But evidence of the care taken in preparing her body hints that embalmers did not neglect to close the mouth, say radiologist Sahar Saleem of Cairo University and anthropologist Samia El-Merghani of Egypt's Ministry of Tourism and Antiquities in Cairo. The internal organs remained inside the body. Her skin had been treated with imported juniper resin and frankincense, and her hair had been dyed with juniper and henna, a chemical analysis found. — *Bruce Bower*

S. SALEEM

ARCHAEOLOGY

How was Egypt's first pyramid built?

A hypothesized hydraulic elevator draws skepticism

BY BRUCE BOWER

Waterpower may have given a big lift to builders of Egypt's oldest known pyramid, the nearly 4,700-year-old Step Pyramid of Djoser at Saqqara.

Ancient architects built a hydraulic system for hoisting stone blocks that were used to assemble King Djoser's roughly 62-meter-tall pyramid, Xavier Landreau and colleagues propose August 5 in *PLOS ONE*. Controlled flows of water into and out of a large shaft inside the pyramid lifted and lowered a platform that carried stones to higher levels, says Landreau, who founded Paleotechnic, a private research institute in Paris that studies ancient technologies.

No generally accepted explanation exists for how ancient Egyptians erected pyramids. Proposed techniques for maneuvering stone blocks, which weighed up to about 2,500 kilograms each, include ramps, cranes, rope-and-pulley devices and rolling rods attached to stones.

A Nile tributary could have helped deliver workers and materials to building sites. But water might have played an even bigger part in building ancient Egypt's first pyramid, says Landreau, who has a background in materials science and plasma physics. He contends that designers of Djoser's pyramid engineered techniques for controlling water flow.

A computer model of the proposed hydraulic system included data on the pyramid's surviving internal features and a network of underground tunnels at the site. The team also used satellite images of the region's landscape to model ancient rainfall.

The model suggests that a walled enclosure near the pyramid captured floodwater during periodic heavy rains. Structures in the walls of the enclosure, known as Gisr el-Mudir, directed the water to a basin west of Djoser's burial grounds. Periods of intense rain may have temporarily turned that basin into a lake, which then drained into a section of a limestone trench that encircled the burial complex.

The trench, known as the Dry Moat, may have served as a quarry for Djoser's burial complex. But Gisr el-Mudir and its nearby lake ensured that the Dry Moat was not always dry in Djoser's time, Landreau says. Water from the moat could have entered a previously excavated shaft inside the pyramid, the model suggests. A granite chamber near the bottom of the shaft contained a stone plug that, when removed, would have allowed water to rush in.

Ancient engineers designed a wooden float and lift platform to counterbalance each other via a pulley system, Landreau's team hypothesizes. As water filled the shaft through the granite chamber, the float would have risen, making the platform descend. When the platform reached a loading area, the water would have been shut off. Once workers stacked stones on the platform, the shaft would have been drained, lowering the float and lifting the platform to new construction levels.

But some archaeologists say that's an unlikely scenario. Gisr el-Mudir could not have held enough rainwater to maintain the proposed hydraulic system, argues Oren Siegel of the University of Toronto.

What's more, the proposed lake is not mentioned in ancient Egyptian writings and may never have existed, says Egyptologist Kamil Kuraszkiewicz of the University of Warsaw. Also, the 300-kilogram stones used for Djoser's pyramid were much easier for workers to transport than the blocks used for later pyramids. "To build the hydraulic device, much more effort would be needed than to move the stone blocks using just manpower," he says. ■

CLIMATE

Earth's jet streams sow cloud seeds

Mingling atmospheric layers are prolific aerosol producers

BY CAROLYN GRAMLING

Scientists have sussed out a new source for the seeds of clouds. When the stratospheric layer of Earth's atmosphere dips a toe into the underlying troposphere, the resulting chemical mixture becomes a fertile environment where new particles, including the microscopic aerosols around which clouds coalesce, can form.

Atmospheric measurements taken during NASA aircraft missions in the Northern Hemisphere between 2016 and 2018 confirmed that this mechanism, called stratospheric air intrusion, is a source of new particles and that the region may be Earth's most productive place for these particles, aerosol scientist Jiaoshi Zhang of Washington University in St. Louis and colleagues report in the July 12 *Science*.

Previously, scientists thought that most particle formation happens in regions where clouds float into the upper troposphere and dissipate. As the clouds rain out, so do any existing particles. What's left behind in these "cloud outflow" regions is a blank slate that's basically particle free. Since gaseous molecules have nothing existing to glom on to, they instead make new particles.

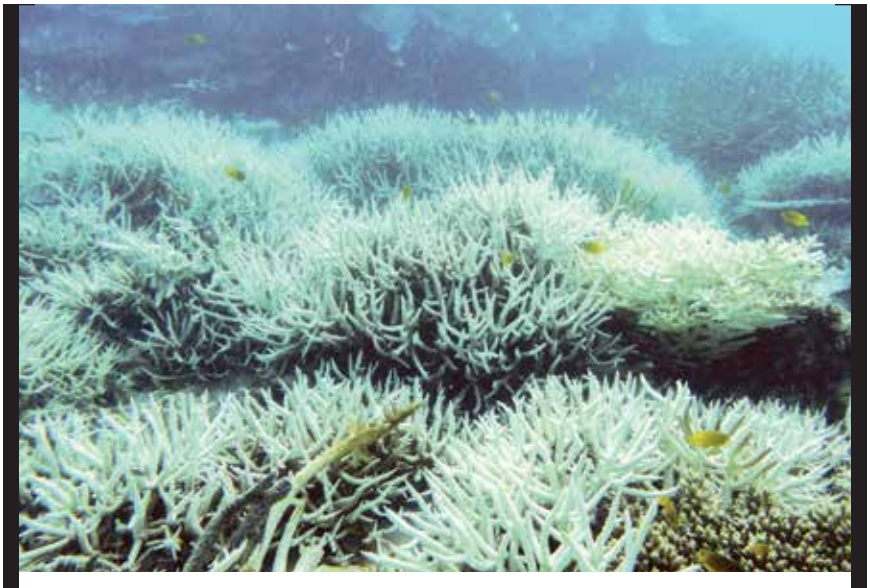
The new study suggests that stratospheric air intrusions are even more productive when it comes to particle formation. Turbulence caused by jet streams, fast-moving currents of air, can cause fingers of stratospheric air to punch down and curl into the troposphere.

The two atmospheric layers have different chemical makeups, and where those air masses mix, they generate very productive particle factories, says Washington University aerosol scientist Jian Wang. The stratosphere is cold and ozone-rich, while the troposphere is warmer, moister and contains a variety of molecules such as sulfur dioxide. Catalyzed by sunlight and water, the chemical reaction of these air masses may generate cloud-seeding sulfate and a variety of other particles.

Exactly which and how many particles are being formed by these air intrusions is a subject for future work, Wang says. "We don't really understand the mechanisms in detail. We know from the data that … you need sunshine, high ozone and moisture" to produce hydroxyl radicals. Those molecules eagerly interact with other atmospheric gases, so there are probably many different chemical reactions going on that produce different particles.

Despite these uncertainties, the analysis of the frequency and productiveness of stratospheric air intrusions, compared with cloud outflow events, suggests that the intrusions may be a bigger source of new particles, particularly in Earth's midlatitudes. With climate change expected to intensify stratospheric circulation, which could increase the frequency of stratospheric intrusions, this mechanism may become even more important to the formation of new particles, Wang says.

The team's work highlights an important source of atmospheric particles that has not yet been included in Earth system models, says atmospheric aerosol chemist Yuanlong Huang of the Eastern Institute for Advanced Study in Ningbo, China. It raises new questions about how much and where sunlight is absorbed by aerosols and clouds high in the atmosphere. ■



OVE HOEGH-GULDBERG

CLIMATE

Record-breaking heat threatens corals

Ocean heat in the Coral Sea, home to the Great Barrier Reef, is at its highest in four centuries, scientists report in the Aug. 8 *Nature*.

Paleoclimatologist Helen McGregor of the University of Wollongong in Australia and colleagues reconstructed sea surface temperatures from 1618 to 1995 by analyzing the chemical makeup of coral skeletons and using sea surface measurements from 1900 to 2024. Before 1900, temperatures were relatively stable. But from 1960 to 2024, they climbed relentlessly. Five of the hottest years were in the last decade, with temperatures as much as 1 degree Celsius higher than average. Mass bleaching occurred in each of those years, as stressed corals ejected algae and turned white (shown above).

Greenhouse gas emissions from human activities are driving this temperature climb, the team found. "The more we cut now, the better off not just the Great Barrier Reef will be, but society is going to be. It's the coral in the coal mine," McGregor said August 6 at a news conference. — *Carolyn Gramling*

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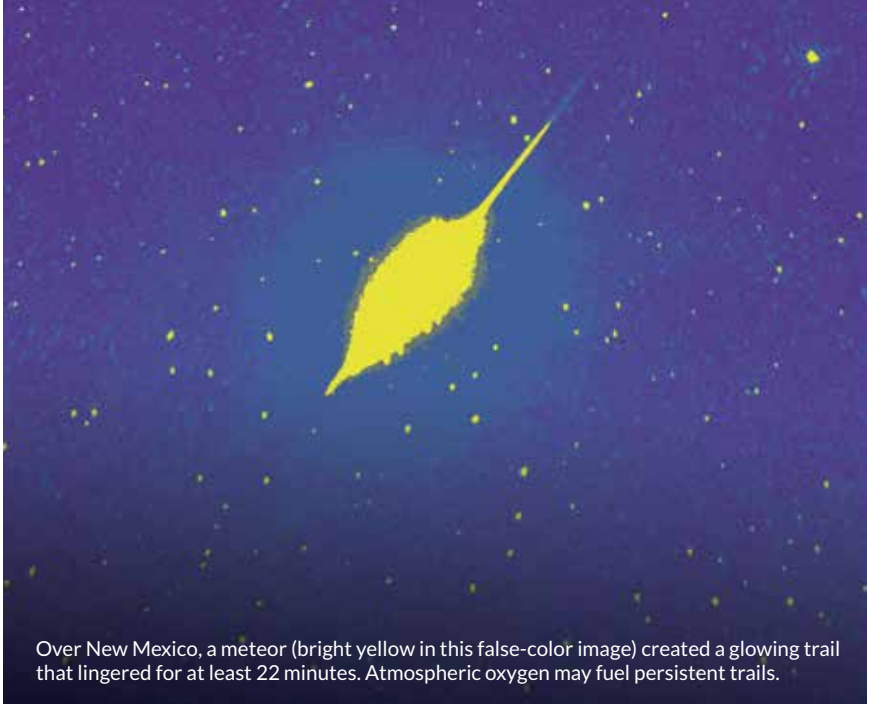
ASTRONOMY

Oxygen may spark meteor afterglow

Lingering light trails seem to rely on atmospheric chemistry

BY LISA GROSSMAN



Over New Mexico, a meteor (bright yellow in this false-color image) created a glowing trail that lingered for at least 22 minutes. Atmospheric oxygen may fuel persistent trails.

To leave a lasting trail, meteors need to aim low. A new survey of shooting stars shows that meteors that blaze 90 kilometers or lower in the sky are more likely to leave a persistent afterglow, unlike those that burn up at greater heights.

Meteors are normally blink-and-you'll-miss-it events. A particle of space dust leaves a fiery trail of light as it zips through the atmosphere, and then it's gone. But sometimes, a meteor leaves a lingering afterglow. Astronomers have noted these persistent trails for more than a century, but questions remained about their origins.

Now, the first systematic survey of persistent trails has revealed what kind of meteor is most likely to leave one behind. Contrary to previous assumptions, the key variable is the meteor's height in the atmosphere, not its speed or brightness, astronomers report in the July *Journal of Geophysical Research: Space Physics*.

Amateur astronomers often record such trails "as a nice movie," says astrophysicist Gunter Stober of the University of Bern in Switzerland, who was not involved in the research. "This is really the first more comprehensive, total overview of statistics."

Persistent trails form when metals that have been burned off the incoming space rock react with oxygen, particularly ozone, in the atmosphere. The chemical reaction emits heat and light, sustaining the trail for tens of minutes or even up to an hour. These trails can writhe and twist like luminous snakes as the wind carries them away.

Catalogs built in the 1940s and '50s suggested that persistent trails are rare, occurring in 1 out of every 750 meteors, and mostly associated with the brightest meteors. More recent studies focused on the Leonid meteor storm, which lasted from 1999 to 2002 and produced the most dramatic showers in decades. Those studies concluded that only the fastest meteors, racing around 70 kilometers per second, leave persistent trails.

But these surveys were either too broad, including one-off views of meteors from observers around the world, or too narrow, focusing on a single spectacular meteor shower.

To create a more uniform catalog, astrophysicist Logan Cordonnier and colleagues set up a camera to stare at the same patch of sky over New Mexico for nearly two years. From October 2021 to July 2023, the instrument recorded every light streak that crossed its field of view. In that time, the team recorded nearly 7,500 meteors, of which about 850 left persistent trails.

Not only were the trails more common than expected—about 1 in 8 meteors left a persistent trail and 1 in 19 trails lasted longer than five minutes—but trails were left by meteors of all speeds and brightnesses.

"Some of the previously held ideas were that these persistent trains were only formed by the fast, bright meteors," says Cordonnier, of the University of New Mexico in Albuquerque. "We found that it doesn't need to be fast. Most of the persistent trains were formed by slower meteors."

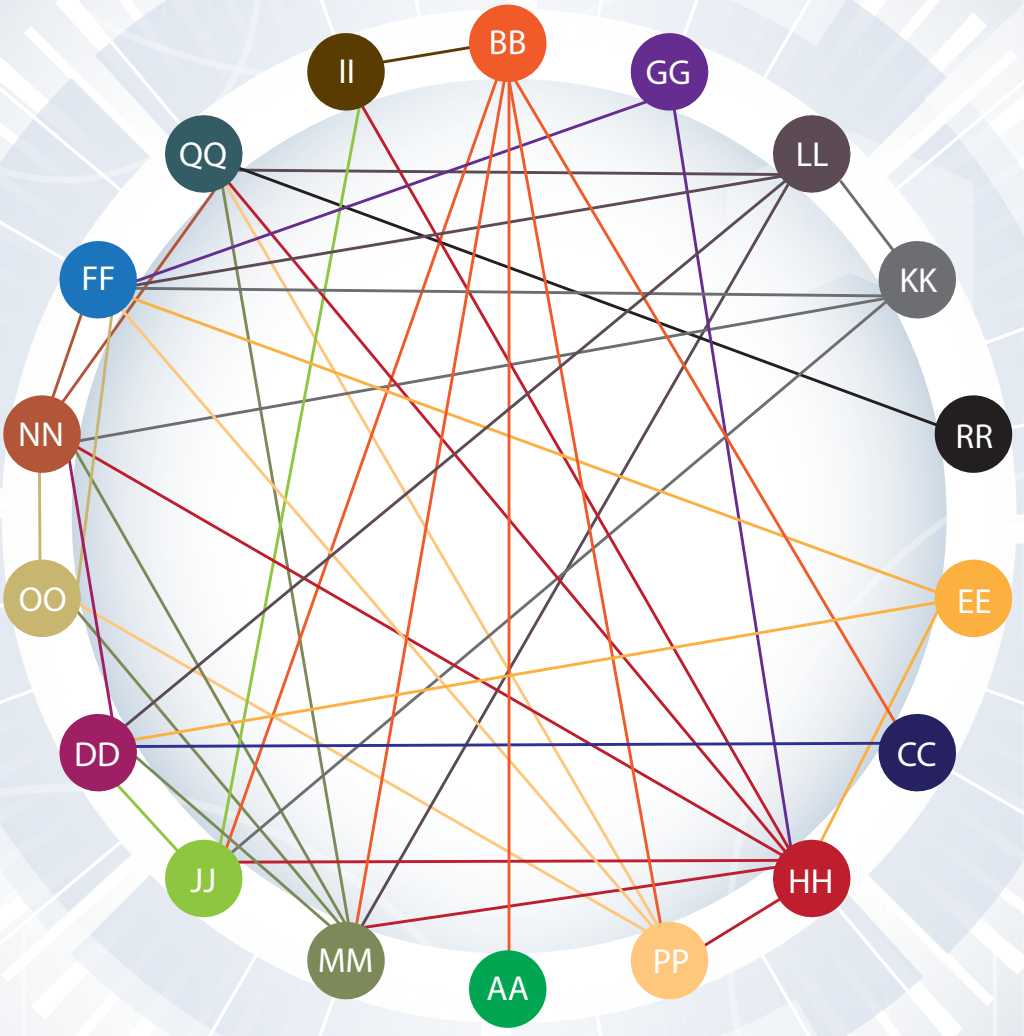
The real determining factor was the availability of ozone, Cordonnier says. Meteors that penetrated to altitudes of 90 kilometers or lower were far more likely to leave persistent trails than those that were higher. Ninety kilometers in the sky is above Earth's ozone layer, but there is a small concentration of ozone at that altitude, Cordonnier says. While theoretically, meteors passing through the ozone layer could also leave trails, Cordonnier notes that few meteors make it that far without disintegrating.

Future observations of persistent trails could help probe the chemistry of this elusive atmospheric layer. The region "is the spot on your back where you can't itch," Cordonnier says. "It's too high in the atmosphere for weather balloons, and it's too low for satellites to take direct measurements. It's a difficult region to probe." Persistent trails, though, "happen for free, all the time. We just have to look and see them."

Stober would like to see the data in the new catalog applied to another question: Why do some trails maintain their shapes for so long, while others diffuse quickly? Explaining the chemistry that produces trails in the first place is interesting, but a force is needed to keep the trail intact, he says.

Atmospheric physicists have suggested that charged dust grains knocked off of the meteorite could produce an electric field that can keep the trail together. More investigations into this catalog and others could prove this notion right or wrong. ■

L.E. CORDONNIER *ET AL./JGR: SPACE PHYSICS* 2024



Freshwater crocodiles have suffered die-offs as poisonous cane toads have spread across Australia.

ANIMALS

How to teach a croc what not to eat

After a good scare, the predators stay away from lethal toads

BY BETHANY BROOKSHIRE

All it takes is one miserable night after a bad dinner to make humans avoid an ingredient for life. To teach crocodiles to avoid a lethally poisonous toad, all it takes is one very, very nasty toad butt.

Freshwater crocodiles in Australia that chowed down on cane toad carcasses laced with a nausea-inducing chemical were far less likely to eat live toads when the poisonous amphibians came hopping along. This type of teaching could help prevent the predator die-offs that occur as cane toads make their way across the continent, researchers report August 14 in *Proceedings of the Royal Society B*.

Cane toads (*Rhinella marina*) were brought to Australia in the 1930s and quickly began to wreak havoc on native species. Their harm comes not from what they eat, but from what eats them. The toads have large glands that contain potent poison. As cane toads have spread, freshwater crocodiles (*Crocodylus johnstoni*) have fallen for the tempting snack. In the 2000s, for example, croc population densities along the Victoria River crashed by as much as 77 percent following cane toad invasions.

But what if the crocodiles could be taught to avoid eating cane toads entirely?

Georgia Ward-Fear, a conservation scientist at Macquarie University in Sydney, has been testing a technique called conditioned taste aversion. In previous work, Ward-Fear and colleagues released "teacher toads" — tadpoles, eggs or very young cane toads that don't yet carry enough poison to be deadly — before adults arrived. Large monitor lizards ate the small toads and got sick, but lived and learned to avoid the lethal adult versions.

But baby toads are far beneath the notice of crocodiles.

To train crocs, Ward-Fear and colleagues worked with the Bunuba Rangers, members of an Australian Indigenous group who see freshwater crocodiles as an important part of their dreamtime stories — a component of the group's religion and culture. The team collected about 2,400 dead toads and removed the heads, poisonous glands and internal organs. Researchers laced the remaining toad butts with lithium chloride, a chemical that produces powerful nausea. The team then set up motion capture cameras and dangled the dead toads as well as unlaced chicken bait over the edge of the water across four gorges in the central Kimberley region of Australia.

After the crocodiles' "lessons," Ward-Fear and colleagues headed back to find out if the crocodiles had learned from the baits. They searched for any dead crocodiles and cut them open to see if a toxic toad was the cause of death.

Crocodiles learned quickly that once was enough when it came to eating a cane toad. The researchers found remarkably few carcasses of crocs that dined on live cane toads. At one site where toads had already arrived, rangers found 63 dead crocodiles in 2020. But after the team baited the group of crocs that came to the same area in 2021, only three died from eating toads. At another site, no crocodiles tasted toads after their training. In contrast, a nearby unbaited area saw between 20 and 40 percent of their crocodiles die from eating newly arrived toads.

"This is a wonderfully innovative and effective example of the tremendous potential of conditioned taste aversion as a tool for conservation," says Colleen St. Clair, a conservation biologist at the University of Alberta in Edmonton, Canada. Many scientists have been leery of conditioned taste aversion since early trials in mammals failed in the 1970s, she says. "I expect this will be a landmark study, showing that a very old [nausea-inducing substance], lithium chloride, is effective for ambush predators like crocodiles."

Before the study, rangers and scientists alike would find dying crocodiles thrashing helplessly in the water after eating deadly toads. It's "very distressing for us as wildlife biologists and Indigenous rangers," Ward-Fear says. The result is both an environmental and emotional success. ■

To teach crocodiles to stay away from poisonous cane toads, scientists set out cane toad bait laced with nausea-inducing lithium chloride (shown on the left stick next to a non-nasty control bait on the right stick).

FROM TOP: CRAIGRJD/GETTY IMAGES; DBCA

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ANDRII SHYP/ISTOCK/GETTY IMAGES PLUS

Next-gen pain treatment

Fighting chronic pain demands more than just medications

By Cassandra Willyard

51.6
million
The number of U.S. adults who experienced chronic pain in 2021
SOURCE: CDC

17.1
million
The number of U.S. adults who experienced chronic pain that substantially reduced daily activities in 2021
SOURCE: CDC

$31
billion
The value of the U.S. pain management drugs market in 2023
SOURCE: NOVA ONE ADVISOR

Megan Hodge's first bout of intense pain arrived when she was in her mid-20s. Hodge and her husband were getting ready to visit family for Thanksgiving. Though Hodge had been dealing with a variety of chronic health issues, her workout had gone well that morning and she finally felt like she was getting a handle on her health.

Hodge began packing. As she reached into her closet to grab a sweater, her back gave out. The pain was excruciating, so intense that she felt lightheaded and thought she might vomit.

As the years passed, Hodge had more frequent and more severe bouts of back pain. Any small movement could be a trigger — grabbing a towel from the linen closet, picking up a toy off the floor, sneezing. In 2021, Hodge experienced a particularly bad flare-up. None of the strategies she had previously used to help her manage seemed to be working. She was afraid to make any movement. She felt hopeless. "I just could not regain footing, metaphorically and physically," she says. "I truly felt frozen in my chronic pain and chronic health journey."

Hodge is far from alone. In the United States, chronic pain affects tens of millions of people — about 1 in 5 adults and nearly 1 in 3 people ages 65 and older. "The amount of suffering from arthritis and aging that I've seen in my pain clinic, it's overwhelming to me as a pain doctor," says Antje Barreveld, an anesthesiologist at Mass General Brigham's Newton-Wellesley Hospital in Massachusetts. What's more, the mainstay therapy for severe acute and chronic pain — prescription opioids — has helped fuel an epidemic that kills tens of thousands of people each year. "We have to have some better alternatives," she says.

So researchers have doubled down in their quest to find new pain treatments that aren't as addictive as opioids. "The pain field has really made very rapid and tremendous progress in the last decade," says D.P. Mohapatra, a former pain scientist who now oversees research at the National Institute of Neurological Disorders and Stroke in Bethesda, Md.

The hope is that all the research will soon lead to new therapies. Vertex Pharmaceuticals is currently seeking regulatory approval for a new drug, suzetrigine, that looks promising in clinical trials. If approved, which could happen in early 2025, it would introduce the first entirely new class of pain therapies in decades. Though an initial approval would be for acute pain, there's hope that the new drug could also curb chronic pain.

"Minor aches and pains, or even really painful acute pain, can largely be dealt with," says Rajesh Khanna, a pharmacology researcher at the University of Florida in Gainesville. "But chronic pain? Unfortunately, there's nothing."

At the same time, there's a growing recognition that treating chronic pain requires more than just pills. "We have a culture where people really turned to medications," Barreveld says. "But there's so much more to pain management than the pills that we prescribe."

Pain researchers are also looking to nonpharmacological treatments, including devices that deliver pain-relieving stimulation and psychological strategies that help people manage their pain. The field is developing ways to boost existing therapies and working to identify the most effective

combinations, as well as trying to figure out which patients might benefit most from which strategies.

"I think the future of pain care is going to be multicomponent therapy," says Daniel Clauw, a pain researcher at the University of Michigan Medical School in Ann Arbor.

What is pain?

Pain is the warning system our body uses to try to protect us. It's what makes you yank your hand away from a hot pan or hobble after twisting an ankle. Pain-sensing nerves in the periphery of the body called nociceptors identify potential threats — changes in temperature or pressure — and send electrical alerts zipping up to the brain. The brain processes these signals and then dials them up or down.

Clauw likes to compare the body's pain system to an electric guitar. The peripheral nerves are the strings of the guitar, the brain is the amplifier. You can increase the volume by plucking the strings harder, or you can turn up the amplifier. If the brain decides the threat is real, it might enhance the pain.

"Then there's the recovery process, where the body heals, and then you start to go back to normal," says Tor Wager, a neuroscientist and psychologist at Dartmouth College. In most cases, the body desensitizes and recovers. The pain ebbs and disappears.

44.4
percent
The drop in the total number of opioid prescriptions in the United States between 2011 and 2020
SOURCE: IQVIA INSTITUTE

With chronic pain, though, the pain continues long after the initial trigger. In some cases, there is a clear physiological explanation and a clear solution. In other cases, neither the problem nor the solution is clear-cut.

"This pain is coming from the brain," Clauw says. Fibromyalgia, a chronic condition that causes pain and fatigue, has become the poster child for this problem — what's known as central sensitization — but, he adds, "most of the common chronic pain conditions are really now thought to be that mechanism."

We have medicines to treat pain, of course. For mild to moderate pain, doctors often recommend nonsteroidal anti-inflammatory drugs, or NSAIDS, including aspirin or ibuprofen, for both acute and chronic pain. Antidepressants like duloxetine and anticonvulsants like gabapentin also seem to offer some relief for people with chronic pain. And doctors still turn to opioids.

But these medicines don't work for everyone. And even when they do, they often provide only modest, short-term improvements. Even powerful opioids don't eliminate chronic pain. A 2020 report by the U.S. Agency for Healthcare Research and Quality found little evidence for any long-term benefits of prescription opioid treatment. Clauw believes opioids may even make many types of chronic pain worse.

"We have this giant need for new treatments for pain," says Stephen Waxman, a neurologist and pain researcher at the Yale School of Medicine.

New pain meds are hard to find

Developing new therapies to treat chronic pain has been tricky. In part that's because a diagnosis doesn't always shed light on the underlying mechanism. Is lower back pain caused by a compressed nerve, for example, or is it an amplifier problem? A treatment that addresses one may not work for the other.

What's more, objective evidence that a medication is alleviating pain is hard to come by. There are no biomarkers, lab values or imaging results that can reliably measure pain. "You ask your patient to rate their pain from 0, no pain, to 10, the worst pain they can imagine. That's a very noisy metric," Waxman says. It depends on stress levels, sleep, mood, pain resilience and a litany of other factors. Plus, "the placebo response is somewhere between large and immense."

Perhaps it's not surprising then that the quest for new pain medicines has been beset by failures. Promising compound after promising compound has fizzled during development, including in late-stage trials. In 2021, Pfizer and Eli Lilly halted development of an antibody for arthritis and chronic back pain that showed promise after regulators raised safety concerns.

Vertex's new pain compound, suzetrigine, could be the first to deliver in a heated race to target specific sodium ion channels found on pain-sensing nerve cells (SN: 6/30/12, *p.* 22). When these channels open, sodium enters the cell, decreasing the voltage between the cell's interior and exterior. Eventually the voltage reaches a threshold, and the nerve sends an electrical impulse to the next nerve.

Scientists started chasing these channels seriously in the late 1990s, and the pace of research accelerated in the mid-2000s after researchers identified families who had a defect in a gene that codes for a particular sodium channel called Nav1.7. The defect cut pain off at the source.

Earlier this year, Vertex reported that suzetrigine, which blocks a related channel called Nav1.8,

curbed pain better than a placebo in people who had just had tummy tuck surgery or bunion removal. But the compound wasn't a slam dunk. In people who underwent bunion removal surgery, it didn't work any better than the opioid hydrocodone combined with acetaminophen. And in tummy tuck patients, the opioid combination better alleviated pain.

Though pain medications that block sodium channels already exist — the anticonvulsant carbamazepine, for example — these compounds target a variety of sodium channels, not just those involved in pain. Blocking these channels causes side effects that limit the maximum dose. That's why drugs like lidocaine and novocaine, which also block sodium channels, are injected locally.

"If you put them in the form of a pill, they block all of the sodium channels, including those in the heart and in the brain. So you get double vision, loss of balance, confusion, sleepiness," Waxman says.

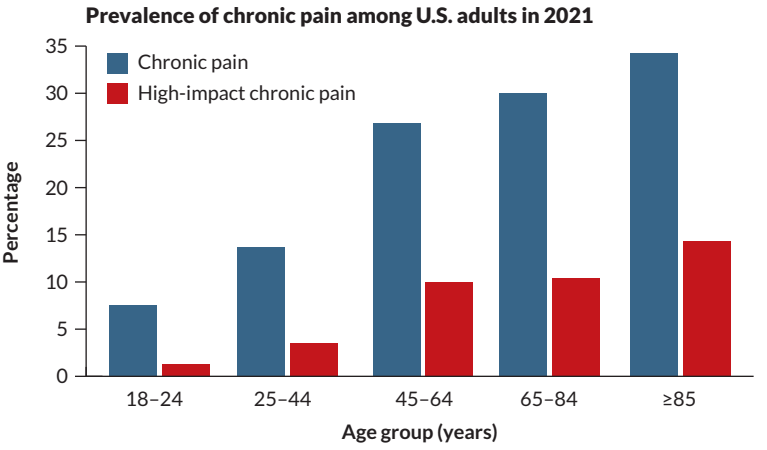
Though the effect of suzetrigine is "modest," Waxman says, it's a proof of principle: Targeting sodium channels specific to pain-sensing neurons works. And the hope is that the next generation of these compounds could be much better. In December, Vertex reported that the drug seems to alleviate pain in people with diabetic peripheral neuropathy, a kind of pain that stems from nerve damage typically in the hands and feet. This is an early step in extending suzetrigine's potential use from acute to chronic pain.

Suzetrigine acts where pain begins, in the periphery. It can quiet the guitar strings, but it doesn't directly address amplifier defects. Will fixing the peripheral component be enough to quell the pain? Waxman is hopeful, but it's "an important intellectual question."

New genetic discoveries may lead to more targets. Waxman has been studying people with a genetic condition called "man on fire" syndrome. Some people with this condition have overactive Nav1.7 channels that typically lead them to experience intense pain, but a subset of these individuals experience far milder pain than expected. He and his colleagues discovered that the individuals who experience milder pain harbor mutations in a gene that controls the activity of a family of potassium channels that act to stabilize neurons so that they don't fire.

Waxman's team is now working with a biotech company to develop a potential drug that would increase the activity of these channels in people who don't have the mutations.

C. CHANG



Pain relief beyond pills

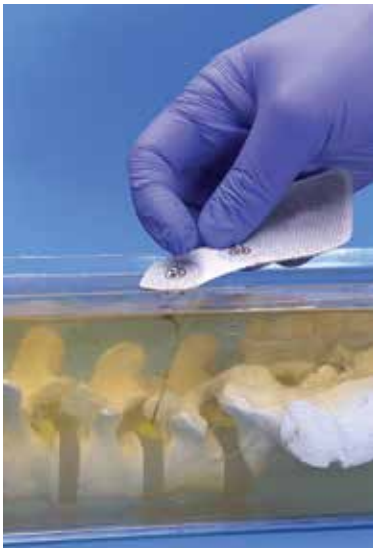
Although many physicians are quick to prescribe pain medications, treating pain isn't just about pills. In some cases, surgical procedures or injections can help relieve pain. Physical therapy can strengthen and stretch muscles and ligaments to curb pain. Neuromodulation therapies deliver electrical pulses directly to nerves to alleviate pain. Some, like spinal stimulation, are invasive. Others rely on electrodes placed on the skin.

A team led by researchers at the University of Wisconsin–Madison has come up with a different, minimally invasive technique. The team developed an injectable electrode to create a pathway from the skin's surface to nerves deep in the body's tissue. This "injectrode," currently being tested in people, enters the body as a flexible polymer-coated metal coil that can deliver electrical stimulation from a device outside the body to nerves deep in the tissues.

There is also a host of complementary and behavioral health therapies that can have a big impact on pain: acupuncture, meditation, yoga, massage, talk therapy — the list goes on and on. Many of these seem to work, at least in part, by addressing the amplifier problem. "The idea that your brain is actively creating pain, turning it up and down, facilitating spinal cord signaling of pain or dampening it, is really kind of a revelation over the past few decades," says Wager, of Dartmouth. And it's an idea that's just beginning to percolate into mainstream medicine.

These therapies aren't new. Cognitive behavioral therapy, for example, has been used to treat pain for decades. But researchers are turning to the latest discoveries in pain science to tweak these therapies to make them more accessible and more effective. Wager has developed a version of cognitive behavioral therapy called pain reprocessing therapy. It

Feeling the pain
About 20 percent of all U.S. adults experience chronic pain, defined as pain on most days or every day during the previous three months. Nearly 7 percent have high-impact chronic pain, which is bad enough to limit daily life or work activities most or every day. SOURCE: CDC



An injectable electrode, an "injectrode," made by the company Neuronoff can deliver electrical stimulation from outside the body directly to nerves deep in tissues. Here, it's shown fully deployed in a gelatin hydrogel (above left). An external pulse generator will snap into the patch that is being applied (right).

aims to help patients understand that chronic pain is often a construct of the brain and not necessarily a warning that needs to be heeded.

In a recent study of 151 people with chronic back pain, two-thirds of the people who received pain reprocessing therapy were pain free or nearly so, meaning their pain score was 0 or 1, at the end of the study, compared with 20 percent in the placebo group and 10 percent who received their standard care. And the effect lasted at least a year.

Talk therapy requires a serious time commitment. But Beth Darnall, a psychologist and pain scientist at Stanford University, is working on strategies that are more user-friendly. She is chief science adviser for AppliedVR, a company working to develop virtual reality tools to treat pain. The company's program for back pain, called RelieVRx, teaches pain-relief strategies such as mindfulness, deep breathing and relaxation. The system also measures respiratory rate to provide participants with biofeedback.

"The world reflects back to them the changes that are occurring in their own body as they engage in a skill. And that's pretty unique to be able to do that from home," Darnall says.

In a recent trial, researchers assigned roughly 1,000 people with chronic lower back pain to receive RelieVRx or a sham virtual reality treatment for two months. Both groups experienced a reduction in pain, but the RelieVRx group reported a slightly larger drop, on average. (The sham treatment's impact was attributed to the placebo effect.)

While the list of potential pain-relief options keeps growing, there is also an understanding that no single therapy or combination of therapies will work for everyone. "Pain is so complex and so diverse," says Mohapatra, of the National Institute of Neurological Disorders and Stroke. "We cannot make pain therapy as a one size fit for all."

Many patients have to find solutions through trial and error, which means it might be months or years before they find any relief. "Right now, we just fly blind," Clauw says. What's needed is a way to identify which therapies might work for which patients.

In 2019, the U.S. National Institutes of Health launched a study that aims to change that. The project, part of the NIH's massive Helping to End Addiction Long-term — or HEAL — Initiative, will aim to find biomarkers to help predict which therapies will work for the most common and debilitating chronic pain condition: lower back pain. "It's applying a precision medicine approach to low back pain for the first time," Clauw says.

In one study, researchers will assign about 1,000 participants to one of four pain relief strategies: an online education program; a kind of cognitive behavioral therapy known as acceptance and commitment therapy; physical therapy; or the pain medication duloxetine. Each participant will undergo an assessment that includes blood work, imaging of the spine and a physical exam. The hope is that these data can be used to create a model to predict which patient will benefit from which treatment — or more likely, treatments.

A multi-treatment approach is what finally gave Hodge some relief. At the Shirley Ryan AbilityLab Pain Management Center in Chicago, she received comprehensive care that included physical therapists, occupational therapists, pain psychologists and physicians, all of whom collaborated and monitored her progress and well-being. "That's not to say that I now live a life without any pain or without any flare-ups," she says. "It's not a cure-all." But she does have a road map for how to deal with her pain, as well as the tools and mind-set to better navigate future flare-ups.

After Hodge graduated from the program, she wrote a letter to her care team about the impact of the skills she learned. "I am no longer constantly on edge, waiting for the other shoe to drop," she wrote. "I finally feel safe in my body." ■

Explore more

- Steven E. Harte, Richard E. Harris and Daniel J. Clauw. "The neurobiology of central sensitization." *Journal of Applied Biobehavioral Research*. June 2018.

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

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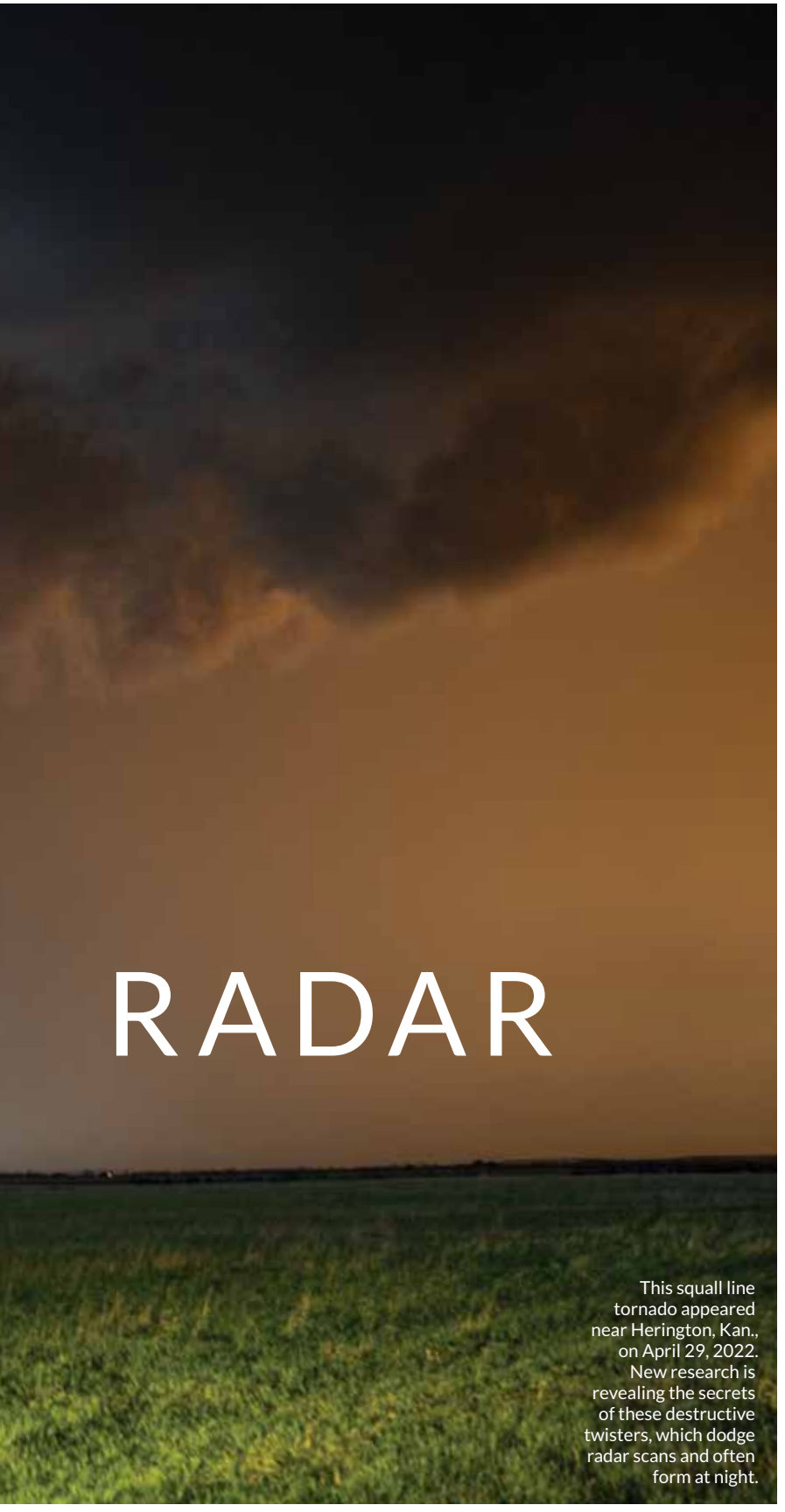


RADAR

This squall line tornado appeared near Herington, Kan., on April 29, 2022. New research is revealing the secrets of these destructive twisters, which dodge radar scans and often form at night.

Squall line tornadoes are sneaky, dangerous and difficult to forecast

By Nikk Ogasa

Meteorologist Thea Sandmael watched the storm close in. It was near enough for her to spot a rotating dome of clouds emerging from its dark underbelly — the quickening of a tornado. By the time the spinning mass was 10 minutes away, Sandmael and her colleagues had packed up their radar equipment and evacuated their post.

"Just keep going," she advised her colleague behind the wheel, who was rightly focused on maneuvering their SUV down the remote Alabama road. Evacuating was a good decision: "We were sitting on the west side of the road, and the tornado touched down in our exact location."

This wasn't just another day of chasing tornadoes for Sandmael, of the Cooperative Institute for Severe and High-Impact Weather Research and Operations, or CIWRO, in Norman, Okla. On this day, she and her crew were after something unusual: a sneaky type of twister called a squall line tornado.

Most tornadoes form in isolated storms called supercells. These tornadoes are the most common, most destructive and most well-studied class of twisters. Squall line tornadoes, on the other hand, develop along the front of long rows of storms known as quasi-linear convective systems, or squall lines. They are generally less intense than supercell tornadoes, says atmospheric scientist Karen Kosiba of the University of Illinois Urbana-Champaign. But, she says, "that doesn't mean they're not dangerous."

Squall line tornadoes tend to surprise. They are ephemeral and often evade detection, forming and dying in the minutes-long interludes between the scans of most radar systems. They are also difficult to anticipate, manifesting suddenly along rows of storms that can reach hundreds of kilometers long. And compared with supercell tornadoes, squall line twisters occur more often in cool months, such as during spring and even winter, and in the dark hours of night, when tornadoes are less expected.

What's more, squall line tornadoes are disproportionately more common in the southeastern United States, a region that is particularly vulnerable to

Squall line tornadoes that hit Mississippi in March 2022 uprooted and destroyed a structure anchored to the ground (top) and a large swath of trees (bottom). Such twisters are disproportionately common in the southeastern United States and during the cool season.

twisters. Over the last 70 years, the country's center of tornadic activity — supercell and squall line alike — has shifted from the Great Plains to the Southeast. And that's a concern because the region not only has a denser population than the Great Plains, but it also contains a higher concentration of easily uprooted mobile and manufactured homes.

In the country's new tornado heartland, a squall line twister need not be of great intensity to pose a grave risk. Recognizing the need to reduce that risk, Sandmael, Kosiba and dozens of other researchers joined forces for the Propagation, Evolution and Rotation in Linear Storms — or PERiLS — field campaign. During the late winter and spring seasons of 2022 and 2023, teams deployed across the Southeast captured an unprecedented trove of data.

Their work has already revealed that squall line tornadoes may be more common and more dangerous than previously thought. Fortunately, researchers may have also discovered clues that could help make these twisters a little less surprising.

A tornado recipe with a twist

Whipping up a tornado requires certain atmospheric ingredients: a source of rotation, a lifting mechanism to trigger the rising of air and something to keep the rising going.

Begin with, say, an advancing cold front pushing from underneath to lift the air ahead. This triggers an updraft. To persist, that updraft will need the air near the ground to possess some buoyancy, what meteorologists call instability. And the secret sauce that gets things spinning? That's vertical wind shear, a change in the speed of winds with increasing height. Think of an upright paddle wheel; if higher winds move faster and push harder on the top paddles, the wheel rotates.

Recent observations suggest that these ingredients can mix in different ways to create tornadoes in squall lines, says Anthony Lyza, an atmospheric scientist with the National Oceanic and Atmospheric Administration who works at CIWRO. Take instability, often measured as convective available potential energy, or CAPE. CAPE is sometimes described as the amount of fuel available to a growing storm.

CAPE values of 1,000 joules per kilogram are usually high enough to power strong storms. But "a lot of these [squall lines] are actually occurring in a low-CAPE, high-shear environment," says atmospheric scientist Alexandra Anderson-Frey of the University of Washington in Seattle.

For instance, in March 2022, PERiLS researchers measured CAPE of only about 500 joules per kilogram in a squall line over Mississippi and Alabama that produced dozens of tornadoes. Lyza says he's seen squall line tornadoes supported by CAPE values as low as 100 joules per kilogram. These low-CAPE settings exemplify environments that have been understudied, Anderson-Frey says.

At the same time, new technology has been uncovering more squall line tornadoes. Unlike older Doppler radar technology, which scans only in the horizontal dimension, newer dual-polarization radar scans both the vertical and horizontal dimensions. Over the last decade, the proliferation of the newer tech has increased detections of squall line twisters.

All this to say, squall line tornadoes appear to be more common than researchers previously thought. Perhaps, then, it is a little less surprising that they may be more dangerous than previously believed, too.

Tornadoes inside tornadoes

On a calm afternoon in March 2022, Lyza and colleagues showed up at a rural farmstead in Noxubee County, Miss. A squall line tornado had torn through

PREVIOUS SPREAD: JAMES LADUE; THIS PAGE, FROM TOP: F. LOMBARDO; GUANGZHAO CHEN

the area the day before, and Lyza had arrived to help assess the damage for PERiLS.

Something about the scene struck him as odd. The operational radar hadn't indicated that the tornado had been particularly intense. But Lyza observed significant damage to a house on the property.

"A good chunk of the roof decking was blown off, and an entire eastern exterior wall was blown out of the house," Lyza says. Nearby rested the remains of a machine shed that had been uprooted and ripped apart. The shed had been anchored to the ground by 1.5-meter-long concrete pillars, Lyza recalls.

"We were pretty shocked," he says. "We didn't necessarily go to Noxubee County thinking we were going to find strong tornado damage there."

The extensive damage wasn't the only surprise: "We noticed that the tornado came into the property from the southwest," Lyza says. But a trail of damaged trees seemed to suggest that the twister then veered due east for a couple hundred yards before swerving back toward the northeast.

It's not unusual for a tornado to change directions, but at high speeds, their turns become wide, just like cars on a highway. This tornado had been advancing at about 100 kilometers per hour, and yet its track appeared to bend sharply.

Fortunately, a mobile radar vehicle had been deployed just four kilometers to the south. Its beams had captured the twister's odd dance, along with evidence that its strange path had been shaped by multiple vortices: tornadoes in a tornado. "It's a first that I know of—that anyone around here knows of—in terms of a [squall line] tornado," Lyza says.

Subvortices appeared and disappeared so quickly, their evolution was difficult to follow via the intermittent radar scans. But "within a single scan, I think the most I was able to confidently identify was four at one time," Lyza says. "These individual vortices were actually responsible for most of the damage," he says, "and the main tornado itself was rather weak."

Researchers have observed that squall line tornadoes tend to be wider than supercell tornadoes; perhaps that's because many house subvortices, Lyza speculates. Squall line tornadoes also tend to be less effective than supercell twisters at lofting debris into the sky. That could be because subvortices are so short-lived that "they won't necessarily have the opportunity to lift debris as high up," Lyza says.

Subvortices "probably increase the maximum intensity of the tornado," says wind engineer Frank Lombardo of the University of Illinois Urbana-Champaign, who assessed the damage at the site with Lyza. The wind speed in a subvortex may compound with the wind speed of the parent tornado.

It's hard to say whether subvortices are common in squall line tornadoes based on a single case. But if they are, "we might have to revisit our tornado risk calculations," Lombardo adds. "We may have totally underestimated their intensity."

Improving twister forecasts

The discovery that squall line tornadoes may be more common and fiercer than previously thought makes predicting them even more urgent. Thankfully, PERiLS atmospheric scientist Todd Murphy of the University of Louisiana Monroe and his colleagues may have found some much-needed clues.

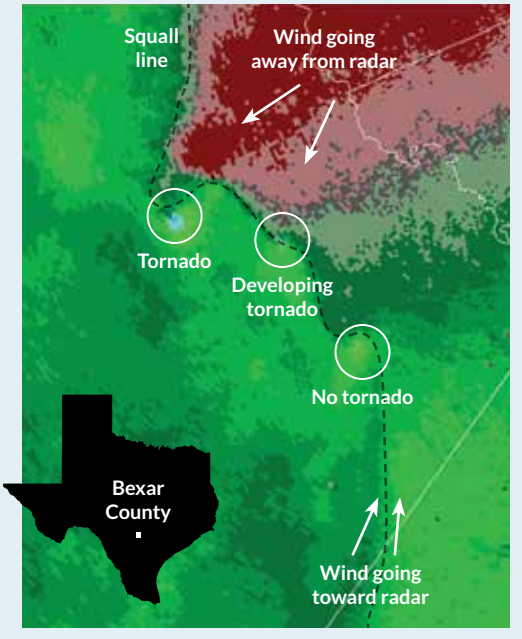
Researchers believe that peculiar wind patterns within squall lines might help them predict twisters. They're especially interested in gyres of wind called mesovortices, which can range in diameter from less than a kilometer to dozens of kilometers. Mesovortices often develop in places where advancing squall lines develop bulges in the shape of an archer's bow. For decades, scientists have observed that tornadoes often formed within these bows.

We can predict squall lines well—generally with more accuracy than we can predict other types of thunderstorms, says atmospheric scientist Patrick Skinner of CIWRO. But forecasting the embedded mesovortices is very difficult, he says. What's more, only some mesovortices form tornadoes, and researchers don't know why that's the case.

During the PERiLS field campaign, Murphy and his team used light detection and ranging, or lidar, instruments to monitor the atmosphere in the hours

Tornado watch

ID'ing mesovortices in a squall line can help experts forecast squall line tornadoes. This radar image shows the front of a squall line (near the dotted line) that passed over Texas in February 2017. Green hues indicate winds heading toward the radar; reds signify winds moving away. Where winds blowing in opposite directions are juxtaposed, mesovortices (circled) can be inferred. Mesovortices can also be inferred where strong and weak winds heading in the same direction (dark and bright shades) are juxtaposed.



NOAA NSSL

Some squall lines bow out as they advance, as seen in this 2016 storm over South Dakota. The radar signature of these bows is called a bow echo, and they are often associated with squall line tornadoes.

MIKE HOLLINGSHEAD/GETTY IMAGES

before a squall line's arrival. These instruments scan the skies with pencil-thin laser beams, which reflect off aerosols that act as tracers for the wind.

"In the vast majority of our cases, the lidar data showed pretty abrupt changes in the wind profile beginning about 90 minutes before the squall line" got to the site, Murphy says. At different levels of the lower atmosphere, the vertical wind shear grew larger, inducing more rotation within the squall line.

It wasn't just the wind shear that changed dramatically; all of the PERiLS key ingredients for tornado formation "can change really rapidly within an hour or two ahead of the arrival of a squall line," Lyza says.

Using data collected during PERiLS, along with about 10 years' worth of radar data gathered jointly by the National Weather Service, the Federal Aviation Administration and the U.S. Air Force, Murphy and colleagues analyzed wind velocities at different levels of the atmosphere ahead of mesovortices that formed tornadoes and those that did not.

Ahead of tornadic mesovortices, there appeared to be slightly more wind shear, Murphy says. More importantly, there was more rotation, and this signature was more pronounced ahead of squall lines that generated at least five twisters.

Along the length of a squall line, mesovertices swirl within updrafts that continually form and dissipate. Ahead of the tornadic mesovortices, these updrafts may align with air circulating near the ground. When this occurs, the updraft may pull the circulation upward, narrowing its diameter like dough stretched thin, causing it to spin faster.

"We call it the ice skater effect," Murphy says, referencing the famous example of a skater spinning faster when both arms are pulled close to the body. "If you stretch that rotation," he says, "it causes the radius to get smaller, but the rotation strengthens."

If meteorologists are monitoring conditions 60 to 90 minutes ahead of a squall line and the wind profile starts to develop this pronounced signature of wind shear and rotation, then they may need to consider issuing warnings, Murphy says.

He hopes that vetting by other researchers will prove the signal's worth as an reliable risk indicator. If all goes well, that could happen sometime in the next couple years, he says. Meanwhile, other projects that could improve forecasts are also in the works. Skinner works on NOAA's Warn-on-Forecast, a project to increase the lead time of forecasts for tornadoes and other severe weather. He'll be using the PERiLS data to determine how much resolution current weather simulations need to accurately portray mesovortices in squall lines.

It's going to take vast improvements in our weather simulations to be able to predict squall line tornadoes as well as we can predict supercell tornadoes, Murphy says. But eventually, he says, "I think we'll get there." ■

"These individual vortices were actually responsible for most of the damage, and the main tornado itself was rather weak."

ANTHONY LYZA

Explore more

- Karen A. Kosiba *et al.* "The Propagation, Evolution and Rotation in Linea Storms (PERiLS) Project." *Bulletin of the American Meteorological Society*. June 12, 2024.

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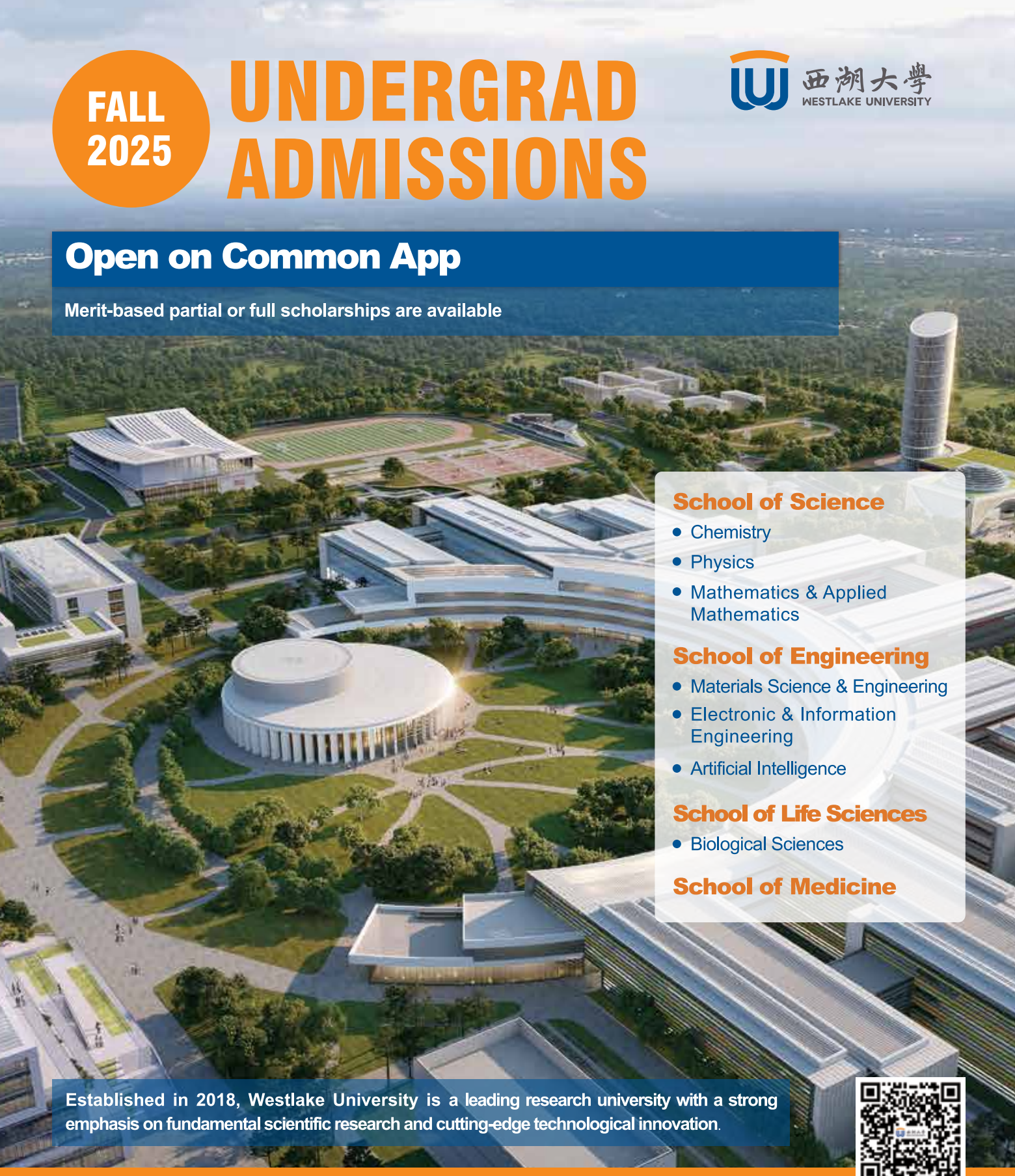

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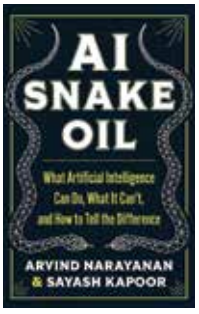


AI Snake Oil
Arvind Narayanan and Sayash Kapoor
PRINCETON UNIV., $24.95

BOOKSHELF

A new book tackles AI hype

A few months ago, I was working on an article about oceans across the solar system. Having read my fill about oceans of water, I turned to Google for a quick refresher on oceans made of other stuff, liquid hydrocarbons, for example. For better or worse, I searched "oceans in the solar system not water." I sought a reliable link, maybe from NASA. Instead, Google's AI Overviews feature served up Enceladus as one suggestion. This Saturn moon is famous for its subsurface sea — of saltwater. I shut my laptop in frustration.

That's one small example of how AI fails. Arvind Narayanan and Sayash Kapoor collect dozens of others in their new book, *AI Snake Oil* — many with consequences far more concerning than irking one science journalist. They write about AI tools that purport to predict academic success, the likelihood someone will commit a crime, disease risk, civil wars and welfare fraud. Along the way, the authors weave in many other issues with AI, covering misinformation, a lack of consent for images and other training data, false copyright claims, deepfakes, privacy and the reinforcement of social inequities (SN: 11/23/19, p. 6). They address whether we should be afraid of AI, concluding: "We should be far more concerned about what people will do with AI than with what AI will do on its own."

The authors acknowledge that the technology is advancing quickly. Some of the details may be out of date — or at least old news — by the time the book makes it into your hands. And clear discussions about AI must contend with a lack of consensus over how to define key terms, including the meaning of AI itself. Still, Narayanan and Kapoor squarely achieve their stated goal: to empower people to distinguish AI that works well from AI snake oil, which they define as "AI that does not and cannot work as advertised."

Narayanan is a computer scientist at Princeton University, and Kapoor is a Ph.D. student there. The idea for the book was conceived when slides for a talk Narayanan gave in 2019 titled "How to recognize AI snake oil" went viral. He teamed up with Kapoor, who was taking a course that Narayanan was teaching with another professor on the limits of prediction in social settings.

The authors take direct aim at AI that can allegedly predict future events. "It is in this arena that most AI snake oil is concentrated," they write. "Predictive AI not only does not work today, but will likely never work, because of the inherent difficulties in predicting human behavior." They also devote a long chapter to the reasons AI cannot solve social media's content moderation woes. (Kapoor had worked at Facebook helping to create AI for content moderation.) One challenge is that AI struggles with context and nuance. Social media also tends to encourage hateful and dangerous content.

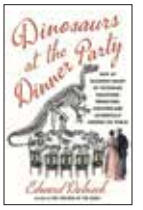
The authors are a bit more generous with generative AI, recognizing its value if used smartly. But in a section titled "Automating bullshit," the authors note: "ChatGPT is shockingly good at sounding convincing on any conceivable topic. But there is no source of truth during training." It's not just that the training data can contain falsehoods — the data are mostly internet text after all — but also that the program is optimized to sound natural, not necessarily to possess or verify knowledge. (That explains Enceladus.)

I'd add that an overreliance on generative AI can discourage critical thinking, the human quality at the very heart of this book.

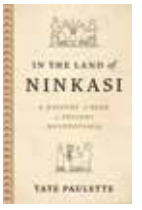
When it comes to why these problems exist and how to change them, Narayanan and Kapoor bring a clear point of view: Society has been too deferential to the tech industry. Better regulation is essential. "We are not okay with leaving the future of AI up to the people currently in charge," they write.

This book is a worthwhile read whether you make policy decisions, use AI in the workplace or just spend time searching online. It's a powerful reminder of how AI has already infiltrated our lives — and a convincing plea to take care in how we interact with it. — *Elizabeth Quill*

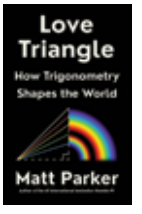
BOOKSHELF



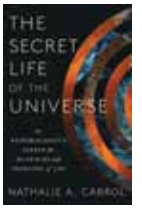
Dinosaurs at the Dinner Party
Edward Dolnick
This book introduces the eccentric characters of the Victorian era whose early discoveries of dinosaur fossils drastically transformed our understanding of the natural world. *Scribner, $30*



In the Land of Ninkasi
Tate Paulette
An archaeologist takes a trip back to the cradle of civilization to recount the beer-drinking habits of people living in ancient Mesopotamia. *Oxford Univ., $27.99*



Love Triangle
Matt Parker
A stand-up comedian and math writer showcases all the ways triangles come into play in our everyday lives, weaving in the stories of history's most daring mathematicians and thinkers along the way. *Riverhead Books, $30*



The Secret Life of the Universe
Nathalie A. Cabrol
An astrobiologist guides readers on a journey through the cosmos to investigate the likeliest places where life could be hiding. *Scribner, $30*

JULY 13, 2024 & JULY 27, 2024

Time to eat

*Astronomers watched in real time as the supermassive black hole at the center of a galaxy went from dim and quiet to bright and actively feeding on material, **Adam Mann** reported in "For the first time, scientists witness a black hole turning on" (SN: 7/13/24 & 7/27/24, p. 7).*

Reader **Chris Sheppard** wondered how a black hole can consume material, when time seems to stop at the outer edge—the event horizon.

"The seeming paradox arises because of the extreme time dilation near the event horizon," says theoretical physicist **Eduardo Martín-Martínez** of the University of Waterloo in Canada. From the perspective of a distant observer, time seems to progress more slowly near the black hole's edge. So infalling matter appears frozen in time, never crossing the event horizon, **Martín-Martínez** says. Light emitted by that matter becomes increasingly stretched to longer wavelengths, or redshifted, and eventually becomes invisible.

"However, from the point of view of the infalling material itself, time is experienced normally," **Martín-Martínez** says. The matter crosses the event horizon after a finite amount of time and moves toward the black hole's center, called the singularity. "If the distant observer were to approach the horizon themselves, once they are close enough, they would see matter cross the horizon at a finite time, and they themselves would cross the horizon at a finite proper time," **Martín-Martínez** says.

Getting up to speed

*If elite athletes are to ever reach humans' projected maximum speed in running or swimming, they will need perfect technique, **Erin Garcia de Jesús** reported in "What's the human speed limit?" (SN: 7/13/24 & 7/27/24, p. 36).*

In the 2000s, a now-banned swimsuit line from Speedo ushered a wave of new records in the 50-meter freestyle, **Garcia de Jesús** reported. The suits compressed swimmers' bodies and made them more buoyant.

Given that compression tends to increase density, which decreases buoyancy, reader **David H. Brands** asked how the suits could have had such an effect.

These were two parallel effects, not one leading to the other, says associate news editor **Christopher Crockett**. The compression made the swimmers' bodies more streamlined and thus reduced drag. At the same time, the suits also trapped air around swimmers' bodies, increasing buoyancy, **Crockett** says.

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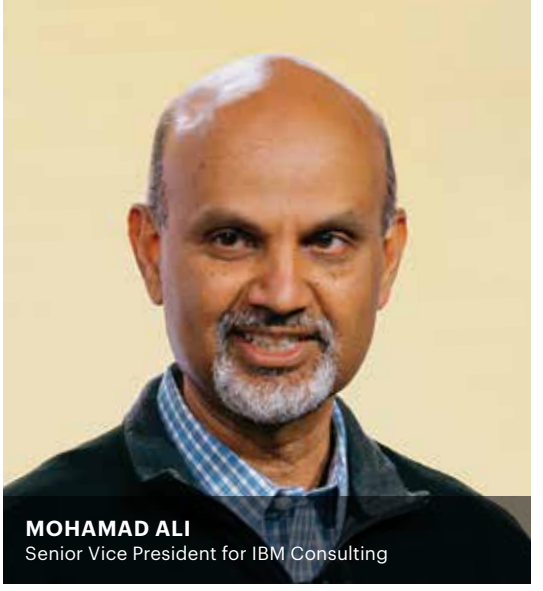


MOHAMAD ALI
Senior Vice President for IBM Consulting

Maya Ajmera, President & CEO of the Society for Science and Executive Publisher of Science News, chatted with Mohamad Ali, Senior Vice President for IBM Consulting, IBM's global professional consulting services unit. The global organization spans 150 countries and solves complex problems using technology-based assets and AI. Ali is a 1988 alumnus of the Science Talent Search (STS), a program of Society for Science.

How did participating in STS impact your life? Do you have any favorite memories from that competition?

I have several memories that I fondly remember. When I visited Washington, D.C., to compete in STS, I visited the U.S. Capitol, a place I had never visited before. It was such an amazing experience. I also met Nobel Prize winners during the competition. I'm a kid from Queens. I'm not supposed to meet Nobel Prize winners. The whole experience was just incredibly inspirational.

Beyond the event itself, the two years that led up to it were impactful, from researching my project to learning how to write a high-caliber paper that other scientists could read. I would say that, in some ways, STS set my life on its trajectory.

What led you to pursue science?

I'm from Guyana, a small country near Venezuela that very few people have ever heard of. I came to the United States when I was 11, and we didn't have much. Everything was new; everything was different. In some ways, the fact that I came from such a humble background and was able to compete in STS is one of the wonderful things about STS. It finds students wherever they are.

We moved to Queens when we came to the United States, and I went to junior high school and high school. I struggled with my language-based classes, but numbers were the same in any language. So, math and physics became my friends. One of my teachers in junior high school suggested that I apply to Stuyvesant High School, one of New York City's specialized high schools. While at Stuyvesant, a woodshop teacher encouraged me to get involved in scientific research. I started doing solar-focused projects and eventually, he recommended that I do a project that the STS program could be interested in.

I decided to do a fusion project, but I wasn't clear on how one could do a fusion project while in high school. My teacher recommended that I call some people at Columbia University to see if anyone was working on the subject, and I ended up connecting with Michael E. Mauel, who still teaches at Columbia today. He said I could work with him, and we started building a machine to simulate how particles would behave in a magnetic field. Then we ran experiments that were the basis for a paper.

In some ways, it was a series of accidents, from meeting that teacher in junior high school to meeting my woodshop teacher to having the good luck of Mauel inviting me to his lab. All of those accidental meetings, combined with the fact that people were willing to help me, had a huge impact on my life's path.

Over the course of your career, you've worked on the leading edge of both technology and industry. Can you tell us a little bit about your professional journey?

After STS, I went on to Stanford University, and then I worked for a neural network start-up. Then, I joined IBM for 14 years. I worked elsewhere in the industry, including HP, Carbonite and IDG, for the next 14 years, and now I'm back at IBM where I'm working on neural networks and AI. The company's interest in generative AI technology and new quantum computing

technologies is such an exciting opportunity. Personally, I think IBM is leading the world in quantum computing. I'm very excited to see what kinds of problems quantum computing can solve for humanity.

What excites you most about the changing AI landscape?

I am most excited about the problems that these new technologies are going to be able to solve. Of course, that's both a good thing and a bad thing. Tremendous technologies in the wrong hands or not managed responsibly could be used for purposes that are not for the betterment of society.

That is part of why I came back to IBM. The technologies that are coming to the world now are extraordinarily powerful, and I want to work on them for a company that I believe prioritizes ethics. Leveraging these extraordinarily powerful AI and quantum technologies in a responsible way, where we know how the AI models are trained, we know where the data comes from and we know what kind of biases are present, we can put bounds on the decisions that can be made. We need these kinds of powerful technologies to solve problems like climate change.

You've been an outspoken advocate for increasing diversity in tech. Why do you think this is important?

In some ways it's personal. I came from an underserved community, and because of the teachers that I encountered and because of institutions like Stuyvesant and STS, I got an "at bat." I got an opportunity to contribute. The world would be a much better place if everyone was able to bring their best and contribute. There is a very good chance that the cure for cancer lies in the brain of a child in one of our poorest communities. We need to give that kid a chance to bring that cure to society. After having lived it, I see the value of giving opportunities to everyone who is willing to take them.

Mohamad Ali was among the 40 finalists of the 1988 Science Talent Search. The finalists pictured here are on the steps of the U.S. Capitol.

What advice do you have for young people just starting out in higher education or their careers?

I can only speak from my own experience and what worked for me, but I would say this: Study hard and enjoy it. You don't know what you don't know. That's a complicated sentence, but for me I always thought I knew everything. But I didn't. Learning helps you discover those things. Some of the things that you are going to discover will change your life dramatically—hopefully for the better. Learn as much as you can and keep learning all your life.

Who inspired you as a young person, and who inspires you today?

I was inspired by the great scientists: Einstein, Ada Lovelace and Marie Curie. They all wanted to solve problems and make the world a better place. Today it's very similar. I am inspired by all the people who are working to solve hard problems with science and then bring those solutions to society in a responsible way.

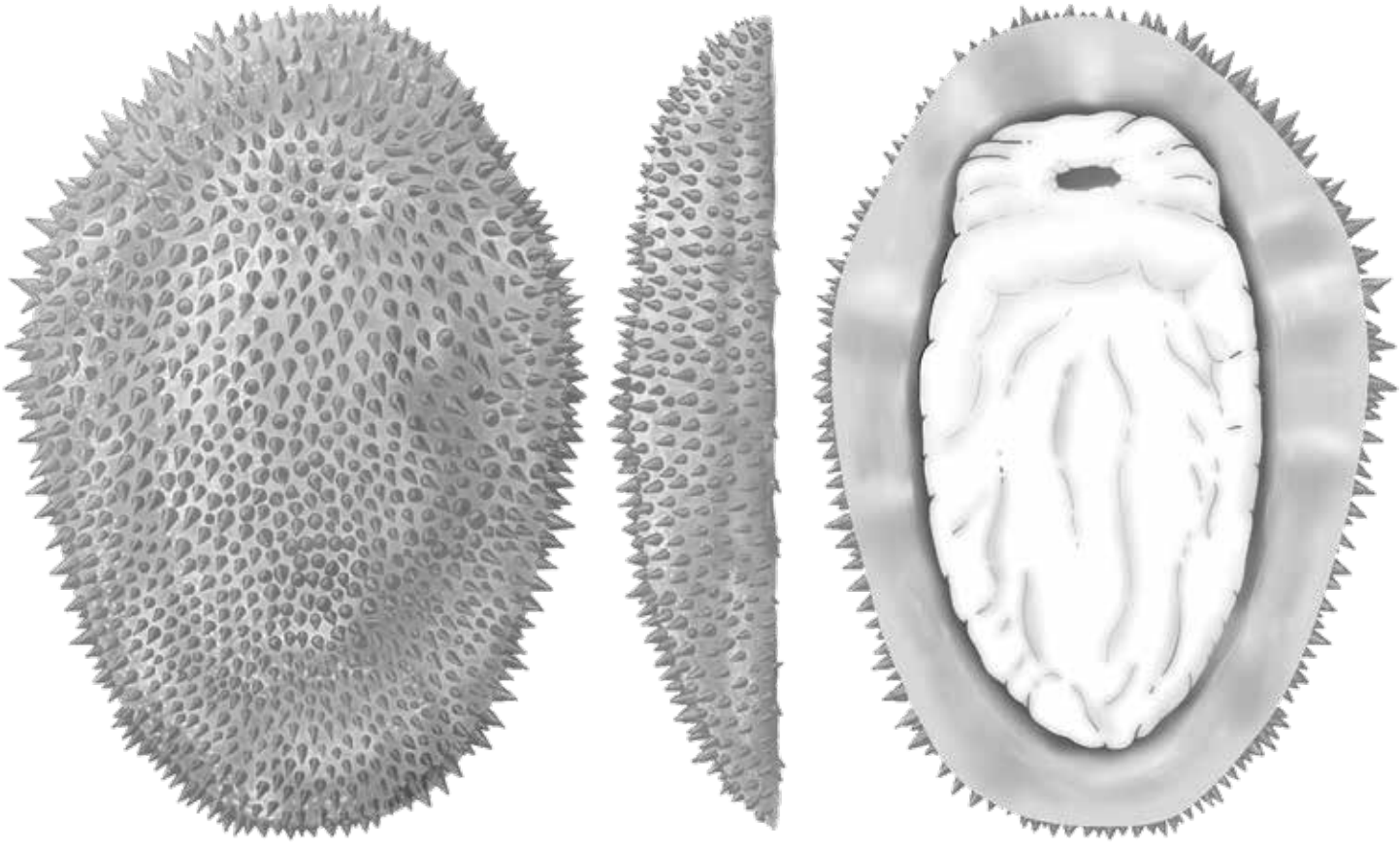
IBM has committed to training 2 million people, primarily from underserved communities, in AI over the next three years. You can be concerned about AI, or you can embrace it, put it in your tool set and become even more valuable than you are today. Many companies like ours that are leading scientific innovation are embracing AI in a way that helps society, which I think is inspirational.

There are many challenges facing the world today. What keeps you up at night, and what gives you hope for the future?

There are a lot of challenges: global geopolitical instability and war, for example. We have more war now than we've had in a while. And people are migrating because of war and because of climate change.

Once again, my response is informed by my own background of growing up in a poor community. Now that I can afford to give back, I contribute to organizations like Oxfam, where I served on the board of directors for 10 years. Those kinds of organizations give me hope, knowing that there are people out there working hard to make our world a better place.

Sometimes it's a little scary that humanity waits until it reaches a precipice before it starts acting. But time and time again, we have acted as a human race. I tend to be just an inherently hopeful person, and given the capabilities that I see in the world brought by science and technology, I am hopeful.



What did early mollusks look like?

An ancient animal that could be mistaken for a spiky fruit is giving scientists a peek at what mollusks looked like half a billion years ago.

Fossils of an invertebrate dubbed *Shishania aculeata* (illustrated from three angles, above) show that it had a sluglike body covered in a prickly armor. The find, reported in the Aug. 2 *Science*, bolsters previous evidence that early mollusks lacked shells and were covered in spikes made of chitin, a fibrous material found in the shells of present-day mollusks and crabs.

Today's mollusks are an incredibly diverse group of animals, says paleobiologist Xiaoya Ma of Yunnan University in China. With species as different as clams and octopuses, it's tough to find common traits that indicate what the group's earliest ancestors looked like.

But "fossils can often provide unique and direct evidence" for how early mollusks appeared, Ma says.

The *S. aculeata* fossils, which were uncovered in China, date to around 510 million years ago, following a burst of evolution among mollusk ancestors during the early Cambrian Period.

Ma and colleagues examined 18 specimens (one shown at right), ranging in size from about 1 to 6 centimeters long. Not all specimens were beautiful, Ma says. Soft tissues such as those in *S. aculeata*'s body don't fossilize well. "But they [were] preserved or compressed from different angles ... [which] helps us put a jigsaw [puzzle] together to reconstruct the animal."

S. aculeata's base was flat, with a singular foot. This characteristic, one of several that helped ID the organism as a mollusk, let the animals scooch across the ground or dig into soft sediments. What's more, the exterior chitin cones that make the critter resemble a durian fruit are filled with narrow canals that are "spectacular and extremely rare," Ma says.

These canals are similar to those found in the exoskeletons of extinct and living worms and brachiopods, suggesting a common origin. —*Erin Garcia de Jesús*

FROM TOP: M. CAWTHORNE; G. ZHANG, L. PARRY

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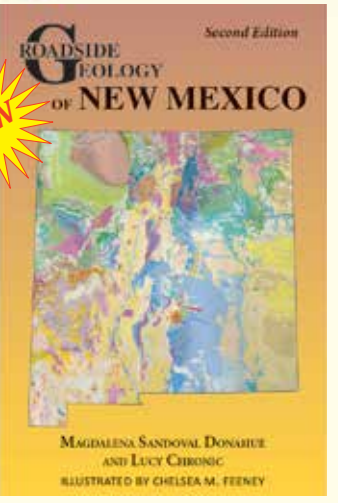

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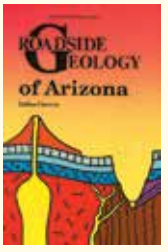

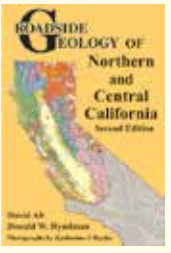

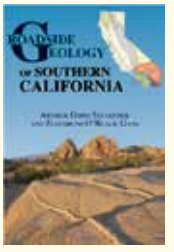

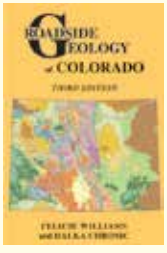

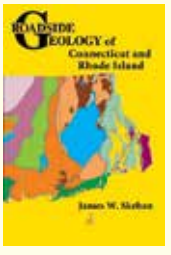

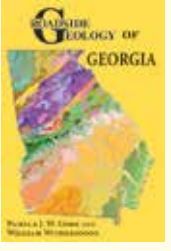

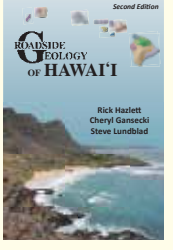

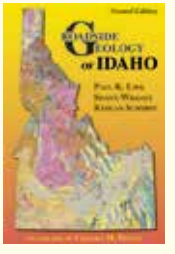

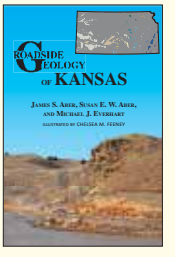

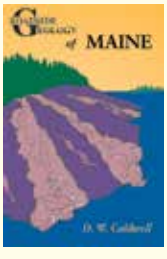

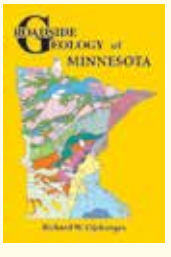

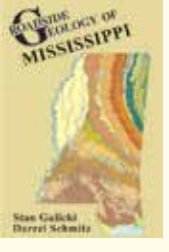

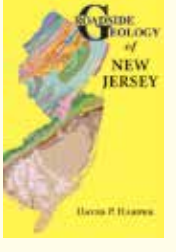

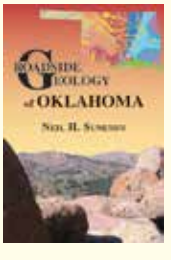

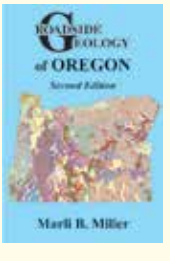

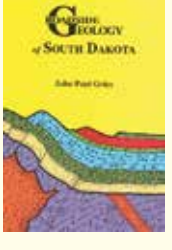

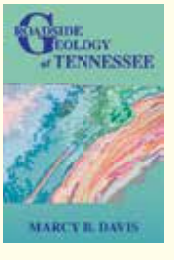

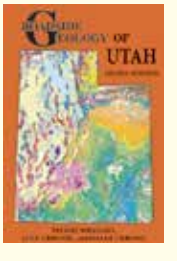

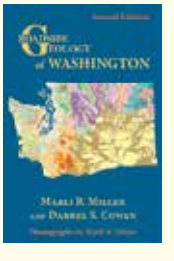

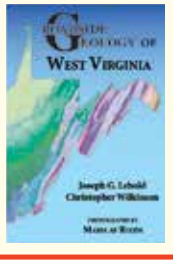

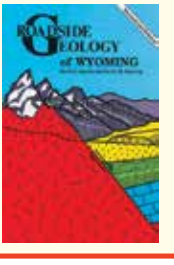

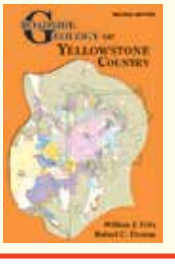

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