Keeping an Eye on Bird Flu | Black Hole on the Run

ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ APRIL 8, 2023

Rising waters

How an Indigenous community in Panama is escaping the encroaching sea

At Michigan Tech, researchers turn plastic into protein powder.

Of all the world's problems, faculty researcher Stephen Techtmann has two on his mind: plastic pollution and world hunger. Can one problem help solve the other? In his award-winning microbiology lab at Michigan Tech, Techtmann and his team of student researchers feed the plastics to oil-eating bacteria that chew them up and use them as fuel to grow. The end result doesn't look like plastic at all—it resembles a yeast byproduct that comes from brewing beer. This majority-protein byproduct is then dried out and turned into an edible powder. While the initial goal is to use the protein powder for disaster relief efforts, Techtmann hopes that plastic-turned-protein-powder could become the sustainable meat substitute of tomorrow.

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ScienceNews

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News

Departments

COVER Many of the homes on the island of Gardi Sugdub, in Panama's Guna Yala province, sit right at the edge of the sea. *Michael Adams*

FROM TOP: GLENN HARVEY; WEBB/ESA, NASA, CSA, J. LEE AND THE PHANGS-JWST TEAM; J. SCHMIDT; LYDIA V. LUNCZ

Did artificial intelligence write this editor's note?

As someone who's been involved in journalism since middle school, I'd like to think that the research, analysis and language skills needed to craft a news article are unique to humans. ChatGPT, a new artificial intelligence tool, is challenging my assumptions.

Since the company OpenAI debuted ChatGPT late last year, people around the world have been testing its eerie ability to create text that reads like it was human-made, unlike the stilted customer-service chatbots that work off a limited script. OpenAI is already upgrading ChatGPT, and other tech companies have been racing to release their own chatbots with similar capabilities. This cavalcade of chatbots is poised to transform any endeavor that requires producing original text.

In this issue, we report on how ChatGPT is already impacting education and explore whether the potential benefits—as a writing coach or helping a student working in a second language—outweigh the risk of sitting back and letting the bot do the work. As freelance contributor Kathryn Hulick reports, teachers say the chatbot's writing is often good enough that it's hard to tell it's not coming from a student (Page 24). And since the chatbot churns out original text, it's not technically plagiarism.

We decided to test ChatGPT's skills by pitting it against real live students from across the United States. We reached out to teachers in our Science News Learning program, which delivers the magazine to more than 5,600 middle and high schools, to ask students to respond to questions such as "What effect do greenhouse gases have on the Earth?" We asked ChatGPT to respond to the same questions. More than 100 students provided answers. When I tried to guess which answers were written by the bot, I got only 20 percent right; worse than random luck.

"It was really hard to distinguish the ChatGPT responses from student responses," Anna Pawlow, director of Science News Learning and a former high school chemistry teacher, told me. With ChatGPT or similar AI tools, she worries that it will become harder for teachers to assess student learning and progress through their writing, making it even more crucial that educators have time and resources to support individual students in the classroom.

Of course, the bots are coming for journalism too. CNET, a website that covers technology, confessed in January to using AI to produce articles that were riddled with factual errors, including one that said a savings account with $10,000 paying 3 percent interest would accrue $10,300 in interest in the first year. ChatGPT and other chatbots don't do research or fact-check the accuracy of their work, as we do at *Science News*. And they don't think about what our readers want and need to know. In fact, they don't think at all.

Still, there's no question that the bots are here to stay (even though I did indeed write this column myself.) The big question is how humans will rely on their powers—and whether we'll be honest about it.

—*Nancy Shute, Editor in Chief*

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SOCIETY FOR SCIENCE

How To Rock a Walking Stick

An essential part of a gentleman's wardrobe

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In the 17th century, the walking stick overtook the sword as an essential part of a gentleman's wardrobe. Though it was primarily used as a decorative accessory, it could also function as a weapon if necessary. For men of the era, these walking sticks were a statement piece, and a way to communicate their wealth and refinement.

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Excerpt from the April 7, 1973 issue of *Science News*

50 YEARS AGO

Twice 'round the world by balloon

Scientists recovered for the first time…a balloon scientific payload after a long-duration, twice-around-the-world flight. The project is called Boomerang and is designed to demonstrate the feasibility of using balloons for long-duration research.

UPDATE: Balloons fill an important niche in science, bearing instruments to study physics, atmospheric chemistry and astronomy, or to test technologies for space missions. For instance, data collected by balloons have helped reveal that the universe is geometrically flat and how wildfire smoke impacts the ozone layer (*SN: 9/14/19, p. 12*). Earlier this year, the United States shot down several objects high above the country, one of which is alleged to be a surveillance balloon from China. Others are likely "tied to private companies, recreation or research institutions studying weather or conducting other scientific research," President Joe Biden said February 16 in a news briefing. Some scientists worry rising concerns over spying could limit where high-altitude balloons go — a tall order for vessels that follow the wind.

Scientists gave the immune system of *Nicotiana benthamiana*, a tobacco relative, a boost by fusing one of its pathogen sensors with antibodies from llamas and alpacas.

SEAN GALLUP/GETTY IMAGES PLUS

INTRODUCING

Hybrid proteins defend plants using an animal tactic

A new biological mashup just dropped.

"Pikobodies," bioengineered immune system proteins that are part plant and part animal, could help flora better fend off diseases, researchers report in the March 3 *Science*. The protein hybrids exploit animals' uniquely flexible immune systems, giving plants the ability to fight off emerging pathogens.

Plants typically rely on physical barriers to keep disease-causing microbes at bay. If something unusual makes it inside the plant, internal sensors sound the alarm and infected cells die. However, as pathogens evolve ways to dodge these defenses, plants can't adapt in real time. But animals can, their adaptive immune systems making antibodies and adjusting those defenses as needed to keep up with evolving pathogens.

In a proof-of-concept study, scientists genetically modified one plant's internal sensors to sport antibodies. Theoretically, it's possible to make pikobodies "against virtually any pathogen we study," says plant pathologist Sophien Kamoun of the Sainsbury Laboratory in Norwich, England.

Eventually, cocktails of these proteins could give plants a way to target pathogens from multiple angles, Kamoun says.

Crops especially could benefit from having more adaptable immune systems, since many farms grow fields full of just one type of plant, says plant immunologist Xinnian Dong, a Howard Hughes Medical Institute investigator at Duke University who was not involved in the work. In nature, diversity can help protect vulnerable plants, perhaps by making it harder for pathogens and pests to find their hosts. A farm is more like a buffet for the marauders.

Researchers have had success fine-tuning plant genes to be disease-resistant, but finding the right genes and editing them can take more than a decade, Kamoun says. He and colleagues wanted to know if plant protection could get an additional boost from animal-inspired solutions.

To create the pikobodies, the team fused small antibodies from llamas and alpacas with a protein called Pik-1 that's found on the cells of *Nicotiana benthamiana*, a close relative of tobacco plants. Pik-1 typically helps detect a protein that allows a deadly blast fungus to infect plants. For this test, the antibodies had been engineered to target fluorescent proteins.

Plants with the pikobodies killed cells exposed to the fluorescent proteins, resulting in dead patches on leaves. Of 11 tested versions, four of the pikobodies were not toxic to the leaves and triggered cell death only when attached to the specific protein that they had been designed to bind.

What's more, pikobodies can be combined to give plants more than one way to attack a foreign invader. But not all pikobody combos worked together in tests. "It's a bit hit or miss," Kamoun says. "We need some more basic knowledge to improve the bioengineering."

— Erin Garcia de Jesús

THE –EST

Baby shrimp crowned quickest draw

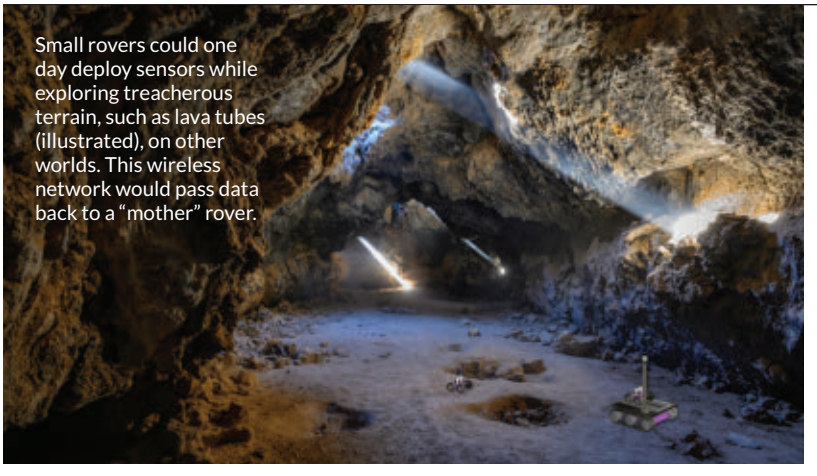
Full-grown snapping shrimp were already known to have some of the fastest claws under the waves. But it turns out they're nothing compared with their kids.

Juvenile snapping shrimp produce the highest known underwater accelerations of any nondetachable body part, researchers report February 28 in the *Journal of Experimental Biology*. While the claws' top speed isn't terribly impressive, they accelerate from zero to full throttle in record time.

Snapping shrimp deter predators by snapping their powerful claws, creating bubbles that release shock waves when popped (SN: 10/6/01, p. 213). To figure out at what age the shrimp start using this weaponry, biologist Jacob Harrison of Georgia Tech in Atlanta and biomechanist Sheila Patek of Duke University reared bigclaw snapping shrimp (*Alpheus heterochaelis*) in the lab. At about 1 month old, the shrimp—less than a centimeter long—began firing their claws when disturbed. The pair captured high-speed footage of the snaps.

When juvenile bigclaw snapping shrimp like this one reach about a month old, they start striking their powerful claws.

The wee shrimp, no more than a tenth as big as an adult, created bubbles just like grown-ups do. But juvenile claws accelerated 20 times as fast, about 600 kilometers per second per second. That is on the same order of magnitude as a bullet leaving a gun, Harrison says. The smallest shrimp didn't always fire successfully, but they still routinely tried snapping. Harrison and Patek speculate the shrimp could be training musculature crucial to claw function. —*Jake Buehler*



Small rovers could one day deploy sensors while exploring treacherous terrain, such as lava tubes (illustrated), on other worlds. This wireless network would pass data back to a "mother" rover.

FUTUROLOGY

How Hansel and Gretel could help space rovers

In the classic fairy tale, Hansel and Gretel dropped bread crumbs while walking through a treacherous forest so they wouldn't lose their way. Rovers may one day use a similar trick to traverse other planets without losing their data.

Typically, if a rover permanently loses communication during a mission, any information that it has not yet transmitted is lost. To avoid this, theoretical physicist Wolfgang Fink of the University of Arizona in Tucson and colleagues suggest using a multirover system in which a smaller rover piggybacks on a larger "mother rover." The smaller rover would venture into uncertain territory, such as a cave or lava tubes, deploying sensors the size of an AirPods case like bread crumbs as it goes. Sensors would then communicate with each other via a wireless network and funnel collected data back to the mother rover without the smaller rover having to backtrack, the scientists propose February 11 in *Advances in Space Research*. The technology could also be useful on Earth, Fink says, especially during search-and-rescue missions after an earthquake or other natural disaster (SN: 12/13/14, p. 16). —*Allison Gasparini*

SCIENCE STATS

Half of all active satellites are now from SpaceX

SpaceX's growing fleet of Starlink internet satellites now make up at least half of all active satellites in low Earth orbit. The aerospace company launched 21 new satellites on February 27, bringing the total number of active Starlink satellites to 3,660. That's about 50 percent of the nearly 7,300 active satellites in orbit at that time, according to an independent analysis of SpaceX and U.S. Space Force data by astronomer Jonathan McDowell of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass.

SpaceX isn't the only company launching internet satellites (SN: 3/28/20, p. 24). By the 2030s, there could be up to 100,000 such satellites crowding low Earth orbit, other scientists estimate March 2 in *Nature Astronomy*. So far, there are no international regulations to curb how many satellites private companies can launch. —*Lisa Grossman*

~50
percent
The proportion of active satellites in low Earth orbit that are Starlink

FROM TOP: J. HARRISON; JOHN FOWLER/WIKIMEDIA COMMONS, MARK TARBELL AND W. FINK/UNIV. OF ARIZONA

Watch a video of a juvenile shrimp fire its claw at **bit.ly/SN_FastestClaw**

A variant of the H5N1 flu virus is killing domestic and wild birds globally, including probably this pelican in Peru.

ERNESTO BENAVIDES/AFP VIA GETTY IMAGES

HEALTH & MEDICINE

Will bird flu spark the next pandemic?

Experts are monitoring infected animals and viral mutations

BY ERIN GARCIA DE JESÚS

An uncomfortable truth is that an influenza pandemic is in humankind's future. But whether it will be caused by a relative of the lethal avian flu strain currently wreaking havoc in bird populations around the world is anyone's guess.

That strain, which is a variant of the H5N1 virus, emerged in 2020 and has spread farther among birds than any other variant. Globally, hundreds of millions of domestic poultry have been culled or died from an infection. Millions of wild birds have also probably succumbed, though few governmental agencies are counting, says Michelle Wille, a viral ecologist at the University of Sydney. "This virus is catastrophic for bird populations."

It's also spilled over into other animals. The variant was linked to a seal die-off in Maine last summer and an outbreak on a mink farm in Spain in October. Sea lions off the coast of Peru have tested positive, as have bears, foxes and skunks, which eat birds, in the United States and Europe.

Humans aren't immune either. As of mid-March, seven cases had been reported in people, and one person had died, though there's no evidence that the virus is spreading among people.

It's impossible to predict which avian influenza viruses might jump to people and spark an outbreak. These pathogens don't typically easily infect or circulate among mammals. And scientists don't have a full grasp on how these viruses might need to change for human transmission to occur.

For now, it's encouraging that so few people have gotten infected amid such a large bird outbreak, says Marie Culhane, a food animal veterinarian at the University of Minnesota in St. Paul. Still, experts are watching for any signs that the virus may be evolving to spread more easily between people.

It's also good news that drugs and vaccines that work against the virus already exist, Wille says. Compared with where the world was when the coronavirus emerged, "we are already ahead of the game."

Some of what scientists know about H5N1's pandemic potential comes from research on ferrets done over a decade ago (SN: 7/4/12, p. 8). Experiments showed that some changes to proteins that help the virus break into cells and make more copies of itself could help the virus travel through the air to infect ferrets, a common lab stand-in for humans in flu research.

These mutations were important in a lab setting, but it's unclear how crucial they are in the real world, says Jonathan Runstadler, a disease ecologist at Tufts University's Cummings School of Veterinary Medicine in North Grafton, Mass.

Viruses change constantly, but not all genetic tweaks work together. A change may help one variant transmit better, while making another variant less likely to spread. "We're not sure how critical or how big a difference or how much to worry about those mutations when they happen in the wild," Runstadler says. "Or when they happen five years down the road when there are other changes in the virus's genetic background that are impacting those [original] mutations."

That doesn't stop researchers from trying to pinpoint specific changes. Runstadler's team looks for viruses in nature that have jumped into new animals and then works backward to figure out which mutations were crucial.

Virologist Louise Moncla says her lab at the University of Pennsylvania is trying to develop ways to scan entire genetic blueprints of viruses from past outbreaks to look for signatures of a virus that can jump between different animal species. "There's a ton that we don't know about avian influenza viruses and host switching," she says.

Genetic analyses of H5N1 circulating on the mink farm in Spain, for instance, revealed a change known to help the virus infect mice and mammalian cells grown in the lab. Such a change could make it easier for the virus to spread among mammals. Though it's unknown how the mink were exposed—an outbreak in wild seabirds did occur near the farm—there could have been mink-to-mink transmission, researchers concluded in January in *Eurosurveillance*. The role of that specific mutation in the outbreak is still unclear.

It's a numbers game for when influenza viruses with the ability to transmit among mammals might make the jump from birds, Runstadler says. "The more chances you give the virus to spill over and adapt, the higher the risk will be that one of those adaptations will be effective [at helping the virus spread among other animals] or take root and be a real problem."

Experts are keeping an eye on infected birds and the animals that eat them to raise the alarm early if it looks like H5N1 is starting to transmit among mammals.

"The mink outbreak, and then the sea lion outbreak, is a wake-up call," Moncla says. "We should be doing our very best to implement all the science we can to try and understand what's happening with these viruses so that if the situation does change, we are better prepared." ■

GENETICS

Genetics studies should ditch race

The labels don't explain human biological diversity, panel says

BY TINA HESMAN SAEY

Race should no longer be used to describe populations in most genetics studies, a panel of experts says.

Using race and ethnicity to describe study participants gives the mistaken impression that humans can be divided into distinct biological groups. Such labels have been used to stigmatize groups of people, but do not explain biological and genetic diversity, the panel, convened by the U.S. National Academies of Sciences, Engineering and Medicine, concluded in a report released March 14.

In particular, the term Caucasian should no longer be used, the panel recommends. The term, coined in the 18th century by German scientist Johann Friedrich Blumenbach to describe what he determined was the most beautiful skull in his collection, carries the false notion of white superiority.

Worse, the moniker "has also acquired today the connotation of being an objective scientific term, and that's what really led the committee to take objection with it," says Ann Morning, a sociologist at New York University and member of the committee. "It tends to reinforce this erroneous belief that racial categories are somehow objective and natural characterizations of human biological difference. We felt that it was a term that … should go into the dustbin of history."

Similarly, the term "black race" shouldn't be used because it implies that Black people are a distinct biological group that can be objectively defined, the panel says.

Racial definitions are problematic "because not only are they stigmatizing, they are historically wrong," says Ambroise Wonkam, a medical geneticist at Johns Hopkins University and president of the African Society of Human Genetics. Race is often used as a proxy for genetic diversity. But "race cannot be used to capture diversity at all," says Wonkam, who was not part of the panel. "There is only one race, the human race."

Some studies might use race to determine how genetic and social factors contribute to health disparities (SN: 5/7/22 & 5/21/22, *p.* 10). But beyond that, race has no real value in genetics research, Wonkam says. Researchers could use identifiers such as geographical ancestry to define groups of people, he says. But those definitions need to be precise.

For instance, some researchers group Africans by language. Speakers of Bantu languages live in many African countries. But those who live in Tanzania or Nigeria, where malaria is prevalent, would have a much higher genetic risk of sickle cell disease than a speaker of a Bantu language whose ancestors are from parts of South Africa where malaria hasn't existed for at least 1,000 years, Wonkam says. A variant of a hemoglobin gene that protects against malaria can also cause sickle cell disease.

> Racial definitions are problematic "because not only are they stigmatizing, they are historically wrong."
>
> **AMBROISE WONKAM**

Genetics studies also have to account for movements of people and mixture between multiple groups, Wonkam says. And labeling must be consistent, he says. Scientists sometimes compare continent-wide racial groups, such as Asian, with national groups, such as French or Finnish, and ethnic groups, such as Hispanic.

Removing race as a descriptor may be helpful for some groups, such as people of African descent, says Joseph Yracheta, a health disparities researcher and the executive director of the Native BioData Consortium, which is headquartered on the Cheyenne River Sioux Reservation in South Dakota. "I understand why they want to get rid of race science for themselves, because in their case it's been used to deny them services," he says.

But Native Americans' story is different, says Yracheta, who was not part of the panel. Native Americans' unique evolutionary history have made their DNA a valuable resource for genetics research. A small starting population and many thousands of years of isolation from people outside the Americas have given Native Americans as well as Indigenous people in Polynesia and Australia some genetic features that may make it easier for researchers to find variants that contribute to health or disease, he says. "We're the Rosetta stone for the rest of the planet."

Native Americans "need to be protected, because not only are our numbers small, but we keep having things taken away from us since 1492. We don't want this to be another casualty of colonialism," Yracheta says. Removing the label of Indigenous or Native American may erode tribal sovereignty and control over genetic data.

The panel recommends that researchers clearly state why they use particular descriptors and involve study populations in making decisions about which labels to use.

Community input is essential, Yracheta says. But the recommendations have no legal or regulatory weight, and he worries that may allow researchers to ignore the wishes of study participants without fear of penalty.

Genetics research has suffered from a lack of diversity of participants (SN: 3/13/21, *p.* 24). To counteract the disparities, U.S. regulations require that scientists funded by the National Institutes of Health collect data on the race and ethnicity of study participants. But those racial categories are social constructs that change over time and don't consider the environmental and social conditions that may affect health, so the labels aren't helpful in most genetic analyses, the panel concludes.

Removing racial labels won't hamper diversity efforts, says Brendan Lee, president of the American Society of Human Genetics. But it should encourage researchers to think more carefully about the type of data they collect and how it might be used to support or refute racism.

Researchers probably won't adopt the counsel right away, says Lee, a medical geneticist at Baylor College of Medicine in Houston, who was not part of the panel. The process "will take time … but [this report] is a very important first step." ■

HEALTH & MEDICINE

FDA requires dense breast notification

Mammogram ruling focuses on a factor that can up cancer risk

BY AIMEE CUNNINGHAM

If you're someone in the United States who has gotten a mammogram, you may also have received a letter in the mail that starts something like: "Your mammogram indicates that you have dense breast tissue."

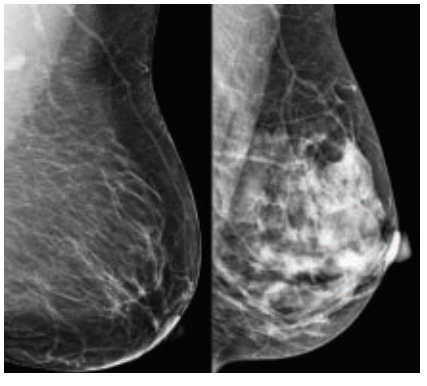
On March 10, the U.S. Food and Drug Administration issued a rule making these letters a nationwide requirement and standardizing the information conveyed in them. Starting September 10, 2024, everyone who has a mammogram will be informed whether their breasts are dense.

Having dense breasts "isn't abnormal," says UCLA internist and epidemiologist Joann Elmore. About 46 percent of women ages 40 to 79 in the United States have them, according to a 2019 report.

But dense breasts modestly increase the risk of being diagnosed with breast cancer. Breast density is just one factor to consider when determining overall risk, so ideally, a notification about breast density would prompt a discussion with a doctor.

Breasts are made up of a few kinds of tissue: glandular tissue, which produces milk and directs it to the nipple, plus connective (fibrous) tissue and fatty tissue. Dense breasts have more glandular and connective tissue than fatty tissue.

A radiologist visually assesses breast density in a mammogram. Nondense breasts are mainly fatty tissue or, most commonly, have scattered areas of dense tissue. Dense breasts are either "heterogeneously dense," which about 40 percent of U.S. women ages 40 to 79 have, or "extremely dense," which 6 percent have. Breast density can change. Older women tend to have less dense breasts than younger women, for example.



Fatty breast tissue is more transparent on a mammogram (left) than dense tissue (right), which looks white and might hide tumors.

CDC

Dense breasts present two challenges. First, on a mammogram, glandular and connective tissue show up as white, which is how tumors look too. So dense tissue could hide what a radiologist is looking for.

One measure of how well mammograms work is sensitivity, the proportion of tumors detected by mammogram out of all diagnosed tumors (whether found by mammogram or not). An analysis of mammograms from a Dutch screening program found that for those with nearly all fatty breast tissue, sensitivity was 86 percent, and 78 percent for those with scattered areas of density. The sensitivity fell to 70 percent for heterogeneously dense breasts and 61 percent for extremely dense breasts, researchers reported in 2017 in *Breast Cancer Research and Treatment*.

The other issue is that dense tissue itself can also contribute to cancer risk. This may be related to the greater amount of glandular tissue. "Breast cancers almost always develop in the glandular tissue," says Priscilla Slanetz, a breast radiologist at Boston Medical Center.

Dense breasts modestly impact the risk of developing breast cancer. Premenopausal women with heterogeneously dense breasts have a 1.5 to 1.8 times greater risk of developing breast cancer than premenopausal women with scattered areas of density, researchers reported in 2020 in *Cancer Epidemiology, Biomarkers & Prevention*. Those with extremely dense breasts are at 1.8 to 2.4 times greater risk.

To think of it another way, consider a case study of a 47-year-old woman who has heterogeneously dense breasts and no family history of breast cancer. Among 1,000 such women, an estimated 20 would develop breast cancer in the next 10 years. That's compared with 13 of 1,000 women with scattered areas of density.

Dense breasts are just one part of the risk picture. The two most significant risk factors are being female and increasing age, Slanetz says. About 1 in 8 cisgender women in the United States will be diagnosed with breast cancer in their lifetime. And while 1 in 65 women starting at age 40 will be diagnosed in the next 10 years, 1 in 24 women starting at age 70 will. Other risk factors include genetic mutations.

There aren't screening recommendations specific to dense breasts. People should have information about breast density, says Ilana Richman, a general internist at the Yale School of Medicine. "But it is an open question what to do with that information," she says, because of the lack of guidelines.

With the new FDA rule, notifications will say that in some people with dense tissue, adding other imaging tests, such as MRI or ultrasound, may help find cancer. However, density alone isn't enough to bump someone up to a high-risk category that calls for supplemental screening, says Karla Kerlikowske, a clinical epidemiologist at the University of California, San Francisco. "There's a lot of people that have dense breasts who are actually at low risk of breast cancer."

A dense breast notification should lead to a discussion with a doctor about different breast cancer risks, to understand a person's overall risk. But the limited time allotted to primary care visits in the United States is an obstacle. "We don't have a system that allows enough time for that nuanced discussion," says Christina Chapman, a radiation oncologist at Baylor College of Medicine in Houston.

Plus, that conversation should happen with people who have nondense breasts too. "The focus on breast density in some ways just distracts from the idea that risk is multidimensional," Richman says.

Many women who develop breast cancer don't have any apparent risk factors, Slanetz says, which is why screening mammograms are important. "We screen [everyone] because we have to." ■

Read more about breast cancer risks and screening at **bit.ly/SN_BreastCancer**

NEUROSCIENCE

In mice, anxiety isn't all in the head

A racing heart can cause a relaxed mouse to act nervous

BY BETHANY BROOKSHIRE

When you're stressed and anxious, you might feel your heart race. Is your heart racing because you're afraid? Or does your speeding heart itself contribute to your anxiety? Both could be true, a new study in mice suggests.

By artificially increasing the heart rates of mice, scientists were able to increase anxiety-like behaviors — ones that the team then calmed by turning off a particular part of the brain. The study, published in the March 9 *Nature*, suggests that in high-risk contexts, a racing heart could go to your head and increase anxiety. The findings could offer a new angle for studying and potentially treating anxiety disorders.

The idea that bodily sensations might contribute to emotions goes back at least to one of the founders of psychology, William James, says Karl Deisseroth, a neuroscientist at Stanford University. In James' 1890 book *The Principles of Psychology*, he put forward the idea that emotion follows what the body experiences. "We feel sorry because we cry, angry because we strike, afraid because we tremble," James wrote.

The brain certainly can sense internal body signals, a phenomenon called interoception. But whether those sensations, such as a racing heart, can contribute to emotion is difficult to prove, says Anna Beyeler, a neuroscientist at the French National Institute of Health and Medical Research in Bordeaux. She studies brain circuitry related to emotion and cowrote a commentary on the new study in the same issue of *Nature*. "I'm sure a lot of people have thought of doing these experiments, but no one really had the tools," she says.

Deisseroth's lab focuses on developing those tools. He is one of the scientists who developed optogenetics, a technique that uses viruses to modify the genes of specific cells to respond to bursts of light (SN: 1/30/10, p. 18). Scientists can use the flip of a light switch to activate or suppress the activity of those cells.

In the new study, Deisseroth and colleagues used a light attached to a tiny vest over a mouse's genetically engineered heart to change the animal's heart rate. When the light was off, a mouse's heart pumped at about 600 beats per minute, normal for a mouse. But when the team turned on a light that flashed at 900 beats per minute, the mouse's heartbeat followed suit. "It's a nice reasonable acceleration, [one a mouse] would encounter in a time of stress or fear," Deisseroth explains.

When the mice were in risky scenarios and felt their hearts racing, they showed anxiety-like behavior. In high-risk places — like being in open boxes where a little mouse might be someone's lunch — the rodents slunk along the walls and lurked in darker corners. When pressing a lever for water that could sometimes be coupled with a mild shock, mice with normal heart rates still pressed without hesitation. But some mice with racing hearts decided they'd rather go thirsty.

"Everybody was expecting that, but it's the first time that it has been clearly demonstrated," Beyeler says.

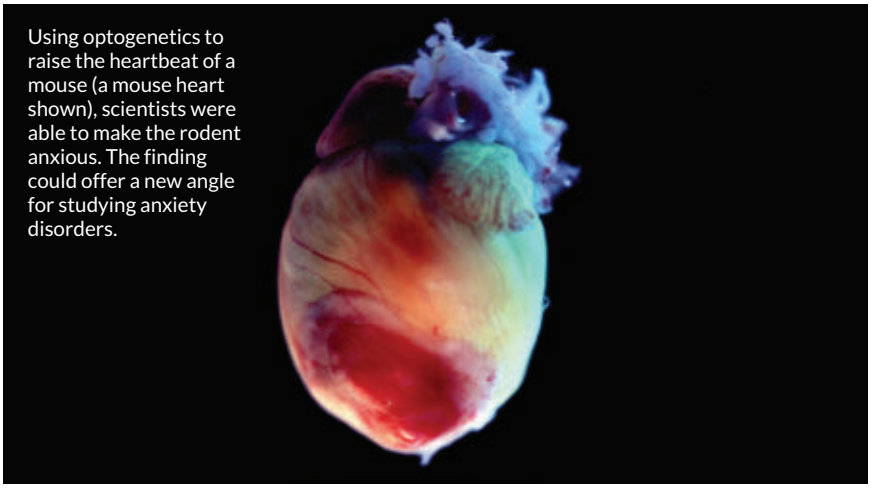
The researchers also scanned the animals' brains to find areas that might be processing the increased heart rate. One of the biggest signals, Deisseroth says, came from the posterior insula. "The insula was interesting because it's highly connected with interoceptive circuitry," he says. "When we saw that signal, [our] interest was definitely piqued."

Using more optogenetics, the team reduced activity in the posterior insula, which decreased the mice's anxiety-like behaviors. The animals' hearts still raced, but they behaved more normally, spending some time in open areas of mazes and pressing levers for water without fear.

A lot of people are very excited about the work, says Wen Chen, the branch chief of basic and mechanistic research at the National Center for Complementary and Integrative Health in Bethesda, Md. "No matter what kind of meetings I go into, in the last two days, everybody brought up this paper," says Chen, who wasn't involved in the research.

The next step, Deisseroth says, is to look at other parts of the body that might affect anxiety. "We can feel it in our gut sometimes, or we can feel it in our neck or shoulders," he says. Using optogenetics to tense a mouse's muscles, or give its tummy butterflies, might reveal other pathways that produce fearful or anxiety-like behaviors.

Understanding the link between heart and head could eventually factor into how doctors treat panic and anxiety, Beyeler says. But the path between the lab and the clinic, she notes, is much more convoluted than that of the heart to the head. ■



Using optogenetics to raise the heartbeat of a mouse (a mouse heart shown), scientists were able to make the rodent anxious. The finding could offer a new angle for studying anxiety disorders.

VOLKER STEGER/SCIENCE SOURCE

PLANETARY SCIENCE

Volcanic activity spotted on Venus

A new analysis of old data confirms scientists' suspicions

BY LISA GROSSMAN

Venus has active volcanism. A new analysis of decades-old images reveals the first definitive sign of a volcano erupting on the hellish planet next door.

NASA's Magellan spacecraft observed the volcano Maat Mons twice in 1991. Sometime in the 243 Earth days between each observation, the volcanic vent appears to have morphed from a 2.2-square-kilometer circle to a 4-square-kilometer blob. That change indicates that an eruption had occurred, researchers reported March 15 in *Science* and at the Lunar and Planetary Science Conference in The Woodlands, Texas.

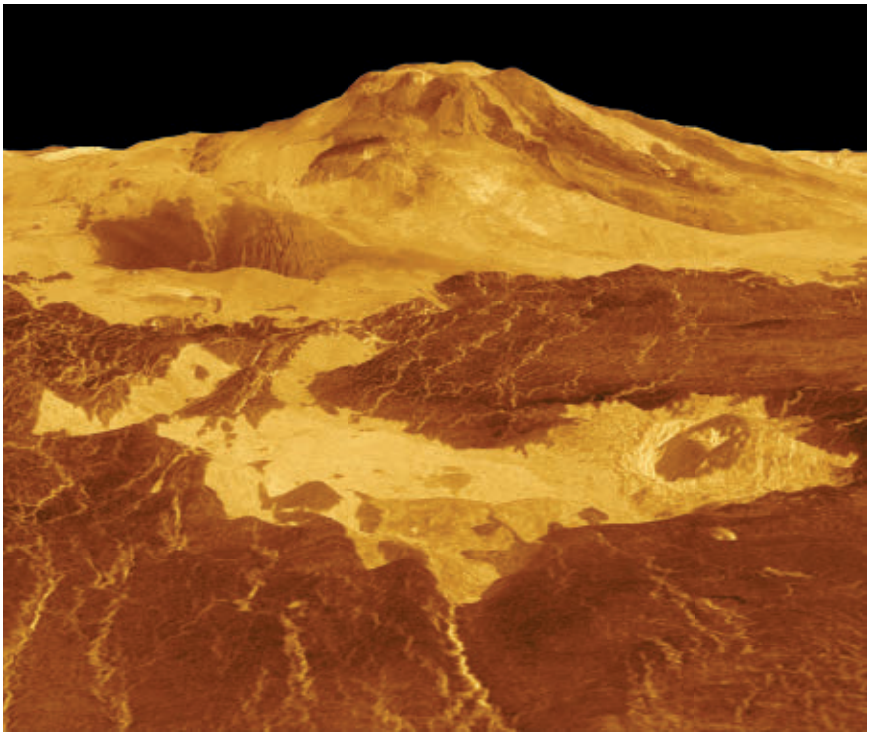
"This world is not quiet, not quiescent, not dead," says planetary scientist Paul Byrne of Washington University in St. Louis, who was not involved in the new research.

Venus is about the same size and mass as Earth, so it should have a similar amount of internal heat. And that heat must escape somehow. Scientists have long thought that Venus should be volcanically active. "We've just never had something we can point to. And now we do," Byrne says. He's also confident that volcanoes on Venus can still erupt now.

"There's no way you have a planet that big that was doing something 30 years ago and stopped," he says. "It's definitely still active today."

Planetary scientist Robert Herrick spotted the change after painstakingly poring through images of the Venusian regions considered most likely to be volcanically active. "This was a needle-in-a-haystack search with no guarantee that the needle exists," says Herrick, of the University of Alaska Fairbanks.

Much circumstantial evidence for eruptions on Venus has been reported over the decades (SN: 11/12/16, p. 11). But it has been difficult to tell whether any particular change was due to real geology on the ground, or just a mirage. Many reported differences have turned out to be due to Magellan's differing viewing angles over successive orbits around Venus.



Venus' Maat Mons volcano, shown in a view based on data from NASA's Magellan spacecraft and the Soviet Venera 13 and 14 spacecraft, seems to have erupted in 1991.

"Fundamentally, looking at these images is very hard," says radar scientist Scott Hensley of NASA's Jet Propulsion Laboratory in Pasadena, Calif. "It's not like people have not looked [for active volcanism]. People have been looking over the years."

Identifying the change in Maat Mons in images alone was not enough to convince Hensley and Herrick that they were seeing evidence for active volcanism. So Hensley ran more than 100 computer simulations of what the volcanic vent would have looked like to Magellan under different imaging conditions. "None of them ever looked like [the 4-square-kilometer blob] on the second cycle," Hensley says. The change must be real, he concluded.

The volcano's change in shape suggests that it probably didn't explosively erupt like Washington's Mount St. Helens did in 1980, Byrne says. Instead, the eruption was probably more like the long, slow lava drainage from Hawaii's Kilauea volcano in 2018, only bigger, he says (SN: 2/2/19, p. 22).

The finding gives scientists an idea of what to expect — and some new ideas for research — when upcoming missions return to Venus. NASA had planned to launch VERITAS, a satellite for mapping the whole planet, in the late 2020s or early 2030s, though the agency recently cut funding to the mission. The European Space Agency plans to launch EnVision, which will take high-resolution radar images of targeted regions, in the 2030s.

"The cool part is it means that Venus is volcanically active now. In these upcoming missions, we are going to see things happening," Herrick said in his talk at the meeting. "We already had plans to try and look for new things and changes with time in both of those missions … we now know that that's a valuable thing to do."

Meeting attendee Darby Dyar, a planetary scientist at Mount Holyoke College in South Hadley, Mass., agreed. "Everybody in this room should be salivating over the features we're going to see" in images from future missions. ■

JPL-CALTECH/NASA

ASTRONOMY

This black hole has fled a far-off galaxy

A galactic smashup likely kicked out the behemoth, scientists say

BY LISA GROSSMAN

A streak of light stretching away from a remote galaxy might be the first sure sign of a gargantuan black hole on the run, a new study reports. The putative black hole, fleeing its host galaxy, appears to be leaving a trail of newborn stars and shocked gas in its wake. If confirmed, the intergalactic escape could help astronomers learn more about what happens to black holes when galaxies collide.

"The possibility that this [streak of light] might be due to a supermassive black hole that's been ejected from its galaxy is very exciting," says astronomer Charlotte Angus of the University of Copenhagen, who was not involved in the new work. "These events have been predicted by theory, but up until now, there's been little evidence for them."

While looking for colliding dwarf galaxies with the Hubble Space Telescope, astronomer Pieter van Dokkum of Yale University and colleagues spotted something peculiar: a long, straight line that seemed to extend away from a distant galaxy, growing narrower and brighter as it went (*SN: 6/18/22, p. 32*).

"Whatever it is, we haven't seen it before," van Dokkum says. "Most astronomical objects are shaped like a spiral or a blob. There are not many objects that are just a line in the sky." When astronomers do see lines, they're usually from something moving, like a satellite crossing the telescope's field of view (see Page 5).

To uncover the object's identity, van Dokkum and colleagues peered at the streak with the Keck Observatory in Hawaii, which can see in wavelengths that Hubble can't. Those observations showed that the streak was associated with a galaxy whose light took about 8 billion years — more than half the universe's age — to reach Earth, the team reports in a paper posted February 10 at arXiv.org. Based on that distance measurement, the team calculated that the line stretches roughly 200,000 light-years.

The findings certainly ruled out a satellite. "We considered a lot of explanations, and the one that fit the best is what we're witnessing is a massive object, like a black hole, moving very rapidly away from the galaxy," van Dokkum says.

Black holes on their own are invisible. But "if a black hole leaves a galaxy, it doesn't leave by itself," van Dokkum says. Some of the stars and gas that are gravitationally bound to the black hole leave with it. That gas will emit radiation strong enough for telescopes to detect. The black hole's path through the gas and dust in the galaxy's outer regions can compress some of that gas into new stars, too, which would also be visible (*SN: 7/21/18, p. 16*).

Another possibility is that the line is a jet of radiation launched by a supermassive black hole at the galaxy's core. But such a beam would broaden as it gets farther away from the galaxy. This streak does the opposite.

If the object is a black hole, it could have been ejected from the galaxy's center by interacting with one or two other black holes nearby. Almost every galaxy has a supermassive black hole at its center. When galaxies merge, their central black holes also eventually merge (*SN: 3/27/21, p. 9*). If the conditions are right, that merger can give the resulting black hole a "kick," sending it flying at high speed (*SN: 6/18/22, p. 8*).

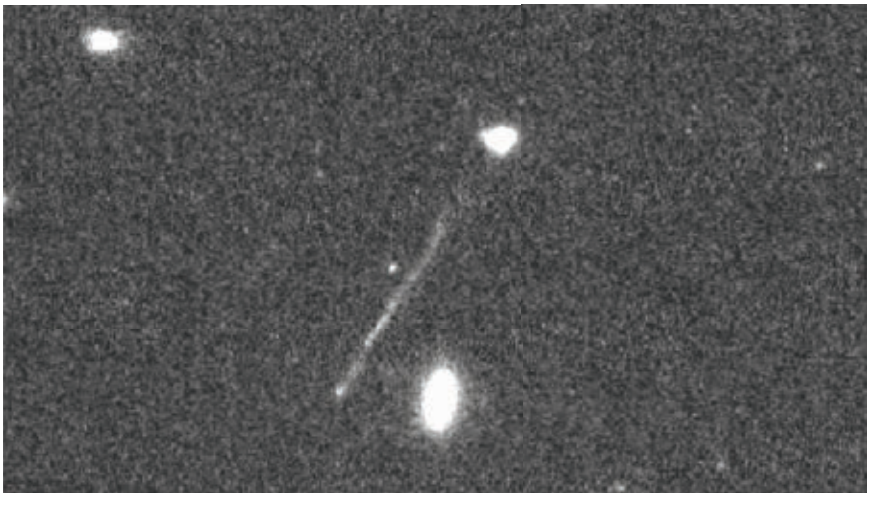
Alternatively, the black hole could have been spat out of a smashup among three galaxies. When a third galaxy joins an ongoing merger, three supermassive black holes jockey for position. One black hole could be tossed out of the galactic smashup, while the other two take off more slowly in the other direction.

That's what van Dokkum thinks happened in this case. There are signs of a shorter, dimmer streak heading in the opposite direction from the bright line.

More observations of this system, perhaps with the James Webb Space Telescope, are needed to confirm that it really is an ejected supermassive black hole, Angus says. More theoretical calculations of what a runaway supermassive black hole should look like would help too.

Angus is now motivated to search through archived data for more potential black hole streaks. "I wonder if there are more of these features out there, sitting in someone's data that might have just been missed," she says.

Van Dokkum does too. "Now that we know what to look for — these very thin streaks — it makes sense to go back to Hubble data. We have 25 years of Hubble images that have not been searched with this purpose," he says. "If there are more to be found, I think we can do it." ■



P. VAN DOKKUM *ET AL*/ARXIV.ORG 2023

A purported runaway black hole showed up as a straight line in this image from the Hubble Space Telescope. Scientists estimate that this far-off black hole's streak stretches for 200,000 light-years.

ARCHAEOLOGY

Bones hint at the first horseback riders

Telltale marks suggest the Yamnaya rode horses 5,000 years ago

BY MCKENZIE PRILLAMAN

WASHINGTON — The tale of the first horseback riders may be written on the bones of the ancient Yamnaya people.

Five excavated skeletons dated to about 3000 to 2500 B.C. show clear signs of physical stress that hint these Yamnaya individuals may have frequently ridden horses, researchers reported March 3 at the American Association for the Advancement of Science Annual Meeting and in *Science Advances*. That makes the Yamnaya the earliest humans identified so far as likely horseback riders.

Five thousand years ago, the Yamnaya migrated widely from Eastern Europe, spreading Indo-European languages and altering the human gene pool across Europe and Asia (SN: 11/25/17, p. 16). Within a couple centuries, the nomads traveled roughly 4,500 kilometers from modern-day Hungary to Mongolia.

"In many ways, [the Yamnaya] changed the history of Eurasia," says archaeologist Volker Heyd of the University of Helsinki.

Horse domestication became widely established around 3500 B.C., probably for milk and meat. Some researchers have suggested the Botai people in modern-day Kazakhstan started riding horses during that time, but that's debated (SN: 3/28/09, p. 15). The Yamnaya had horses as well, and archaeologists have speculated that the people probably rode them, but evidence was lacking.

Complicating efforts to determine when the behavior emerged, possible riding gear would have been made of long-decayed natural materials, and scientists rarely, if ever, find complete horse skeletons from that time.

Heyd and colleagues weren't seeking evidence of horsemanship. They were working on a project called the Yamnaya Impact on Prehistoric Europe to understand every aspect of the people's lives.

While assessing over 200 human skeletons from countries including Romania, Bulgaria and Hungary, bioanthropologist Martin Trautmann, also of the University of Helsinki, noticed that one individual's bones had distinct traits he'd seen before. As he continued analyzing skeletons, he noticed that several more had similar traits. Trautmann immediately suspected horseback riding.

Trautmann, Heyd and colleagues assessed all the skeletons for six physical signs of horseback riding, a constellation of traits dubbed horsemanship syndrome in previous research, and scored each trait's severity, preservation and relative importance. The signs include pelvis and femur marks that could have come from the biomechanical stress of sitting with spread legs while holding onto a horse, as well as healed vertebrae damage from injuries that could have come from falling off a horse.

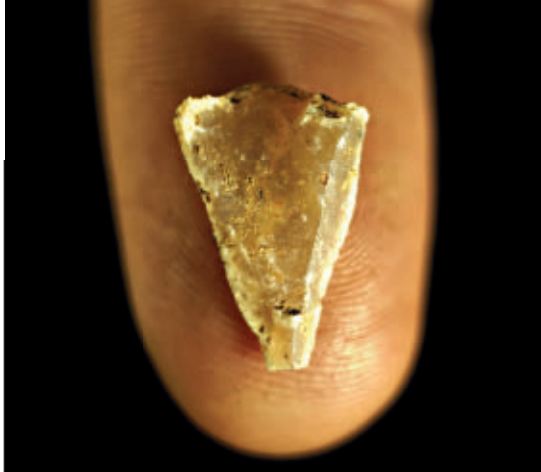
"Bones are living tissue," Trautmann says. "They react to any type of environmental stimulus."

Five Yamnaya males had four or more signs of horsemanship syndrome, suggesting they were frequent horseback riders. Nine other Yamnaya individuals probably also rode horses, the team says, but those skeletons each had only three markers.

"It's very logical," says bioarchaeologist Maria Mednikova of the Russian Academy of Sciences in Moscow. The Yamnaya were very close to horses. At some point, they probably experimented with riding, Mednikova says. She now plans to check for horse-riding traits in additional Yamnaya skeletons. "The human skeletal system is like a book. If you have some knowledge, you can read it," she says.

Archaeologist Ursula Brosseder of the University of Bonn in Germany, sees the discovery as humans still figuring out what they could do with horses as part of early domestication.

As for Heyd, he has long suspected that the Yamnaya rode horses, considering that they had the animals and expanded rapidly across such a large area. "Now, we have proof." ■



The small size of ancient stone points found in France, such as this one on an adult's fingertip, made them suitable for hunting only when used as arrowheads, experiments suggest.

L. METZ, LUDOVIC SLIMAK

ARCHAEOLOGY

Homo sapiens spread archery

Humans may have been Europe's first arrow slingers

BY BRUCE BOWER

Homo sapiens who reached Europe around 54,000 years ago introduced bows and arrows to that continent, a new study suggests.

Researchers examined tiny triangular stone points and other artifacts excavated at a rock-shelter called Grotte Mandrin in southern France. *H. sapiens* on the move probably brought archery techniques from Africa to Europe, archaeologist Laure Metz of Aix-Marseille University in France and colleagues report in the Feb. 24 *Science Advances*.

"Metz and colleagues demonstrate bow hunting [at Grotte Mandrin] as convincingly as possible without being caught bow-in-hand," says archaeologist Marlize Lombard of the University of Johannesburg.

No bows were found at the site. Wooden items such as bows preserve poorly. The oldest intact bows, found in northern European bogs, date to around 11,000 years ago, Metz says.

Previous stone and bone point discoveries suggest that bow-and-arrow hunting originated in Africa between about 80,000 and 60,000 years ago. And previously recovered fossil teeth indicate that *H. sapiens* visited Grotte Mandrin as

early as 56,800 years ago, well before Neandertals' demise around 40,000 years ago and much earlier than researchers had thought that *H. sapiens* first reached Europe (SN: 3/12/22, p. 9).

"We've shown that the earliest known *Homo sapiens* to migrate into Neandertal territories had mastered the use of the bow," Metz says.

There's no evidence to suggest that Neandertals already in Europe at that time launched arrows at prey. Neandertals also resided at Grotte Mandrin, but its unclear if they overlapped with *H. sapiens*. It's also unclear whether archery gave any substantial hunting advantages to *H. sapiens* relative to spears that were thrust or thrown by Neandertals.

Among 852 stone artifacts excavated in a *H. sapiens* sediment layer at Grotte Mandrin dated to about 54,000 years ago, 196 triangular stone points displayed high-impact damage. Another 15 stone points showed signs of both high-impact damage and alterations caused by butchery activities, such as cutting.

Those finds were compared with damage on stone replicas of the artifacts that the researchers had used as arrowheads shot from bows and as the tips of spears inserted in handheld throwing devices. Additional comparative evidence came from stone and bone arrowheads used by recent and present-day hunting groups.

Impact damage along the edges of stone points from the French site indicated that these implements had been attached at the bottom to shafts.

The smallest Grotte Mandrin points, many with a maximum width of no more than 10 millimeters, could have pierced animals' hides only when shot from bows as the business ends of arrows, the researchers say. Experiments they conducted with replicas of the ancient stone points found that stone points less than 10 millimeters wide reach effective hunting speeds only when attached to arrow shafts propelled by a bow.

Larger stone points, some of them several times the size of the smaller points, could have been arrowheads or might have tipped spears that were thrown or thrust by hand or launched from handheld spear throwers, the researchers conclude.

Lombard suspects that the first *H. sapiens* at Grotte Mandrin hunted with bows and arrows as well as with spears, depending on where and what they were hunting. Earlier studies directed by Lombard have indicated that *H. sapiens* in sub-Saharan Africa similarly alternated between the two types of hunting weapons starting between about 70,000 and 58,000 years ago.

H. sapiens newcomers to Europe may have learned from Neandertals that spear hunting in large groups takes precedence on frigid landscapes, where bow strings can easily snap and long-distance pursuit of prey is energy inefficient, Lombard says.

But learning about archery from *H. sapiens* may not have been in the cards for Neandertals. Based on previous analyses of brain impressions on the inside surfaces of fossil skulls, Lombard suspects that Neandertals' brains did not enable the enhanced visual and spatial abilities that *H. sapiens* exploited to hunt with bows and arrows.

That's a possibility, though other controversial evidence suggests that Neandertals behaved no differently from Stone Age *H. sapiens* (SN: 4/25/20, p. 12). If Neandertals at Grotte Mandrin never hunted with bows and arrows but still survived just fine alongside *H. sapiens* archers for roughly 14,000 years, reasons for Neandertals' ultimate demise remain as mysterious as ever. ■

LYDIA V. LUNCZ

ARCHAEOLOGY

Monkeys' stone flakes look like hominid tools

Thailand's long-tailed macaques (*Macaca fascicularis*) use rocks to pound open oil palm nuts, inadvertently shattering stone pieces off their makeshift nutcrackers. These flakes resemble some sharp-edged stone fragments presumed to have been created on purpose by ancient hominids in East Africa about 3.3 million to 1.56 million years ago, researchers say.

The finding suggests that ancient hominids may sometimes have created the stone flakes by accident while using rocks to smash nuts, bones or other objects, archaeologist Tomos Proffitt of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, and colleagues report March 10 in *Science Advances*. It may also undermine the long-held assumption that hominids intentionally made certain stone flakes, including some of the earliest known tools.

The team identified 219 stone flakes and other rocks with signs of pounding at 40 macaque sites on the island where the monkeys live. But differences exist between monkey and hominid flakes, such as damage to one side versus two. Such clues may help archaeologists develop guidelines for estimating whether ancient hominids made stone flakes on purpose or by accident. — *Bruce Bower*

PALEONTOLOGY

Ancient animal may actually be algae

Fossils stir debate about the oldest known bryozoan's identity

BY SID PERKINS

A species that lived about 520 million years ago and was thought to be the oldest known bryozoan is instead a type of colony-forming algae, a new study proposes.

Bryozoans are filter-feeding, tentacle-bearing animals that live in apartment complex–like colonies attached to rocks, shells or other surfaces on seafloors or lake bottoms. Trouble is, so do some other simple animals and algae. In 2021, researchers categorized a group of fossils first described in 1993 as being from a newfound species of bryozoan, dubbed *Protomelission gatehousei*.

Now, analyses of better-preserved fossils show that the species may not have been a bryozoan after all, says paleobiologist Martin Smith.

New fossils of *Protomelission gatehousei* (dark brown strip attached to a shell) suggest that the species may be a type of colony-forming algae rather than a marine animal called a bryozoan.

Where previous fossils preserved only the skeletal framework of colonies, the new fossils — unearthed in southern China — include soft parts of the organism too, says Smith, of Durham University in England. And instead of the tentacles expected to have been found in an immaculately preserved bryozoan, the fossils have simple leaflike flanges typical of some types of algae, he and colleagues report in the March 16 *Nature*.

If borne out, that conclusion means that the oldest known unequivocal bryozoan fossils are only about 480 million years old. That, Smith contends, makes bryozoans the only major group of animals not to have first appeared during the Cambrian Period, a burst of biological diversification that some scientists refer to as "life's Big Bang" and that ended about 488 million years ago (SN: 4/27/19, p. 32).

As a result, the Cambrian Period was not, as previously thought, a unique interval of innovation in evolutionary history during which the blueprints of animal life were completely mapped out, the researchers conclude.

ANIMALS

Honeybees need dance lessons

Youngsters without older mentors flub waggle dances

BY SUSAN MILIUS

In a test setup, groups of castaway young honeybees figuring out how to forage on their own start waggle dancing spontaneously — but badly.

Waggling matters. A honeybee's rump-shimmy runs and turning loops encode clues that help her colony mates fly to food she has found, sometimes kilometers away. However, five colonies in the test had no older sisters around as role models for getting the dance moves right.

Still, dances improved in some ways as the youngsters wiggled and looped day after day, report behavioral ecologist James Nieh of the University of California, San Diego and colleagues. But when waggling the clues for distance information, *Apis mellifera* without role models never matched the timing and coding of colonies where young bees practiced with older foragers before waggling themselves.

The youngsters-only colonies thus show that social learning, or the lack of it, matters for communicating by dance among honeybees, the researchers report in the March 10 *Science*. Bee waggle dancing turns out to be both innate and learned, like songbird or human communication.

The dance may appear simple, but executing it on expanses of honeycomb cells gets challenging. Bees are "running forward at over one body length per second in the pitch black trying to keep the correct angle, surrounded by hundreds of bees that are crowding them," Nieh says.

Beekeepers and biologists know that some kinds of bees can learn from others of their kind. But when it comes to waggle dancing, "people have largely assumed it's genetic," Nieh says. The new experiments instead show a nonhuman example of "social learning for sophisticated communication," he says.

At an apiary research center in Kunming, China, scientists collected thousands of brand-new winged adult honeybees as they emerged from incubators. These youngsters went into five colonies of same-age worker newbies. Each colony got a queen, who would lay eggs but not leave the colony to forage. The young workforce had to search for food with no older, experienced foragers dancing the locations of flowers.

The five colonies were left to figure out dancing on their own, in contrast to five mixed-age colonies. Researchers analyzed the first dances of five bees from each hive.

Dances on honeycomb surfaces encode the food's direction in the angle that a dancer waggles across the comb, measured relative to gravity. Waggling duration tells how far the bonanza is.

Dancers didn't always get the angle perfect. In mixed-age hives, the extremes in a set of six waggle runs might differ by more

ZHANG XIGUANG

"The question is, did evolution lose its ability to create new body plans [at the end of the Cambrian Period]?" Smith says. The team's new study suggests not, he says.

Not everyone agrees that the new fossils aren't bryozoans. The leaflike flanges described by Smith and colleagues could just as easily be interpreted as body parts of individual animals in the bryozoan colony, says invertebrate paleontologist Paul Taylor of London's Natural History Museum.

Because the tentacles that bryozoans use to snatch prey from the water are made of soft tissue and typically don't preserve well, their absence from the new fossils is not at all surprising, Taylor says.

For him, the new findings are not sufficient to dismiss *P. gatehousei* as a Cambrian bryozoan. But they do underline the inherent uncertainty in identifying fossils with simple body plans, Taylor says. More fossils that preserve additional features, such as the organism's early growth stages, are needed to settle the question. ■

than 30 degrees. Castaway hives had more trouble. Out of five dancers with the most extreme angles, two bees veered more than 50 degrees apart, and one bee strayed more than 60 degrees in six runs.

But the castaways improved as they gained experience. When tested a few weeks later, the same bees angled about as well as dancers in mixed-age hives.

What the castaways didn't change much were dance features encoding distance to food. The team had set up the hives the same distance from a feeder. Yet castaway bees persisted in dancing as if the feeder were farther away, giving more rump wags per waggle run and taking longer on each run than bees from mixed-age hives.

The findings are just the latest evidence for the importance of learning in complex bee behaviors, says insect ecologist Tamar Keasar of the University of Haifa in Israel. In her own work, she has seen bees learning to extract food from complicated flowers. Bees aren't, after all, just little automatons with wings. ■

ANIMALS

Chernobyl dogs' DNA gets mapped

The first genetic analysis may help tease out radiation effects

BY MEGHAN ROSEN

For generations of dogs in Ukraine, home is the radioactive remains of the Chernobyl Nuclear Power Plant.

The first genetic analysis of these animals has revealed that dogs living in the power plant industrial area are genetically distinct from dogs living farther away.

Though researchers could distinguish between dog populations, they did not pinpoint radiation as the reason for any genetic differences. But future studies that build on the findings, reported in the March 1 *Science Advances*, may help uncover how radioactive environments leave their mark on animal genomes.

That could have implications for other nuclear disasters and even human space travel, says evolutionary ecologist Timothy Mousseau of the University of South Carolina in Columbia. "We have high hopes that what we learn from these dogs … will be of use for understanding human exposures in the future," he says.

Mousseau has made trips to Chernobyl since 1999. He first encountered the semi-feral dogs in 2017, during a trip with the Clean Futures Fund+, an organization that provides veterinary care to the animals.

Not much is known about how local dogs survived after the nuclear accident. In 1986, an explosion at one of the plant's reactors kicked off a disaster that lofted radioactive isotopes into the air. Contamination from the plant's radioactive cloud largely settled nearby, in a region now called the Chernobyl Exclusion Zone.

Dogs have lived in the area since the disaster, fed by cleanup workers and tourists. Some 250 strays were known to live in and around the power plant, in the shadow of the ruined reactor. Hundreds more roam in the exclusion zone, an area about the size of Yosemite National Park.

Mousseau and colleagues took blood samples from the dogs for DNA analysis, which let the scientists map out the animals' family structures. "We know who's related to who," says geneticist Elaine Ostrander of the National Human Genome Research Institute in Bethesda, Md.

Dogs living in and around Chernobyl, like the ones shown here, make up a genetically distinct population. Whether that's due to decades of radiation exposure is unclear.

The canine packs are not just a hodgepodge of feral dogs. "There are actually families of dogs breeding, living, existing in the power plant," Ostrander says.

Dogs within the exclusion zone share ancestry with German shepherds and other shepherd breeds, like many other free-breeding dogs in Eastern Europe. And though dogs around the power plant are genetically distinct from dogs about 15 kilometers away in Chernobyl City, it's unclear whether radiation caused the differences, Ostrander says. Dogs around the power plant may be genetically distinct because they live in relative isolation.

Environmental scientist Jim Smith of the University of Portsmouth in England isn't surprised by the findings. He worries that people might assume "the radiation has something to do with it," he says. But "there's no evidence of that."

Teasing out the effects of low-dose radiation among other factors isn't easy, Smith says. "There's lots of other stuff going on in the natural environment." What's more, animals can benefit when humans leave contaminated zones, he says.

Still, knowing the dogs' genetic backgrounds will make spotting radiation red flags easier, says evolutionary geneticist Bridgett vonHoldt of Princeton University. "It's a cliffhanger," she says. "I want to know more." ■

CLEAN FUTURES FUND+

CLIMATE

How wildfires deplete ozone

Smoke amps up reactions that make ozone-eating molecules

BY CAROLYN GRAMLING

In late 2019 and early 2020, Australia's wildfires produced towering columns of smoke (shown) that ascended into the stratosphere and reacted with Earth's ozone layer.

Towering clouds of smoke sent into the stratosphere by ferocious wildfires can eat away at Earth's ozone layer thanks to a potent mix of smoke, atmospheric chemistry and ultraviolet light, a new study finds.

During late 2019 and early 2020, Australia's skies turned black, darkened by thick wildfire smoke that reached into the stratosphere (SN: 1/16/21, p. 9). In the aftermath, satellite data revealed that the smoke was somehow reacting with atmospheric molecules to ravage Earth's ozone layer. But how exactly that was happening wasn't clear.

Now, scientists have put together the pieces of that chemical puzzle. Once in the stratosphere, the smoke particles interacted with stratospheric gases as well as lingering emissions of ozone-destroying chemicals. Add in solar radiation, and that smoky brew churned out chlorine radicals, a type of chemical with an affinity for attacking ozone, researchers report in the March 9 *Nature*.

This series of events depleted about 3 to 5 percent of the ozone layer in parts of the Southern Hemisphere during 2020, the team estimates. That's a small fraction of the whole, but it rivals the scale of the impact of human emissions of chlorofluorocarbons in their heyday, says MIT atmospheric chemist Susan Solomon.

Chlorofluorocarbons, or CFCs, were once used in air conditioners and refrigerators, and their emission to the atmosphere led to a large hole over Antarctica in Earth's ozone layer, which limits how much of the sun's ultraviolet radiation reaches the planet's surface.

The 1987 Montreal Protocol, an international treaty that banned the use of CFCs, is helping to shrink the hole, researchers have found. Since the treaty went into effect in 1989, Solomon says, "we're starting to see a recovery on the order of 1 percent per decade."

However, this newfound wildfire-related process for destroying ozone is a worrisome potential setback to the ozone layer's recovery, Solomon says. Ozone loss in part of the Southern Hemisphere due to the wildfires in 2020 is comparable in scale to how much ozone might have recovered for that year.

Climate change is expected to increase the intensity and frequency of wildfires around the globe, sending more towering smoke clouds high into the sky. If these fires "are a one-time deal, it's maybe not so bad" for ozone recovery, Solomon says. "But if it happens every five years, that's a different kettle of fish."

Solomon and colleagues compared atmospheric observations of chlorine, ozone and other molecules following the Australian wildfires with simulations of atmospheric chemistry. Satellites had measured the abundance of certain chemicals in the stratosphere in 2020, including ozone, hydrogen chloride gas and chlorine nitrate.

Those levels caught Solomon's attention. "What we saw over Australia was a tremendous drop in hydrogen chloride" in the satellite data, she says. "I thought, gosh, this looks just like Antarctica. How can this be happening over Australia?"

Hydrogen chloride gas is a product of the breakdown of CFCs, which can linger for decades in the stratosphere. The frigid air over Antarctica was a key part of the ozone hole's formation. At those temperatures, hydrogen chloride gas can dissolve into the stratosphere's icy clouds. The absorption of that gas is essential to starting the chain of reactions that form ozone-depleting chemicals.

The atmosphere over Australia is too warm for this process—but the satellite data indicated that something was still removing hydrogen chloride gas from the atmosphere. Solomon's team realized that the culprit was organic particles in the smoke. Those particles can absorb hydrogen chloride gas at higher temperatures, kicking off that essential first step.

With the absorbed hydrogen chloride, smoke particles can act as catalysts that help speed up reactions. In particular, these particles amp up the transformation of chlorine-containing gases into chlorine compounds that are highly reactive to sunlight. Mixing the sun's ultraviolet radiation with those new chlorine compounds produces chlorine radicals, freewheeling molecules that attack ozone.

Over the next few decades, Solomon says, ozone recovery "is going to be sort of a race between CFCs getting destroyed and chlorine dropping and climate change getting worse and wildfires getting worse."

The study elegantly explains several puzzling satellite observations made in the wake of the Australian fires, including the drop in hydrogen chloride and the strange increases in other chlorine compounds like chlorine nitrate and chlorine oxide, says atmospheric chemist Ross Salawitch of the University of Maryland in College Park.

But the "icing on the cake," Salawitch says, is how the discovery of the role of organic particles can improve our understanding of what controls the size of the ozone hole. This is important because "one of the unfortunate consequences of global warming is likely an increase in the frequency and severity of wildfires." ■

DLMCK/E+/GETTY IMAGES PLUS

EARTH

Earth's inner core has a core of its own

Seismic data hint at a roughly 600-kilometer-wide innermost core

BY CAROLYN GRAMLING

Earth's heart may have a secret chamber. The planet's inner core isn't just a solid ball of nickel and iron, researchers say. It also contains two layers: a distinct central region nestled within an outer shell.

Evidence for the existence of this innermost inner core comes from a previously unreported type of seismic wave. This wave not only travels through Earth's core but also bounces back and forth within it, collecting invaluable data about the core's structure along the way.

Focusing on temblors of magnitude 6 or larger that struck in the last decade, the researchers combined data collected at seismic stations around the world. Combining signals from these quakes made it possible to detect very faint reflections of the seismic waves. Of the 200 or so quakes analyzed, 16 events spawned seismic waves that bounced through the inner core multiple times.

The origin, structure and fate of Earth's core is of intense interest because the core generates the planet's magnetic field, which shields Earth from the solar wind and helps keep the planet's denizens safe from too much radiation.

"Understanding how the magnetic field evolves is extremely important for the life on Earth's surface," says seismologist Hrvoje Tkalčić of the Australian National University in Canberra.

The entire core, about 7,000 kilometers wide, consists of two main parts: a liquid outer core and a solid inner core (SN: 2/25/23, *p.* 7). As iron-rich fluid circulates in the outer core, some of the material cools and crystallizes, sinking to form the solid center. That interplay generates Earth's magnetic field.

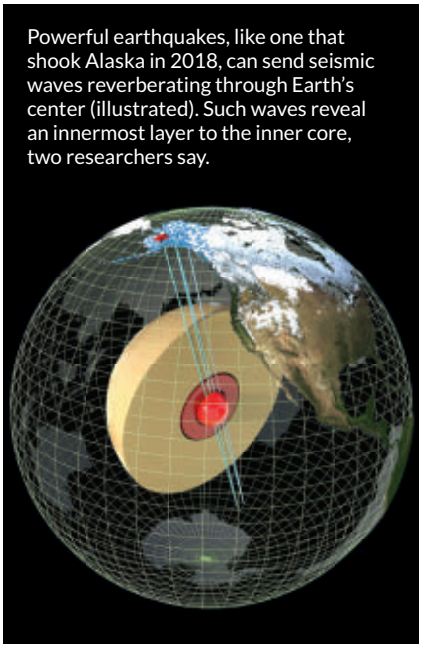
Exactly when this swirling dance began is unclear. Some studies have suggested it was as recent as 565 million years ago, a fraction of Earth's 4.5-billion-year life span (SN: 3/2/19, *p.* 13). The dance has faltered from time to time, its stuttering steps preserved in tiny magnetic grains in rocks.

Those data suggest the planet's magnetic poles have flip-flopped many times over the years, temporarily weakening the magnetic field (SN: 11/21/20, *p.* 4). As more and more crystals cool, the dance may eventually slow and stop, shutting off the planet's magnetic field millions or billions of years from now.

Different types and structures of minerals, as well as different amounts of liquid in the subsurface, can change the speed of seismic waves traveling through Earth, offering clues to the makeup of the interior. In 2002, researchers noted that seismic waves traveling through Earth's inner core move slightly slower in one direction relative to the planet's poles than in other directions.

The finding suggests there's some oddity there — a difference in crystal structure, perhaps. There might be a hidden heart, the team suggested, that is a kind of fossil: a long-preserved remnant of the core's early formation.

Since that observation, Tkalčić and others have pored over seismic data, finding independent lines of evidence that help support the idea of an innermost inner core. The reverberating waves, described February 21 in *Nature Communications*, also show a slowdown, and are the strongest evidence yet that this hidden heart exists.



Powerful earthquakes, like one that shook Alaska in 2018, can send seismic waves reverberating through Earth's center (illustrated). Such waves reveal an innermost layer to the inner core, two researchers say.

DREW WHITEHOUSE, T.-S. PHẠM AND H. TKALČIĆ

Tkalčić and seismologist Thanh-Son Phạm, also of the Australian National University, estimate that the inner core's secret chamber is roughly 600 kilometers across, or about a quarter of the diameter of the full inner core. And the pair was able to assess the direction of the slowest waves at about 50 degrees relative to the planet's rotation axis, which provided more insight into the region and helped distinguish the innermost core from the inner core.

The exact source of the seismic wave slowdown isn't clear, Tkalčić says. The phenomenon might be related to the structure of the iron crystals, which may pack together differently farther into the center. Or it could be from a different crystal alignment caused by some long-ago global event that changed how inner core crystals solidified out of the outer core.

The inner core holds many other mysteries too. Lighter elements present in small amounts in the core — hydrogen, carbon, oxygen — may flow around the solid iron in a liquidlike "superionic" state, further complicating the seismic picture of the inner core's structure (SN: 3/12/22, *p.* 12).

By identifying and reporting seismic waves that bounced back and forth through the planet's core multiple times, the researchers have made an invaluable contribution that will help scientists study the core in new ways, says seismologist Paul Richards of Columbia University's Lamont-Doherty Earth Observatory in Palisades, N.Y.

Still, the team's interpretation of the inner core's structure from those waves "is probably more iffy," Richards says.

One reason for this uncertainty is that as the waves bounce back and forth, they can become weaker and more difficult to see in the data. "Many further observations will help decide" what these new data can reveal about the heart of the planet, Richards says. ■

SWALLOWED LAND

Amid rising seas, Indigenous people of Panama plan to leave their island home

By Melba Newsome

The residents of the island of Gardi Sugdub in Panama's Guna Yala province (the island is shown here in 2014) face overcrowding and rising seas. More than a decade ago, they initiated a plan to move more than 300 families to a new community on the mainland.

ARNULFO FRANCO/AP PHOTO

In pictures from high above, the island of Gardi Sugdub resembles a container shipyard — small, brightly colored dwellings are jammed together cheek to jowl. At ground level, the island, one of more than 350 in the San Blas archipelago off the northern coast of Panama, is hot, flat and crowded. More than 1,000 people occupy the narrow dwellings that cover virtually every bit of the 150-by-400-meter island, which is slowly being swallowed by rising seas driven by climate change.

This year, about 300 families from Gardi Sugdub are expected to begin moving to a new community on the mainland. The resettlement plan was initiated by the residents there more than a decade ago when they could no longer deny that the island couldn't accommodate the growing population. Rising seas and intense storms are only making the predicament more dire.

Many of the older adults will opt to stay put. Some still don't believe climate change poses a threat, but 70-year-old Pedro Lopez is not among them. Lopez, whose cousin interpreted for him

THE CLIMATE FIX

This article is part of a series of stories on climate change solutions and how people around the world are tackling the biggest challenge of our time.

during our Zoom interview, currently shares a small house with 16 family members and the family dog. He doesn't plan to move. He knows Gardi Sugdub, translated as Crab Island, along with many others in the archipelago, is going underwater, but he believes it won't happen within his lifetime.

The Indigenous Guna people have occupied these Caribbean islands since around the mid-1800s, when they abandoned the coastal jungle area near what is now the Panama-Colombia border to establish better trade and escape disease-carrying pests. Now, they are among the estimated hundreds of millions of people worldwide who by the end of the century may be forced to flee their land because of rising sea levels (SN: 5/9/20 & 5/23/20, *p.* 22).

In the Caribbean, sea level rise currently averages around 3 to 4 millimeters per year. As global temperatures continue to rise, it is expected to hit 1 centimeter per year or more by century's end.

All of the islands of the San Blas archipelago will eventually be underwater and uninhabitable, says Steven Paton, who directs the Physical Monitoring Program at the Smithsonian Tropical Research Institute in Panama. "Some may need to be abandoned very soon while others not for many decades," he adds.

Anthropologist Anthony Oliver-Smith of the University of Florida in Gainesville has studied people who are forced from their homes by disasters for more than 50 years. Around the world, he says,

climate change has become a major driver of displacement, with people who have limited resources facing the worst of it.

The impacts of climate change — flooding, rising seas and erosion — are threatening the Tuvaluans in the South Pacific, the Mi'Kmaq of Prince Edward Island in Canada and the Shinnecock Indian Nation of New York. Half of some 1,600 remaining tribe members there still occupy a more than 300-hectare territorial homeland on Long Island surrounded by multimillion-dollar Southampton mansions.

The Guna relocation is being closely watched as a possible template for other threatened communities. What sets the Guna apart from many others is that they have a place to go.

Waters are rising

More than 30,000 Indigenous Guna inhabit the province now called Guna Yala, which includes the archipelago once known as San Blas and a strip of mainland. Most live on the islands, traveling back to the mainland to get water from the mouth of the river there, and in some cases to tend crops. Some of the islands sit several meters above average sea level, but the vast majority are uninhabited spits of land with palm trees, many only a meter or less above sea level.

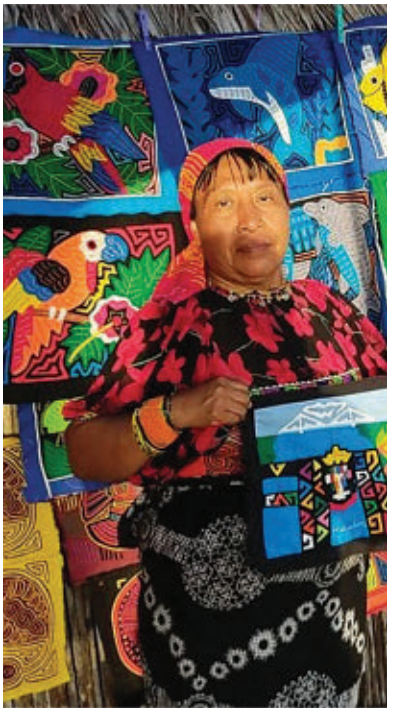
So far, only the residents of Gardi Sugdub are included in the relocation plan.

The Guna people of the islands are sustained by the biodiversity there. The sea, mangroves and nearby mainland forests provide food, medicine and building materials. The men hunt and fish to provide seafood to the best restaurants in Panama City, and agriculture remains part of the economy. Guna communities elect traditional authorities known as *sailas* ("chiefs" in Guna) and *argars* ("chief's spokesmen"), and they hold regular meetings to address community issues.

In recent decades, the Guna have moved toward an economy based on tourism and providing services to outsiders. They earn money supplying food, souvenirs and cultural artifacts to tourists but allow visitors to the islands only with prior approval from the *sailas*. Outsiders are not permitted to own property or operate businesses.

Carlos Arenas is an international human rights lawyer and an adviser on social and climate justice issues. When he visited Gardi Sugdub in 2014 as a consultant for Displacement Solutions, a nonprofit initiative focused on housing, land and property rights, he was tasked to assess the nascent relocation plans and provide recommendations. He was shocked to see the visible threat posed by the rising sea. "You cannot see much elevation," Arenas says. "The level of exposure was extremely high, but they don't see it necessarily that way. They have been living there for more than 170 years."

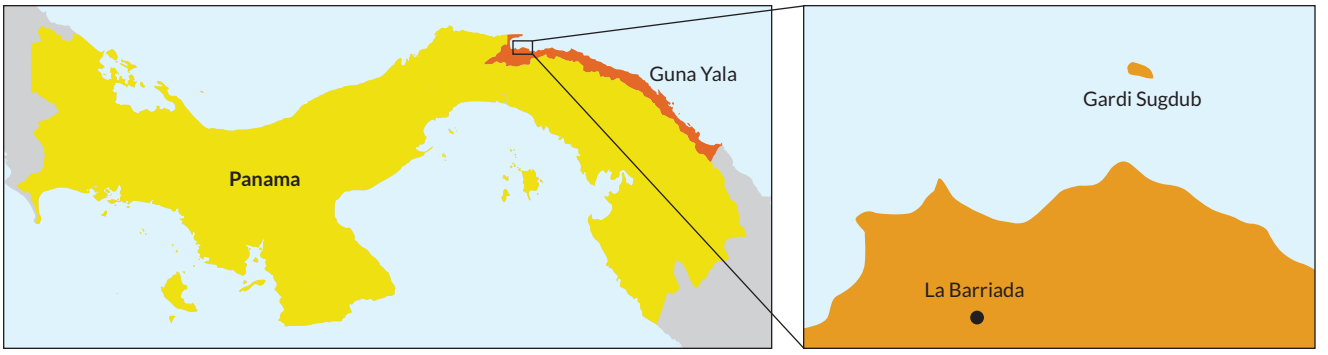
Heliodora Murphy grew up on Gardi Sugdub and has watched the ocean rise higher each year. The 52-year-old grandmother doesn't understand those who dismiss climate change in light of the growing



Gardi Sugdub resident Pedro Lopez, left, plans to stay on the island, while Heliodora Murphy, middle, has already picked out her new home on the mainland. The Guna hope to retain their traditional customs through the move, including handiwork called *wini* and *molas* (examples at right).

LEFT TWO: COURTESY OF IVETTE N. ROGERS; RIGHT: DIXON HAMBY/MOMENT/GETTY IMAGES PLUS

Where the Guna live



C. CHANG

physical evidence all around. Murphy, also speaking through an interpreter, recalls her father bringing rocks and sand from a river on the mainland to shore up pathways and keep their home dry.

Arenas says that some families face a daily struggle against the ocean. They build barriers that are immediately destroyed and have to be built again.

Some of the stopgap measures have been counterproductive, like filling in coral reefs to expand the land area. Reefs are a natural buffer against wave action, storm surges, flooding and erosion. Destroying them has only added to the peril.

Today, Murphy says, storm surges carry water into her small, ground-level home. "It's very different than in the past," she says. "The waves are so much higher now." About two years ago, she decided she'd move with her family. "We can't stay here."

A legacy of autonomy

Historically, the Guna have had a level of autonomy rare among Indigenous people. When the Spanish conquistadors arrived in what is now Colombia and Panama, the Guna lived primarily near the Gulf of Urabá on the northern coast of Colombia. The two groups clashed violently, prompting the Guna to abandon the coastal border area and move north into the jungle of Panama near the Caribbean. By the mid-1800s, entire villages had relocated again, this time to the San Blas archipelago.

Panama declared its independence from Spain in 1821 and became a part of Gran Colombia. Throughout the 19th century, the Guna lived independently according to their customs. That changed in 1903 when Panama broke from Colombia. The new nation attempted to assimilate the people living on the archipelago.

But having escaped Spanish rule centuries earlier and avoided Colombian authority as well, the Guna resisted Panama's acculturation efforts. When the Guna couldn't achieve détente through other means, they launched an armed attack against the Panamanians in February 1925.

The United States, having occupied the Panama Canal Zone since 1903, had geopolitical interests in the region and threw its support behind the Guna. That support forced the Panamanian government into a negotiated peace that allowed the Guna to continue their way of life. In 1938, the Guna islands and adjacent coastline were recognized as a semi-autonomous Indigenous territory, Guna Yala. The Guna have maintained control of that territory since.

A new home

The Gardi Sugdub residents first broached the idea of relocation in 2010. "They basically ran out of room," Oliver-Smith says.

He describes the Guna as the Indigenous people in Latin America who have been perhaps most successful in defending their cultural heritage, language and territory. They initiated the plans for resettlement and made arrangements among themselves to set aside 17 hectares of property on the mainland for these purposes. The land, within the Guna Yala territory, is near a school and health center being built by the Panamanian government.

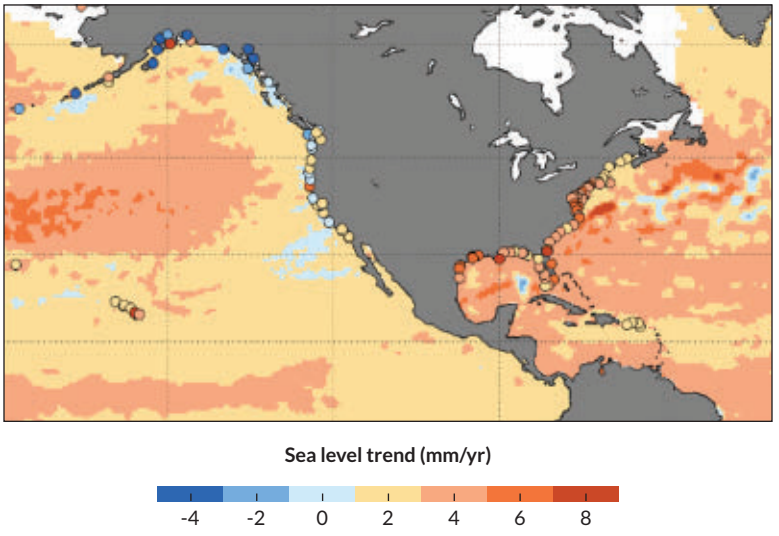
When Guna leaders approached the government, the Ministry of Housing initially promised to build 50 houses on the parcel. But it remained just that—a promise—until around 2014, when the Guna began to speak publicly about their situation. News of their predicament caught the attention of Indigenous rights organizations and eventually Displacement Solutions, which turned to Arenas and Oliver-Smith to evaluate the situation and offer recommendations about the best way forward.

Following Displacement Solutions' first report in 2014, Panama's Ministry of Housing agreed to build 300 houses, along with the hospital and school. But Arenas, who until the COVID-19 pandemic started had visited Guna Yala every year or so, says progress remained slow, causing the Guna to question Panama's commitment to the relocation. The Guna

Off the island

The Guna Yala territory includes a strip of land along Panama's northern coast and the more than 350 nearby islands. Families on the island of Gardi Sugdub will be moving to a new mainland community, sometimes called La Barriada.

Sea level rise in North and Central America, from 1993–2020



Rising seas
Measurements of the ocean surface height from satellites suggest sea levels are rising at an average rate of several millimeters per year across much of the Caribbean. Estimates for local sea level rise are limited by the availability of data from tide gauges (shown as dots).

leveraged support from international groups and members of the Panamanian government to get the project moving. "They were the originators of the idea of resettlement," Oliver-Smith says. "And they kept it alive."

Arenas estimates that roughly 200 of the 300 houses in the new community are complete. The cost for the houses, which are being paid for by the Panamanian government, exceeds $10 million, and the Inter-American Development Bank has invested $800,000 in technical assistance. The new homes will have cement floors, bamboo walls, zinc roofs, running water and full electrification.

Before plans to relocate began, many Guna had already moved to cities including Panama City and Colón for school, work or simply to have more room. Arenas expects that many more people already living in mainland Panama will likely join their families in the new community. People on other Guna Yala islands will likely have to move eventually too.

Murphy has already picked out her two-bedroom home for her small nuclear family of seven. Two daughters moved to Panama City years ago, and she hopes to see them more. But at around 40 square meters, the homes may not accommodate the typical multigenerational, double-digit Guna families. Lopez plans to stay on the island, letting the younger generations live in the family's new home on the mainland.

To ensure that the ethnic and cultural identities they fought to preserve are not lost in the move, the Guna plan to develop programs to teach traditions and culture to the resettled generations. But even on Gardi Sugdub, younger generations seem less inclined to practice the traditional customs — like making and wearing *wini* (vibrantly colored beads worn around the arms and legs) and *molas* (intricately designed fabric dresses that have become a symbol of Guna life and resistance to colonialism). Murphy began learning the craft when she was 6 years old. She spends two months constructing each ensemble, which she sells to tourists for $80.

Oliver-Smith is optimistic about the relocation plan but worries that the Panamanian government has repeated some mistakes that have doomed projects elsewhere by treating resettlement solely as a housing issue. "You don't just pick people up and move them from point A to point B. It is a reconfiguring of a life of a people," Oliver-Smith says. "It has political, social, economic, environmental, spiritual and cultural dimensions."

As is often the case when Indigenous and rural communities relocate, Arenas says, the government failed to make the Guna equal participants in the design concept. "The Panamanian government is trying to build a Panama City neighborhood in the middle of a tropical forest," he says. "They have not tried to save a single tree of this beautiful landscape.... They removed everything. They tried to flatten the land because it's cheaper.... It's also extremely hot there, and the building materials are hot." This increases the risk of failure, he says, because the houses don't match the environment.

But Murphy hopes everything will be better. The new village promises dry land and more space. And perhaps returning to the mainland the Guna occupied nearly 150 years ago will lead to a stronger connection to Guna historical culture and traditions.

Oliver-Smith says the Guna are facing the challenge of resettlement with an intact culture and language that he hopes will be a basis for maintaining cultural continuity. His time spent with the Guna has convinced him that, as disruptive and devastating as resettlement can be, the Guna relocating as a cohesive group are perhaps best equipped to emerge intact even if not unscathed.

"Carlos [Arenas] and I asked an old, retired *saila* if he thought resettlement would change the Guna," he says. "He said, 'No. Individuals may change out of choice, but our culture is eternal. It will never die.'" ■

Explore more

- Alister Doyle. *The Great Melt: Accounts from the Frontline of Climate Change.* Flint, 2023.

Melba Newsome is a freelance journalist based in Charlotte, N.C.

NOAA

The Watch for When It's a Million O'Clock

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"This is a beautiful watch and it keeps the time perfectly ... Highly recommended."
— Daniel J., Antioch, IL

When traveling the globe, my friend Cynthia has a term for that slightly delirious, unmoored feeling of jumping time zones and not being sure what hour it is: "It's a million o'clock."

I found myself in such a situation this past summer while changing planes in Jakarta. My phone had run out of juice, and I'd somehow managed to pack my phone charger in my checked bag. I had a long layover and might have missed my flight entirely if it weren't for my In the Nick of Time Watch. This sturdy chronograph has a precision movement that oscillates an incredible 32,768 times per second. With a 24-hour dial, 60-second dial, 60-minute dial and a date window, this timekeeper will help you stay on top of whatever your travels throw at you.

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Homework HELP?

ChatGPT and other AI tools are poised to disrupt education

By Kathryn Hulick

GLENN HARVEY

We need to talk," Brett Vogelsinger said. A student had just asked for feedback on an essay. One paragraph stood out. Vogelsinger, a ninth grade English teacher in Doylestown, Pa., realized that the student hadn't written the piece himself. He had used ChatGPT.

The artificial intelligence tool, made available for free late last year by the company OpenAI, can reply to simple prompts and generate essays and stories. It can also write code.

Within a week, it had more than a million users. As of early 2023, Microsoft planned to invest $10 billion into OpenAI, and OpenAI's value had been put at

$29 billion, more than double what it was in 2021.

It's no wonder other tech companies have been racing to put out competing tools. Anthropic, an AI company founded by former OpenAI employees, is testing a new chatbot called Claude. Google launched Bard in early February, and the Chinese search company Baidu released Ernie Bot in March.

A lot of people have been using ChatGPT out of curiosity or for entertainment. I asked it to invent a silly excuse for not doing homework in the style of a medieval proclamation. In less than a second, it offered me: "Hark! Thy servant was beset by a horde of mischievous leprechauns, who didst steal mine quill and parchment, rendering me unable to complete mine homework."

But students can also use it to cheat. ChatGPT marks the beginning of a new wave of AI, a wave that's poised to disrupt education.

When Stanford University's student-run newspaper polled students at the university, 17 percent said they had used ChatGPT on assignments or exams at the end of 2022. Some admitted to submitting the chatbot's writing as their own. For now, these students and others are probably getting away with it. That's because ChatGPT often does an excellent job.

"It can outperform a lot of middle school kids," Vogelsinger says. He might not have known his student had used it, except for one thing: "He copied and pasted the prompt."

The essay was still a work in progress, so Vogelsinger didn't see it as cheating. Instead, he saw an opportunity. Now, the student and AI are working together. ChatGPT is helping the student with his writing and research skills.

"[We're] color-coding," Vogelsinger says. The parts the student writes are in green. The parts from ChatGPT are in blue. Vogelsinger is helping the student pick and choose a few sentences from the AI to expand on—and allowing other students to collaborate with the tool as well. Most aren't turning to it regularly, but a few kids really like it. Vogelsinger thinks the tool has helped them focus their ideas and get started.

This story had a happy ending. But at many schools and universities, educators are struggling with how to handle ChatGPT and other AI tools.

In early January, New York City public schools banned ChatGPT on their devices and networks. Educators were worried that students who turned to it wouldn't learn critical-thinking and problem-solving skills. They also were concerned that the tool's answers might not be accurate or safe. Many other school systems in the United States and around the world have imposed similar bans.

Keith Schwarz, who teaches computer science at Stanford, said he had "switched back to pencil-and-paper exams," so students couldn't use ChatGPT, according to the *Stanford Daily*.

Yet ChatGPT and its kin could also be a great service to learners everywhere. Like calculators for math or Google for facts, AI can make writing that often takes time and effort much faster. With these tools, anyone can generate well-formed sentences and paragraphs. How could this change the way we teach and learn?

The good, the bad and the weird

ChatGPT has wowed its users. "It's so much more realistic than I thought a robot could be," says Avani Rao, a sophomore in high school in California. She hasn't used the bot to do homework. But for fun, she's prompted it to say creative or silly things. She asked it to explain addition, for instance, in the voice of an evil villain.

Given how well it performs, there are plenty of ways that ChatGPT could level the playing field for students and others working in a second language or struggling with composing sentences. Since ChatGPT generates new, original material, its text is not technically plagiarism.

Students could use ChatGPT like a coach to help improve their writing and grammar, or even to explain subjects they find challenging. "It really will tutor you," says Vogelsinger, who had one student

Who said what? When prompted, ChatGPT can craft answers that sound surprisingly like those from a student. We asked middle school and high school students from across the country, all participants in our Science News Learning education program, to answer some basic science questions in two sentences or less. The examples throughout the story compare how students responded with how ChatGPT responded when asked to answer the question at the same grade level.

What effect do greenhouse gases have on the Earth?

AGNES B. | GRADE 11, HARBOR CITY INTERNATIONAL SCHOOL, MINN.

Greenhouse gases effectively trap heat from dissipating out of the atmosphere, increasing the amount of heat that remains near Earth in the troposphere.

CHATGPT

Greenhouse gases trap heat in the Earth's atmosphere, causing the planet to warm up and leading to climate change and its associated impacts like sea level rise, more frequent extreme weather events and shifts in ecosystems.

come to him excited that ChatGPT had clearly outlined a concept from science class.

Educators could use ChatGPT to help generate lesson plans, activities or assessments — perhaps even personalized to address the needs or goals of specific students.

Xiaoming Zhai, an expert in science education at the University of Georgia in Athens, tested ChatGPT to see if it could write an academic paper. He was impressed with how easy it was to summarize knowledge and generate good writing using the tool. "It's really amazing," he says.

All of this sounds wonderful, but really big problems exist. Most worrying, ChatGPT and other similar tools can often get things very wrong. They don't pull facts from databases. Rather, they are trained to generate new text that sounds natural. They remix language without understanding it, which can lead to glaring mistakes.

The news website CNET came under fire earlier this year for using AI to churn out dozens of articles, many of them packed with errors. In an early advertisement for the Bard chatbot, it made a factual error about the James Webb Space Telescope, incorrectly claiming that it had taken the very first picture of an exoplanet. And ChatGPT said in a conversation posted on Twitter that the fastest marine mammal was the peregrine falcon. A falcon, of course, is a bird and doesn't live in the ocean.

ChatGPT is "confidently wrong," says Casey Fiesler, an expert in the ethics of technology at the University of Colorado Boulder. "There are mistakes and bad information." She has made multiple TikTok videos about the pitfalls of ChatGPT.

Most of ChatGPT's training data come from before September 2021, and it does not provide sources for its information. If asked for sources, it makes them up, Fiesler revealed in one video. Zhai, who sees the tool as an assistant, discovered the exact same thing. When he asked ChatGPT for citations, it gave him sources that looked correct. But they didn't actually exist.

ChatGPT does not provide sources for its information. If asked for sources, it makes them up.

Under the hood

ChatGPT's mistakes make sense if you know how it works. "It doesn't reason. It doesn't have ideas. It doesn't have thoughts," explains Emily M. Bender, a computational linguist at the University of Washington in Seattle.

ChatGPT was developed using at least two types of machine learning. The primary type is a large language model based on an artificial neural network. Loosely inspired by how neurons in the brain interact, this computing architecture finds statistical patterns in vast amounts of data.

A language model learns to predict what words will come next in a sentence or phrase by churning through vast amounts of text. It places words and phrases into a multidimensional map that represents their relationships to one another. Words that tend to come together, like peanut butter and jelly, end up closer together in this map.

The size of an artificial neural network is measured in parameters. These internal values get tweaked as the model learns. In 2020, OpenAI released GPT-3. At the time, it was the biggest language model ever, containing 175 billion parameters. It had trained on text from the internet as well as digitized books and academic journals. Training text also included transcripts of dialog, essays, exams and more, says Sasha Luccioni, a Montreal-based researcher at Hugging Face, a company that builds AI tools.

OpenAI improved upon GPT-3 to create GPT-3.5. In early 2022, the company released a fine-tuned version of GPT-3.5 called InstructGPT. This time, OpenAI added a new type of machine learning. Called reinforcement learning with human feedback, it puts people into the training process. These workers check the AI's output. Responses that people like get rewarded. Human feedback can also help reduce hurtful, biased or inappropriate responses. This fine-tuned language model powers freely available

Define the term biodiversity.

DANTE A. | GRADE 10, CLARK MAGNET HIGH SCHOOL, CALIF.

Biodiversity refers to the variety of living species and ecosystems that exist in a particular region or on the planet as a whole. It encompasses the different genes, species and ecosystems that make up the natural world and the relationships between them.

CHATGPT

Biodiversity refers to the variety of living organisms that inhabit the Earth and the ecosystems they form. It includes the diversity of species, genes and ecosystems, and is important for maintaining the balance of nature and sustaining life on our planet.

ChatGPT. As of March, paying users receive answers powered by GPT-4, a bigger language model.

During ChatGPT's development, OpenAI added extra safety rules to the model. It will refuse to answer certain sensitive prompts or provide harmful information. But this step raises another issue: Whose values are programmed into the bot, including what it is—or is not—allowed to talk about?

OpenAI is not offering exact details about how it developed and trained ChatGPT. The company has not released its code or training data. This disappoints Luccioni because it means the tool can't benefit from the perspectives of the larger AI community. "I'd like to know how it works so I can understand how to make it better," she says.

When asked to comment on this story, OpenAI provided a statement from an unnamed spokesperson. "We made ChatGPT available as a research preview to learn from real-world use, which we believe is a critical part of developing and deploying capable, safe AI systems," the statement said. "We are constantly incorporating feedback and lessons learned." Indeed, some experimenters have gotten the bot to say biased or inappropriate things despite the safety rules. OpenAI has been patching the tool as these problems come up.

ChatGPT is not a finished product. OpenAI needs data from the real world. The people who are using it are the guinea pigs. Notes Bender: "You are working for OpenAI for free."

People versus robots

How good is ChatGPT in an academic setting? Catherine Gao, a doctor and medical researcher at Northwestern University's Feinberg School of Medicine in Chicago, is part of one team of researchers that is putting the tool to the test.

Gao and her colleagues gathered 50 real abstracts from research papers in medical journals and then, after providing the titles of the papers and the journal names, asked ChatGPT to generate 50 fake abstracts. The team asked people familiar with reading and writing these types of research papers to identify which were which.

"I was surprised by how realistic and convincing the generated abstracts were," Gao says. The reviewers mistook roughly one-third of the AI-generated abstracts as human-generated.

In another study, Will Yeadon and colleagues tested whether AI tools could pass a college exam. Yeadon, a physics instructor at Durham University in England, picked an exam from a course that he teaches. The test asks students to write five short essays about physics and its history. Students have an average score of 71 percent, which he says is equivalent to an A in the United States.

What are black holes and where are they found?

ALTHEA C. | GRADE 11, WAIMEA HIGH SCHOOL, HAWAII

A black hole is a place in space where gravity is so strong that nothing, not even light, may come out.

CHATGPT

Black holes are extremely dense regions in space where the gravity is so strong that not even light can escape, and they are found throughout the universe.

Yeadon used the tool davinci-003, a close cousin of ChatGPT. It generated 10 sets of exam answers. Then Yeadon and four other teachers graded the answers using their typical standards. The AI also scored an average of 71 percent. Unlike the human students, though, it had no very low or very high marks. It consistently wrote well, but not excellently. For students who regularly get bad grades in writing, Yeadon says, it "will write a better essay than you."

These graders knew they were looking at AI work. In a follow-up study, Yeadon plans to use work from the AI and students and not tell the graders whose is whose.

Checking for cheating

When it's unclear whether ChatGPT wrote something or not, other AI tools may help. These tools typically train on AI-generated text and sometimes human-generated text as well. They can tell you how likely it is that text was composed by an AI. Many of the existing tools were trained on older

What is heat?

PRECIOUS A. | GRADE 6, CANYON DAY JUNIOR HIGH SCHOOL, ARIZ.

Heat is the transfer of kinetic energy from one medium or object to another, or from an energy source to a medium or object through radiation, conduction and convection.

CHATGPT

Heat is a type of energy that makes things warmer. It can be produced by burning something or through electricity.

What is DNA and how is it organized?

LUKE M. | GRADE 8, EASTERN YORK MIDDLE SCHOOL, PA.

DNA, or deoxyribonucleic acid, is kept inside the cells of living things, where it holds instructions for the genetics of the organism it is inhabiting.

CHATGPT

DNA is like a set of instructions that tells our cells what to do. It's organized into structures called chromosomes, which contain all of the DNA in a cell.

language models, but developers are working quickly to put out new, improved tools.

A company called Originality.ai sells access to a tool that trained on GPT-3. Founder Jon Gillham says that in a test of 10,000 samples of texts composed by models based on GPT-3, the tool tagged 94 percent of them correctly as AI-generated. When ChatGPT came out, his team tested a smaller set of 20 samples. Each only 500 words in length, these had been created by ChatGPT and other models based on GPT-3 and GPT-3.5. Here, Gillham says, the tool correctly identified 97 percent of them as AI-generated.

In late January 2023, OpenAI released its own free tool for spotting AI writing, cautioning that the tool was "not fully reliable." The company is working to add watermarks to its AI text, which would tag the output as machine-generated, but doesn't give details on how. Gillham describes one possible approach: Whenever it generates text, the AI ranks many different possible words for each position. If its developers told it to always choose the word ranked in third place rather than first place at specific points in its output, those words could act as a fingerprint, he says.

As AI writing tools improve, the tools to sniff them out will need to improve as well. Eventually, some sort of watermark might be the only way to sort out true authorship.

As AI writing tools improve, the tools to sniff them out will need to improve as well.

The future of writing

There's no doubt we will soon have to adjust to a world in which computers can write for us. But educators have made these sorts of adjustments before. As high school student Rao points out, Google was once seen as a threat to education because it made it possible to look up facts instantly. Teachers adapted by coming up with teaching and testing materials that don't depend as heavily on memorization.

Now that AI can generate essays and stories, teachers may once again have to rethink how they teach and test. Rao says: "We might have to shift our point of view about what's cheating and what isn't."

Some teachers will prevent students from using AI by limiting access to technology. Right now, Vogelsinger says, teachers regularly ask students to write out answers or essays at home. "I think those assignments will have to change," he says. But he hopes that doesn't mean kids do less writing.

Teaching students to write without AI's help will remain essential, agrees Zhai. That's because "we really care about a student's thinking," he stresses. And writing is a great way to demonstrate thinking. Though ChatGPT can help a student organize their thoughts, it can't think for them, he says.

Kids still learn to do basic math even though they have calculators (which are often on the phones they never leave home without), Zhai acknowledges. Once students have learned basic math, they can lean on a calculator for help with more complex problems.

In the same way, once students have learned to compose their thoughts, they could turn to a tool like ChatGPT for assistance with crafting an essay or story. Vogelsinger doesn't expect writing classes to become editing classes, where students brush up AI content. He instead imagines students doing prewriting or brainstorming, then using AI to generate parts of a draft, and working back and forth to revise and refine from there.

Though he's overwhelmed about the prospect of having to adapt his teaching to another new technology, he says he is "having fun" figuring out how to navigate the new tech with his students.

Rao doesn't see AI ever replacing stories and other texts generated by humans. Why? "The reason those things exist is not only because we want to read it but because we want to write it," she says. People will always want to make their voices heard. ■

Explore more

- Try ChatGPT at https://openai.com/blog/chatgpt

Kathryn Hulick is a freelance writer and author of Welcome to the Future: Robot Friends, Fusion Energy, Pet Dinosaurs and More!

Period
Kate Clancy
PRINCETON UNIV., $27.95

BOOKSHELF

This book will change how you think about menstruation

In a February golf tournament, after Tiger Woods hit his ball farther on the ninth tee than Justin Thomas, Woods handed Thomas a tampon. Get it? Thomas is weak! Haha.

Contrast this with the viral videos of writhing men hooked up to a menstrual cramp simulator created to bring awareness to period pain. When CBS News correspondent Jamie Yuccas' producer tried the simulator set at the pain level Yuccas regularly experiences, he was visibly distressed. "Are you serious? This is your baseline?" he said, with a following comment bleeped out.

There probably aren't enough cramp simulators to enlighten everyone who doesn't menstruate. But here's another option: Hand them a copy of Kate Clancy's *Period: The Real Story of Menstruation*. Better yet, give this book to everyone. Getting accurate information about the why and how of periods is difficult even for those who do menstruate. There remains considerable stigma and revulsion toward this physiological event that half the population experiences during a large portion of life.

Clancy, an anthropologist at the University of Illinois Urbana-Champaign, studies the impact of environmental stressors on the physiology of menstruating people. In *Period*, she lays out the science of menstruation along with details on the reproductive cycle and the uterus. She also challenges readers to think about the research climate, dominated by white men, that has shaped the views of menstruation and the female reproductive system (SN: 4/9/22, p. 29).

"Given anthropology's history of removing women from the hero myths of human evolution or never noticing their worth in the first place," Clancy writes, "menstruation is worth a closer look."

For example, Clancy lays out emerging evidence on menstrual priming, the idea that each time the body prepares the lining of the uterus for a possible embryo and then repairs the lining during menstruation, it's conditioning the uterus to better provide a rich and nourishing site for an eventual pregnancy. In other words, periods serve an evolutionary purpose. It's not just the body expelling the lining because it's reached the end of its shelf life, as a major hypothesis contends.

Clancy also discusses the long history of viewing menstruation as polluting. A popular "medical" textbook from medieval times contended that menstruating women emitted dangerous fumes that could "poison the eyes of children lying in their cradles by a glance."

This notion has persisted. In 1920 in Vienna, a doctor named Béla Schick claimed that menstruating women secreted toxins, after a series of experiments in which such women handled flowers that then wilted. These "menotoxins" became a go-to explanation for a number of women's illnesses — as well as the ailments of those who were *nearby* a menstruating woman — for decades. Poisonous fumes all over again.

Of course, "menotoxins" aren't real. But the idea that menstruation is polluting still shapes attitudes. Clancy writes of a 2002 study in which a participant was paired with a woman, an actor playing a participant. After reaching into her handbag, the actor would accidentally drop either a tampon or a hair clip. In questionnaires, the participants who had seen the tampon rated the woman less capable and likeable. And in a sign of disgust, participants were more likely to sit away from the actor after she had dropped a tampon than after she had dropped a hair clip.

Considering the stigma, it's no surprise that menstruating people tend to hide their periods. To change attitudes, Clancy writes, it's time to become "more visible as menstruating people." The disgust about menstruation is learned and it leads to silence, she writes, which means that people with uteruses cede their agency. When menstruation is hidden, it makes it easier for the rest of society to ignore menstruating people.

Clancy would like society to acknowledge and better accommodate menstruation, and she's not alone. In a survey of nearly 33,000 women in the Netherlands, 81 percent reported that menstrual symptoms are disruptive to work and school, researchers reported in *BMJ Open* in 2019. Sixty-eight percent said that, during their periods, they'd like more flexibility with tasks and their work and school hours. The Spanish parliament took a step in this direction in February, passing legislation for paid menstrual leave.

Clancy ends *Period* by envisioning a society that considers menstruating people's needs, that offers contraception and menstrual suppression options that work for more people, that takes menstrual pain seriously, and more. "What I am imagining is a world where it is as unremarkable for someone to openly carry a tampon as it is to carry a hair clip and where discussing the care of our bodies does not label us weak." — *Aimee Cunningham*

"Given anthropology's history of removing women from the hero myths of human evolution or never noticing their worth in the first place, menstruation is worth a closer look."

20 YEARS & COUNTING

Society for Science celebrates two decades of journalism for young people

When Society for Science first launched an online news website for young people in March 2003, the world was a different place. People used dial-up internet access, cell phones were mainly used for talking and social media was still in its infancy. As the world has transformed, so has Science News Explores.

First launched as Science News for Kids, new stories were posted just once a week. Fast forward to 2023, and now, Science News Explores offers so much more—daily news written by top-notch journalists, a print magazine, email newsletters, puzzles, comics and educator resources.

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SOCIETY FOR SCIENCE

FEBRUARY 25, 2023

Earth's uneven layers

The rotation of Earth's solid inner core may have recently paused relative to the mantle and crust and now appears to be reversing direction, ***Nikk Ogasa*** *reported in "Earth's inner core may 'reverse' its spin"* (SN: 2/25/23, p. 7).

The inner core's rotation is thought to be partly influenced by the mantle's gravitational pull, **Ogasa** reported. Reader **Robert G. Chester** wondered how that could be true given the shell theorem, which states that a body inside a spherically symmetrical shell should experience a net-zero gravitational force.

The mantle indeed serves as a shell around the core. And if Earth's layers were perfectly spherical and symmetrical, the inner core would not experience a gravitational force as it rotates, says geophysicist **Yi Yang** of Peking University in Beijing. But Earth's structure is not uniform. The mantle is elliptical and its density varies, so the gravitational forces acting on the inner core at different points are not exactly the same, **Yang** says.

Plant power

Thanks to special motorlike cells, Mimosa pudica *plants can close their feathery leaflets like a book when touched,* ***Susan Milius*** *reported in "How 'plant muscles' fold up a mimosa"* (SN: 2/25/23, p. 13).

Reader **Van Snyder** mused over the variety of ways that plants move, from leaves that follow the sun to the killer close of Venus flytraps. Do these plant motions use different mechanisms?

Various mechanisms can drive plant motion, says biomechanist **David Sleboda** of the University of California, Irvine. "Sunflowers, for example, track the movement of the sun by only growing one side of their stem at a time, causing the stem to bend back and forth over the course of a day," **Sleboda** says. In contrast, Venus flytraps use pressure building in specialized cells. The trap's bowed shape increases speed and power for a "snap-buckle" close when prey enters the trap, he says.

While these mechanisms have distinct features, "almost all plant movements involve manipulation of water," **Sleboda** says. Sunflowers draw water from the ground that inflates cells during growth. *M. pudica* and Venus flytraps shunt water within their bodies to make cells swell and induce motion. "Plants are hydraulic beings," he says.

Milius' story resurfaced fun memories for educator **Maggie Eisenberger**. "My middle school students, on a trip to Costa Rica, chose to investigate whether it was possible to fatigue the response to touch in [*M. pudica*]," **Eisenberger** wrote. "They timed the closing of the leaflets, then timed the reopening. Repeating the cycle with the same plant revealed that not only did the motion take longer each time, the leaflets also eventually failed to close very tightly or open fully," she recalled. Her students "hypothesized that the motion was to deter leaf-eating insects, but if an insect persisted, it might still win the battle."

Clarification

While describing quantum entanglement in "Store data with a quantum twist," the story stated that something that affects one member of an entangled photon pair instantly affects the other (*SN: 2/25/23, p. 12*). It would have been more accurate to say that entangled particles have properties that are linked. *Science News* has previously explained in detail the nuances of talking about quantum entanglement. Read more about it at bit.ly/SN_Entanglement.

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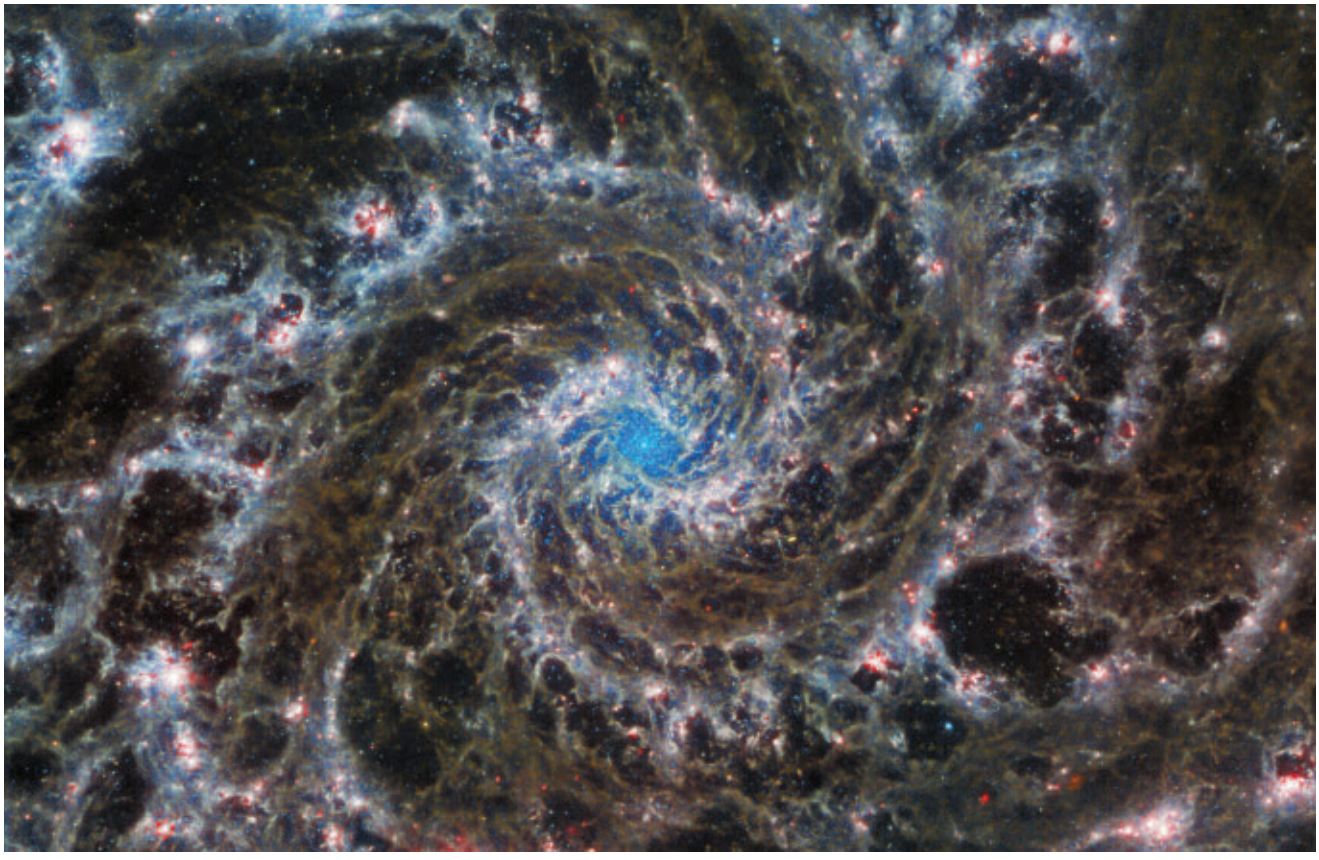

How newborn stars sculpt their galaxies

A gaggle of galaxies crackle with intricate detail in new images from the James Webb Space Telescope. JWST's sharp infrared eyes are revealing how newborn stars shape their surroundings, giving hints to how stars and galaxies grow up together.

"For the first time, we're seeing the youngest sites of star formation in a lot of these galaxies," says Janice Lee, an astronomer at the University of Arizona in Tucson. Before JWST launched in December 2021, Lee and her colleagues selected 19 relatively nearby galaxies that, if observed with the telescope, might reveal new details of the life cycles of stars. She and others reported on scientists' first look at some of these galaxies with JWST in the Feb. 20 *Astrophysical Journal Letters*.

Until now, parts of these galaxies had always looked flat and featureless. But a JWST image of galaxy NGC 628 (above), for example, reveals never-before-seen dark voids that pockmark glowing filaments of gas and dust in the spiral arms winding out from its center. Comparisons with images from the Hubble Space Telescope reveal the voids to be bubbles carved out of the gas and dust by radiation from new stars in the bubbles' centers. (The new stars aren't visible in the JWST image.)

When the most massive of those stars explode, that gas and dust seems to get pushed out even more. Some of the larger bubbles have smaller bubbles (not visible in this image) on their edges, which could indicate spots where the gas pushed by dying stars has started to build new stars. JWST also revealed a horde of young stars (blue) in the galaxy's center.

Comparing how star birth and death influence different types of spiral galaxies will help astronomers understand how galaxies' shapes and properties influence the life cycles of their stars, and how galaxies grow and change with their stellar denizens. A JWST image of the barred spiral NGC 1365 (left) reveals that its center glows with dust. Why this one is dusty while NGC 628's center is not—and how that difference might relate to star formation—isn't yet clear.

"We've only studied the first few [of the 19 selected] galaxies," Lee says. "We need to study these things in the full sample to understand how the environment changes … how stars are born." —*Lisa Grossman*

FROM TOP: WEBB/ESA, NASA, CSA, J. LEE AND THE PHANGS-JWST TEAM, J. SCHMIDT; NASA, ESA, CSA, JANICE LEE/NOIRLAB, ALYSSA PAGAN/STSCI

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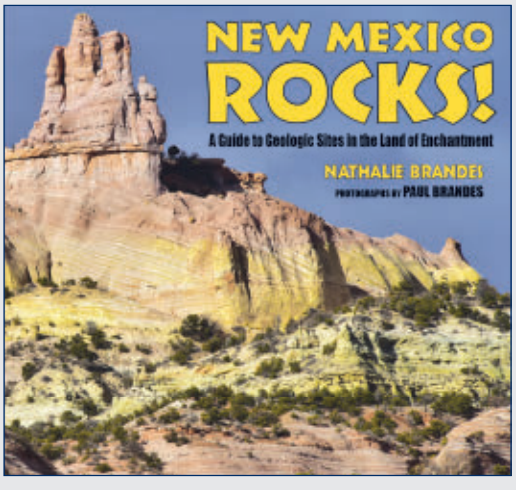

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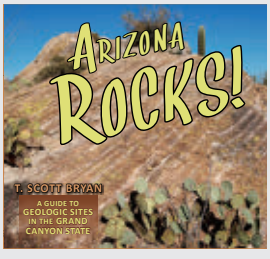

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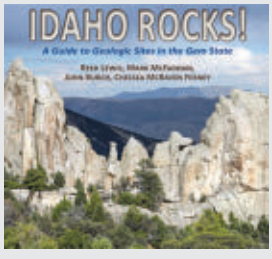

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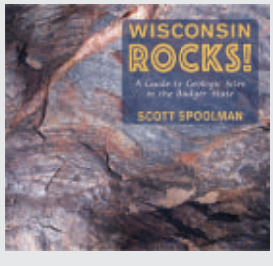

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