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ScienceNews

MAG ...TOR SCIENCE ■ FEBRUARY 11, 2023

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COVER The skeleton of Stan the *T. rex* sold at a Christie's auction in 2020 for $31.8 million, the highest price ever paid for a fossil. *Francois Gohier/Science Source*

So much is lost when fossil treasures go private

I don't remember exactly which dinosaurs I saw when I first visited Chicago's Field Museum as a child, but I'll never forget the thrill of seeing the gigantic skeletons striding forth out of the past. Since then, I've seen many other fossilized dinos at many other museums, and the thrill remains the same.

This issue's cover story investigates the soaring popularity of museum-quality dinosaur fossils as collectibles, with highbrow auction houses like Christie's selling off *Tyrannosaurus rex* skeletons as if they're pieces of art. As earth and climate writer Carolyn Gramling reports, Stan the *T. rex*, a skeleton discovered on private land in South Dakota, sold for an eye-popping $31.8 million in 2020, and a *T. rex* skull went for $6.1 million last December (Page 24).

Stan disappeared after it was auctioned off. Last year, it was revealed that the United Arab Emirates is the owner and intends to place Stan in a new natural history museum. The fossil trade is nothing new, but most museums can't compete at these price points. And though many countries regulate fossil sales, loopholes abound.

With each fossil that disappears from public view, science — and the public — loses. Scientists fear that new finds could go straight to private owners without being properly studied. With so few *T. rex* fossils unearthed, each specimen holds tremendous scientific value.

Fortunately for us dinophiles, museums do have *T. rex* skeletons on display and in their collections. The Field Museum houses Sue, whose $8.36 million purchase in 1997 was underwritten by corporations and academic institutions. The Smithsonian's National Museum of Natural History in Washington, D.C., is home to a *T. rex* discovered in Montana in 1988. Because the fossil was found on federal land, it avoided the auction block and now chomps on an unlucky *Triceratops* in the museum's recently renovated fossil hall.

In this issue, we also explore another source of frustration in science: Our limited understanding of depression (Page 18). The often-debilitating disorder affects millions of people worldwide. But despite decades of effort, scientists still can't describe how it works or what causes it. The familiar "chemical imbalance" theory doesn't fully capture what's going on in the brain, let alone the influence of external factors like gender, race and culture. How an individual experiences depression also depends on where they live and how they experience the world around them.

Researchers are seeking not only a better grasp on what's happening inside the brain, but also how internal and external factors interact. One barrier to moving the science forward is that different researchers rely on different definitions of depression and different methods of assessing whether a person is depressed. As neuroscience and senior writer Laura Sanders notes, it's like trying to figure out the science of temperature without a thermometer.

It's an extraordinary challenge, and one that researchers may not solve in their lifetimes. But I'm grateful that they're trying to discover the roots of a malady that plagues so many. — *Nancy Shute, Editor in Chief*

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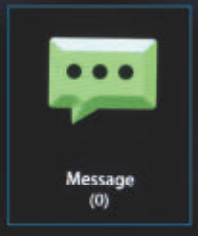

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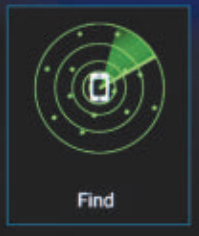

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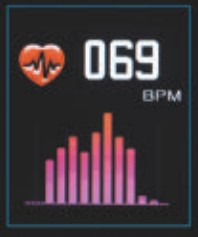
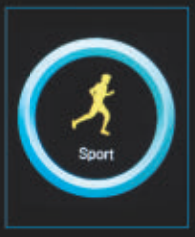


Monitor heart rate



Track steps and calories

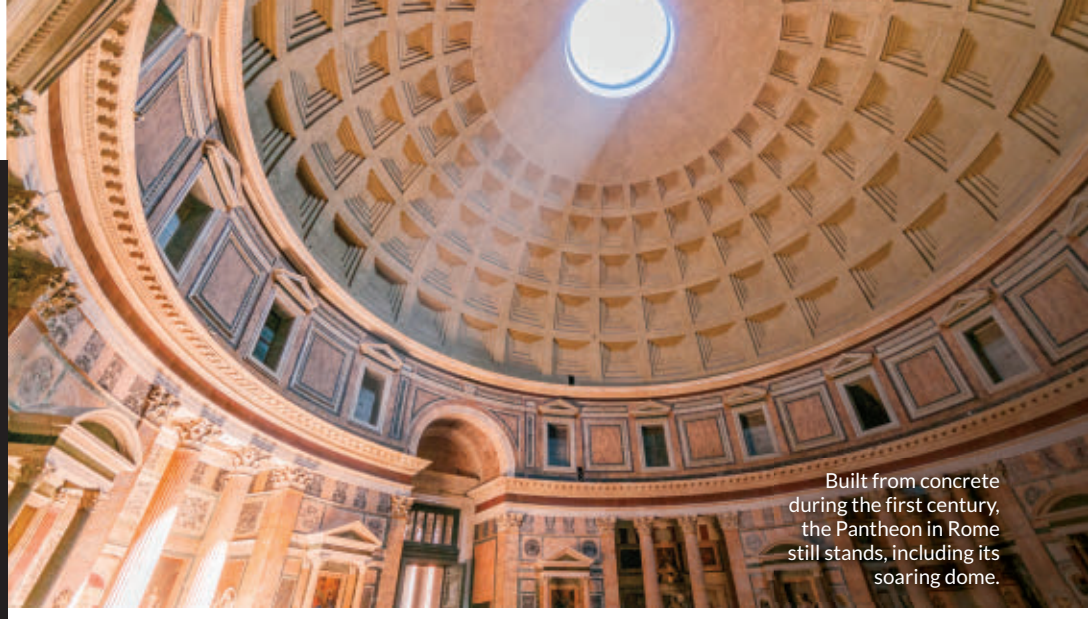
Excerpt from the February 10, 1973 issue of *Science News*

50 YEARS AGO

Setting sail into a plastic sea

Scientists on an oceanographic voyage in the Central North Pacific last August became startled about the number of manmade objects littering the ocean surface. [Far from civilization and shipping lanes], they recorded 53 manmade objects in 8.2 hours of viewing. More than half were plastic. They go on to compute that there are between 5 million and 35 million plastic bottles adrift in the North Pacific.

UPDATE: The Great Pacific Garbage Patch is larger now than it was in 1973, containing an estimated 1.8 trillion pieces of plastic within an area twice the size of Texas (*SN Online: 3/22/18*). In recent years, marine biologists have started seeing evidence that garbage is disrupting ocean ecosystems. For instance, large pieces of trash have helped species cross into new territories (*SN: 10/28/17, p. 32*). But an even greater threat may lurk beneath the waves. Tiny bits of plastic concentrate hundreds of meters deep where they can be eaten by filter feeders and potentially make their way into the guts of larger predators (*SN: 7/6/19 & 7/20/19, p. 5*).



Built from concrete during the first century, the Pantheon in Rome still stands, including its soaring dome.

STEPHEN KNOWLES PHOTOGRAPHY/MOMENT/GETTY IMAGES PLUS

THE SCIENCE LIFE

Chemists crack the code to ancient Roman concrete

MIT chemist Admir Masic really hoped his experiment wouldn't explode.

Masic and colleagues were trying to re-create an ancient Roman technique for making concrete, a mix of cement, gravel, sand and water. The team suspected the key was a process called hot mixing, in which dry granules of calcium oxide, also called quicklime, are mixed with volcanic ash to make the cement. Then water is added.

Hot mixing, they thought, would produce cement containing small calcium-rich rocks. "In every sample we have seen of ancient Roman concrete, you can find these white inclusions," Masic says. Those might be the key to why Roman structures such as the Pantheon, which is nearly 2,000 years old, have withstood the ravages of time.

The reaction of quicklime with water can produce a lot of heat—and possibly an explosion. But no big bang happened. Instead, the reaction produced heat, a damp sigh of water vapor and a Roman-like cement with the rocks, as expected.

Scientists have been trying for decades to re-create the Roman recipe for concrete longevity, with little success. The team's idea that hot mixing was key was an educated guess, guided by texts by ancient Roman architect Vitruvius and historian Pliny the Elder. The texts cited strict instructions for the raw materials, including that the source of quicklime must be pure and that mixing quicklime, hot ash and water could produce a lot of heat. Rocks weren't mentioned, but the team suspected they were important.

Previously, scientists suspected the rocks resulted from incomplete mixing. But ancient Romans were highly organized. It's unlikely that every operator improperly mixed the cement and that every single building has a flaw, Masic says.

Perhaps, he thought, the rocks were a feature, helping the buildings heal themselves from cracks. The calcium rocks may dissolve when exposed to water, seep into the cracks and recrystallize. Voila! Cracks healed.

To find out, Masic's team created cement with and without the hot mixing process and tested the resulting concrete blocks side by side. The team broke each block in half, placed the pieces a small distance apart and trickled water through the crack to see how long it took for the seepage to stop.

Hot-mixed blocks healed within two to three weeks, while the blocks produced without hot mixing never healed, the team reports in the Jan. 6 *Science Advances*.

The recipe could be a boon to the planet, helping curb greenhouse gas emissions. Concrete manufacturing is responsible for about 8 percent of annual global carbon dioxide emissions. And the life span of modern concrete structures, roughly 150 years, is measly compared with that of the Pantheon. Fewer replacements of concrete structures could mean less emissions.

Masic and several colleagues are working to bring hot-mixed concrete to market through a startup. "It's very appealing simply because it's a thousands-of-years-old material," Masic says. —*Carolyn Gramling*

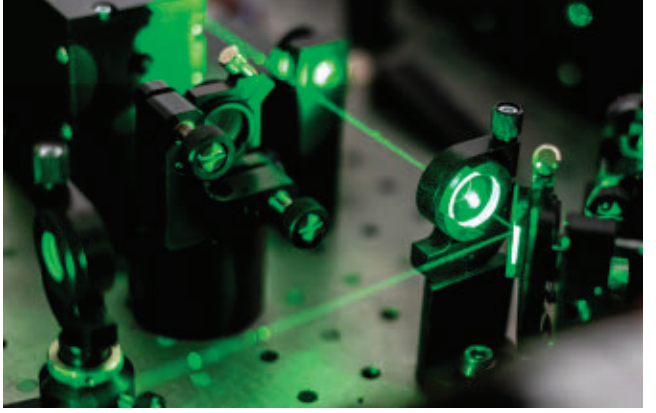
TEASER

Here's how to create 'fiber-optic cables' using just lasers and air

Tubular laser beams can create what amount to fiber-optic cables made of thin air, researchers report in a study to appear in *Physical Review X*.

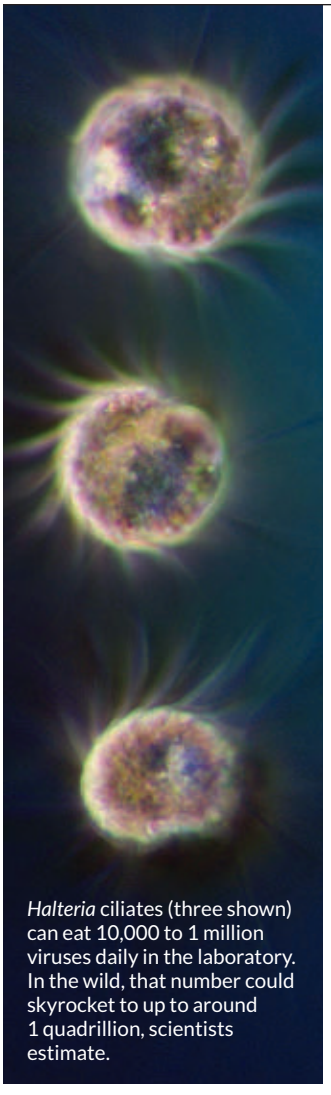
Laser-heated air can efficiently transmit light signals without the need to lay fiber-optic cables. These air-based "wave guides" can also make way for ultrahigh-energy lasers that don't travel well through air on their own, building on earlier efforts often touted as a route to laser weapons (SN: 4/5/14, *p.* 10).

In the latest tests, says physicist Howard Milchberg of the University of Maryland in College Park, wave guides extended nearly 50 meters long — 60 times longer than the team's previous attempts. The researchers ran a laser in "doughnut mode," where the beam has a hollowed-out core and resembles a stack of luminous doughnuts. This beam creates a hot, tubular air layer wrapped around cooler, denser air that's akin to a fiber-optic cable made of air. Instead of a transparent core covered in plastic cladding that guides light in conventional fiber optics, the dense air acts as the core, while the hot air around it serves as cladding.



Specially tailored laser beams similar to the setup shown above create channels in the air that efficiently transmit light.

The technology could extend the range of spectroscopic systems, Milchberg says, which reveal the chemical makeup of materials by firing lasers at them and measuring the light given off. — *James R. Riordon*



Halteria ciliates (three shown) can eat 10,000 to 1 million viruses daily in the laboratory. In the wild, that number could skyrocket to up to around 1 quadrillion, scientists estimate.

FROM TOP: МИХАИЛ РУДЕНКО/ISTOCK/GETTY IMAGES PLUS; SCENICS & SCIENCE/ALAMY STOCK PHOTO

FIRST

These microbes make a meal out of viruses

Single-celled pond dwellers take "viral diet" literally. *Halteria* ciliates are virovores, able to survive on a virus-only diet, scientists report in the Jan. 3 *Proceedings of the National Academy of Sciences*. They are the first creatures known to thrive when viruses alone are on the menu.

In lab experiments, *Halteria* that were given only viruses for sustenance reproduced, University of Nebraska–Lincoln ecologist John DeLong and colleagues found. As the number of viruses dwindled, *Halteria* numbers went up. Ciliates without access to viral morsels, or any other food, didn't multiply. A larger ciliate, *Paramecium*, didn't thrive on a virus-only diet, hinting that viruses can't satisfy the nutritional requirements for all ciliates to grow.

Viruses may provide phosphorus, which is essential for making copies of genetic material, DeLong says. But it probably takes a lot of viruses to account for a full meal.

In the lab, each *Halteria* microbe ate about 10,000 to 1 million viruses daily, the team estimates. *Halteria* in small ponds with abundant viral snacks might chow down on about a quadrillion viruses per day. The team plans to start finding out once ponds in Nebraska thaw. — *Erin Garcia de Jesús*

SAY WHAT?

Dark lightning \därk lite-ning\n.

Bursts of gamma radiation from thunderclouds

Dark lightning flashes an estimated thousand times a day, typically about 10 to 15 kilometers high where airplanes fly. The lightning forms when a thunderstorm's electric fields accelerate electrons to nearly the speed of light. When an avalanche of the particles smashes into airborne atoms, gamma radiation is unleashed, atmospheric scientist Mélody Pallu reported December 13 at the American Geophysical Union fall meeting in Chicago.

On rare occasions, the bursts — the most energetic radiation to naturally arise on Earth — might threaten passing airplanes. By combining dark lightning observations and airline routes, Pallu, of the Astroparticle and Cosmology Laboratory in Paris, and colleagues calculated that dark lightning strikes a plane about once every one to four years.

Simulations have suggested that the zap could briefly expose passengers to doses of radiation exceeding 0.3 sieverts, Pallu said. That's way more than the occupational safety level of 0.02 sieverts per year put forth by the International Commission on Radiological Protection. — *Nikk Ogasa*

News

PLANETARY SCIENCE

Look for these gases to find aliens

On Earth, methylated gases are almost always made by life

BY JAMES R. RIORDON

Attention alien hunters: If you want to find life on distant planets, try looking for signs of toxic chemical cleanup.

Gases that organisms produce as they tidy up their environments could provide clear signs of life on planets orbiting other stars, researchers announced January 9 at the American Astronomical Society meeting. All scientists need to do to find hints of alien life is to look for those gases in the atmospheres of exoplanets, in images coming from the James Webb Space Telescope, or JWST, or other observatories that could come online soon.

Barring an interstellar radio broadcast, the chemistry of a remote planet is one of the more promising ways that researchers could detect extraterrestrial life. On Earth, life produces lots of chemicals that alter the atmosphere: Plants churn out oxygen, for example, and a host of animals and plants release methane. Life elsewhere in the galaxy might do the same thing, leaving a chemical signature humans could detect from afar (SN: 9/25/21, p. 9).

But many of life's gases are also released in processes that have nothing at all to do with life. Detecting such gases could lead to the false impression of a living planet in a faraway solar system, when it's really just a sterile rock.

At least one type of compound that some organisms produce to protect themselves from toxic elements, however, might provide unambiguous indications of life.

The life-affirming compounds are called methylated gases. Microbes, fungi, algae and plants are among the organisms that create the chemicals by linking carbon and hydrogen atoms to toxic elements such as chlorine or bromine. The resulting compounds evaporate, sweeping the deadly elements away.

The fact that living creatures almost always have a hand in making methylated gases means the presence of the compounds in a planet's atmosphere would be a strong sign of life of some kind, planetary astrobiologist Michaela Leung of the University of California, Riverside said at the meeting.

The same isn't true of oxygen and methane. Oxygen, in particular, can accumulate when a hot star warms a planet's oceans. "You have a steam atmosphere, and the [ultraviolet] radiation from the star splits up the water" into oxygen and hydrogen, Leung says. Hydrogen is lightweight, so much of it is lost to space on small planets. "What you have left is all of this oxygen," she says, which leads to "really convincing oxygen signals in this process that at no point involved life."

Similarly, while living organisms produce methane in abundance, lifeless geologic phenomena like volcanoes do too.

At the concentrations of methylated gases typical of Earth, these gases will be hard to see in the atmospheres of distant planets, even with an instrument as powerful as JWST (SN *Online*: 12/20/22). But Leung has reason to believe there may be planets where the gas abundance is thousands of times that of Earth.

"The most productive environments [for releasing methylated gases] that we see here on Earth," she said, "are things like estuaries and wetlands." A watery planet with lots of small continents and correspondingly more coastline, for example, could be packed with organisms cleaning away toxic chemicals with methylated gases.

One of the benefits of looking for the compounds as a sign of life is that it doesn't require that the life resembles anything like what we have on our planet. "Maybe it's not DNA-based, maybe it has other weird chemistry going on," Leung said. But by assuming chlorine and bromine are likely to be toxic generally, methylated gases offer what Leung calls an agnostic biosignature, which can tell us that something is alive on a planet even if it's utterly alien to us.

"The more signs of life we know to look for, then the better our chances of recognizing life when we do encounter it," says Vikki Meadows, an astrobiologist at the University of Washington in Seattle who was not involved with the study. "It also helps us understand what kind of telescopes we should build, what we should look for and what the instrument requirements should be. Michaela's work is really important for that reason." ■

Light passing through the atmospheres of planets in distant solar systems, like the one illustrated here, could reveal compounds that organisms make to protect themselves from toxic elements.

NASA'S GODDARD SPACE FLIGHT CENTER

PLANETARY SCIENCE

‘Tatooine’ planets may be habitable

Exoplanets orbiting pairs of stars could be good places to find life

Planets with twin suns, such as the planet in this illustration of the Kepler-35 system, may make up the bulk of habitable worlds.

JPL-CALTECH/NASA

BY JAMES R. RIORDON

Luke Skywalker’s home planet in *Star Wars* is the stuff of science fiction. But Tatooine–like planets in orbit around pairs of stars might be our best bet in the search for habitable exoplanets.

Many stars in the universe come in pairs, and lots of them should have planets. So there could be plenty of planets much like Earth in binary solar systems. But it has been unclear whether those planets’ environments would be conducive to life. New computer simulations suggest that, in many cases, life could imitate art.

Earthlike planets orbiting some configurations of binary stars might stay in stable orbits for at least a billion years, researchers reported January 11 at the American Astronomical Society meeting. That sort of stability, the researchers propose, would be enough to potentially allow life to develop, provided the planets aren’t too hot or cold.

The researchers ran simulations of 4,000 configurations of binary stars, each with an Earthlike planet in orbit around them. The team varied things like the relative masses of the stars, the sizes and shapes of the stars’ orbits around each other and the size of the planet’s orbit around the binary pair.

The scientists then tracked the motion of the planets for up to a billion years of simulated time to see if the planets would stay in orbit over the sorts of timescales that might allow life to emerge.

A planet orbiting binary stars can get kicked out of the star system due to complicated interactions between the planet and stars. For planets with large orbits around star pairs, only about 1 in 8 were kicked out. The rest were stable enough to continue orbiting for the full billion years. Of those, about 1 in 10 settled in their habitable zones — the temperate region around a star where water could stay liquid.

Of the 4,000 simulated planets, roughly 500 maintained stable orbits that kept them in their habitable zones 80 percent of the time.

“The habitable zone, as I’ve characterized it so far, spans from freezing to boiling,” said Michael Pedowitz, an undergraduate student at the College of New Jersey in Ewing who presented the research. That definition is overly strict, Pedowitz said, because it is based on a model of Earthlike planets without atmospheres or oceans. While that’s simpler to simulate, it also allows temperatures to fluctuate wildly on a planet as it orbits.

“An atmosphere and oceans would smooth over temperature variations fairly well,” says collaborator Mariah MacDonald, an astrobiologist also at the College of New Jersey. An abundance of air and water could allow a planet to maintain habitable conditions, even if it spent more of its time outside of the nominal habitable zone.

The number of potentially habitable planets “will increase once we add atmospheres,” MacDonald says, “but I can’t yet say by how much.”

She and Pedowitz hope to build more sophisticated models, as well as extend the simulations beyond a billion years and include stellar changes that can affect conditions in a solar system as it ages.

The possibility of stable, habitable planets in binary star systems is a timely issue, says Jason Wright, an astrophysicist at Penn State who was not involved in the work. These simulations could serve as a guide for future experiments, Wright says. “This is an underexplored population of planets. There’s no reason we can’t go after them, and studies like this are presumably showing us that it’s worthwhile to try.” ■

MEETING NOTE

James Webb telescope finds ‘Green Peas’ in the early universe

Galaxies that helped transform the early universe may have been small, round and green. Astronomers using the James Webb Space Telescope, or JWST, have detected “Green Pea” galaxies dating to 13.1 billion years ago. These viridescent runts, spotted 700 million years after the Big Bang, might have helped trigger one of the greatest makeovers in cosmic history, scientists said at a January 9 news conference at the American Astronomical Society meeting.

Green Peas get their greenish hue because most of their light comes from glowing gas clouds, rather than directly from stars. These galaxies are rare in the present-day universe. Astronomers think that the ones that do exist are analogs of galaxies that were more plentiful in the early universe. These galaxies leak much more ultraviolet light, which can rip electrons from atoms, than typical galaxies do. So Green Peas dating to the universe’s first billion years or so could be partly responsible for a dramatic and mysterious cosmic transition called reionization, when most of the hydrogen atoms in the early universe had their electrons torn away (*SN: 2/1/20, p. 10*).

Three ancient Green Peas turned up in JWST’s first deep-field image, released in July 2022 (*SN: 8/13/22, p. 30*). The objects look red in JWST’s infrared vision, but the wavelengths of light they emit are like those of previously discovered Green Peas.

“This helps us explain how the universe reionized,” said astrophysicist James Rhoads of NASA’s Goddard Space Flight Center in Greenbelt, Md. “This is an important piece of the puzzle.” — *Lisa Grossman*

HEALTH & MEDICINE

The truth about 'good' cholesterol

High levels of HDL cholesterol may not matter for heart health

BY AIMEE CUNNINGHAM

"Good" and "bad" cholesterol: These well-known characters have long starred in the saga of heart health. But in a major plot twist, "good" cholesterol, it turns out, is not always so good.

In the last dozen years or so, research on the particles that carry so-called good cholesterol — known as high-density lipoprotein, or HDL — has presented a much more nuanced and conflicted story about HDL's effect on cardiovascular disease.

And a recent large study brings fresh doubt. High levels of HDL cholesterol were not associated with protection against heart disease in Black or white participants, researchers reported in the Nov. 29 *Journal of the American College of Cardiology*. For low levels of HDL cholesterol, there was a split, with a link to higher risk of heart disease in white participants but not in Black participants.

> "While you can measure the cholesterol, it doesn't really reflect the actual functions that HDL is doing in the body."
>
> **ANAND ROHATGI**

The study is the first to find a difference in the risk tied to low levels of HDL cholesterol between Black and white people. It also adds to accumulating evidence that a high level of HDL cholesterol isn't necessarily helpful for one's heart health.

There appear to be other attributes of HDL that can be good. But researchers have also found that HDL's role in health is complicated, with plenty to figure out.

HDL and heart disease

Cholesterol has long been explained as the "good" versus the "bad." A high level of the "good" kind has been tied to a lower risk of cardiovascular disease, while having lots of the "bad" kind — carried by low-density lipoprotein, or LDL, particles — has been linked to a higher risk.

One of the big reports to bestow HDL cholesterol with the label of "good" came out of the Framingham Heart Study, a U.S. government–led effort launched in 1948 to investigate risk factors for cardiovascular disease. In 1977, Framingham researchers reported an inverse relationship between HDL cholesterol and coronary disease risk in a group made up of white participants.

But later studies undercut the premise that high levels are automatically good for heart health. People with a genetic mutation that boosts their HDL cholesterol level, for example, do not have a lower risk of heart attacks than people without the mutation (*SN: 6/16/12, p. 14*). And a class of drugs developed to increase HDL cholesterol did a great job of upping numbers but didn't make a difference when it came to cardiovascular disease risk.

A person's HDL cholesterol level is just one part of the story, though. Commonly reported on blood tests, the level reflects the amount of cholesterol that HDL particles have on board. HDL carries cholesterol away from the arteries to the liver to be excreted. This helps keep cholesterol from building up in artery walls, which can eventually impede blood flow.

Recently, research on HDL has started looking beyond its cholesterol payload. "The big understanding over the last decade or so is that while you can measure the cholesterol, it doesn't really reflect the actual functions that HDL is doing in the body," says Anand Rohatgi, a cardiologist at the University of Texas Southwestern Medical Center in Dallas.

How well HDL removes cholesterol appears to matter. One measure of this job performance is HDL's ability to receive cholesterol from a type of cell called a macrophage. In a U.S. study of close to 3,000 adults, of which 49 percent were Black, the higher this capacity, the lower the incidence of heart attacks or strokes, Rohatgi and colleagues reported in the *New England Journal of Medicine* in 2014.

Ridding the body of cholesterol is just one of HDL's many jobs. HDL also has anti-inflammatory and other protective effects that appear to guard against cardiovascular disease. But even these effects don't always lead to a net good. In certain circumstances, HDL can become dysfunctional, such that its capacity to receive cholesterol is reduced and it contributes to inflammation.

The fact that HDL's roles can change, depending on the context, has made studying HDL particles challenging, Rohatgi says.

How well HDL performs is still far from something that can be tested as part of a regular physical exam. It's not clear "how to do it yet for the general public," says Nathalie Pamir, a researcher who studies cardiovascular disease at the Oregon Health & Science University in Portland.

The role of race

As researchers work toward a fuller understanding of HDL and how it might be better used as a clinical measure, the view of HDL cholesterol as uniformly "good" is still out there. And HDL cholesterol level is still one entry in a widely used calculator that estimates cardiovascular risk. Pamir and colleagues wanted to examine what high and low HDL cholesterol levels mean in a contemporary, diverse population.

In the new study, the team analyzed data from the REGARDS trial, designed to study potential regional and racial differences in deaths from stroke in the United States. The study included nearly 24,000 participants — of which 42 percent were Black — who did not start out with coronary heart disease. Over roughly 10 years, 664 out of 10,095 Black participants and 951 out of 13,806 white participants had a heart attack or died from one.

Increased levels of "bad" LDL cholesterol were tied to a higher risk of coronary heart disease, in line with past research, the team found. But for HDL cholesterol, high levels weren't protective for

anyone, and low levels were only predictive of higher risk in white people. That finding suggests it may be necessary to revisit how HDL cholesterol is used in the cardiovascular disease risk calculator, Pamir says.

Rather than just good, HDL cholesterol "is complicated," she says. If a patient has high HDL cholesterol, a doctor "can say, 'Well, currently we don't know what that means.'"

Although the study suggests that the impact of HDL cholesterol levels on disease risk may differ by race, it's important to remember that race is a social construct, not a biological one, says Clyde Yancy, chief of cardiology at the Northwestern University Feinberg School of Medicine in Chicago.

Some of the risk factors for coronary heart disease, including high blood pressure and smoking, "are more prevalent in self-described Black Americans," he says. And a community's access to health care, nutritious food and opportunities for education and employment can influence those risk factors.

"There is something unique about place and the history of place which may predispose to the burden of hypertension, obesity, even diabetes," Yancy says.

More research is needed to understand what's behind the potential race-based difference that the study reports, Yancy says, and what it means in terms of HDL cholesterol levels and cardiovascular disease risk. But it remains the case that high levels of LDL cholesterol—which can accumulate in artery walls—are associated with an increased risk, he says. "The LDL cholesterol seems to be our most relevant barometer."

For all that is known about what impacts cardiovascular disease risk, researchers still don't have the full picture. The number of times that cardiologists see heart attacks in patients with normal cholesterol levels and normal blood pressure, Yancy says, suggests that, with current methods, "we're not able to capture the entirety of the risk." ■

HEALTH & MEDICINE

Nose bacteria may worsen hay fever

Streptococcus salivarius can boost inflammation

BY AIMEE CUNNINGHAM

A type of bacterium that's overabundant in the nasal passages of people with hay fever may worsen symptoms. Targeting the bacterium may provide a way to rein in ever-runny noses.

Hay fever occurs when allergens, such as pollen or mold, trigger an inflammatory reaction in the nasal passages, leading to itchiness, sneezing and overflowing mucus.

Researchers analyzed the composition of the microbial population in the noses of 55 people who have hay fever and those of 105 people who don't. There was less diversity in the nasal microbiome of people who have hay fever and a whole lot more of one species called *Streptococcus salivarius*, the team reports January 12 in *Nature Microbiology*.

S. salivarius was 17 times as abundant in the noses of allergy sufferers as in the noses of those without allergies, says Michael Otto, a molecular microbiologist at the National Institute of Allergy and Infectious Diseases in Bethesda, Md. That imbalance appears to play a part in further provoking allergy symptoms. In lab experiments with allergen-exposed cells that line the airways, the presence of *S. salivarius* boosted the cells' production of proteins that promote inflammation.

And *S. salivarius* really likes runny noses. One prominent symptom of hay fever is the overproduction of nasal discharge. The researchers found that *S. salivarius* binds very well to airway-lining cells exposed to an allergen and slathered in mucus—better than comparison bacteria that also reside in the nose.

Because of that binding, the substances on *S. salivarius*' surface that can drive inflammation, common among many bacteria, are close enough to exert their effect on cells, Otto says.

Hay fever, which disrupts daily activities and disturbs sleep, is estimated to affect as many as 30 percent of adults in the United States.

The new research opens the door "to future studies targeting this bacteria" as a potential treatment for hay fever, says Mahboobeh Mahdavinia, a physician-scientist who studies immunology and allergies at Rush University Medical Center in Chicago. But any treatment would need to avoid harming the helpful bacteria that live in the nose, says Mahdavinia, who was not involved in the research.

The proteins on *S. salivarius*' surface that are important to its ability to attach to mucus-covered cells might provide a target, Otto says. The bacteria bind to proteins called mucins found in the slimy, runny mucus. By learning more about *S. salivarius*' surface proteins, Otto says, it may be possible to come up with "specific methods to block that adhesion." ■

The overabundance of *Streptococcus salivarius* bacteria (shown in false color) in the noses of people with hay fever may exacerbate allergy symptoms.

DR. KARI LOUNATMAA/SCIENCE SOURCE

ENVIRONMENT

Light pollution is worse than thought

Night sky glows about 10 percent brighter every year

BY LISA GROSSMAN

The night sky has been brightening faster than researchers realized. A study of more than 50,000 observations of stars by citizen scientists reveals that the entire night sky grew about 10 percent brighter, on average, every year from 2011 to 2022 thanks to the use of artificial lights.

A baby born where roughly 250 stars were visible every night would see only 100 stars on their 18th birthday, researchers report in the Jan. 20 *Science*.

The perils of light pollution go far beyond not being able to see as many stars. Too much nighttime brightness can harm people's health, send migrating birds flying into buildings and disrupt food webs by drawing pollinating insects toward lights instead of plants (*SN: 9/2/17, p. 10*).

"In a way, this is a call to action," says astronomer Connie Walker of the National Optical-Infrared Astronomy Research Laboratory in Tucson. "People should consider that this does have an impact on our lives. It's not just astronomy. It impacts our health. It impacts other animals who cannot speak for themselves."

Walker works with the Globe at Night campaign, which began in the early 2000s as an outreach project to connect students in Arizona and Chile and now has thousands of participants worldwide. Contributors compare the stars they can see above with mobile app–based maps of what stars would be visible at different levels of sky brightness, and select the map that best matches what they see.

"I'd been quite skeptical of Globe at Night" as a research tool, admits physicist Christopher Kyba of the GFZ German Research Centre for Geosciences in Potsdam. "The individual data are not precise," he says.

But the power is in the sheer numbers: Kyba and colleagues analyzed 51,351 individual data points collected from 2011 to 2022. "This Globe at Night project is not just a game; it's really useful data. And the more people participate, the more powerful it gets."

Those data, combined with a global atlas of sky luminance published in 2016 (*SN: 7/9/16, p. 32*), allowed the team to conclude that the brightness of the entire night sky increased by an average of 9.6 percent per year from 2011 to 2022.

Most of that increase was missed by satellites that collect data on emitted light. Those measurements, which are used to calculate brightness, saw about a 2 percent increase per year from 1992 to 2017.

There are several reasons for that, Kyba says. Since the early 2010s, many outdoor lights have switched from high-pressure sodium lightbulbs to LEDs. LEDs are more energy efficient, which has environmental benefits and cost savings.

But LEDs also emit more short-wavelength blue light, which scatters off particles in the atmosphere more than sodium bulbs' orange light, creating more sky glow. Existing satellites are not sensitive to blue wavelengths, so they underestimate the light pollution coming from LEDs. And satellites may miss light that shines toward the horizon, such as light emitted by a sign or from a window, rather than straight up or down.

John Barentine, an astronomer and light pollution researcher who leads a private dark-sky consulting firm, is not surprised that satellites underestimated the problem. But "I was still surprised by how much of an underestimate it was," he says.

The good news is that no major technological breakthroughs are needed to help fix the problem. Scientists and policy makers just need to convince people to change how they use light at night — easier said than done.

"People sometimes say light pollution is the easiest pollution to solve, because you just have to turn a switch and it goes away," Kyba says. "That's true. But it's ignoring the social problem — that this overall problem of light pollution is made by billions of individual decisions."

Some simple solutions include dimming or turning off lights overnight, especially floodlighting or lights in empty parking lots.

As an example, take a church in Slovenia that switched from four 400-watt floodlights to a single 58-watt LED, shining behind a cutout to focus the light on the building's facade. The result was a 96 percent reduction in energy use and much less wasted light, Kyba reported in 2018 in the *International Journal of Sustainable Lighting*. The church was still lit up, but the grass, trees and sky around it remained dark.

"If it was possible to replicate that story over and over again throughout our society, it would suggest you could really drastically reduce the light in the sky, still have a lit environment and have better vision and consume a lot less energy," he says. "This is kind of the dream."

Barentine thinks widespread awareness of the problem — and subsequent action — could be imminent. For comparison, he points to a highly publicized oil slick fire on the Cuyahoga River, outside of Cleveland, in 1969 that fueled the environmental movement of the 1960s and '70s, and prompted the U.S. Congress to pass the Clean Water Act.

"I think we're on the precipice, maybe, of having the river-on-fire moment for light pollution," he says. ■

In this photo of Milan taken from the International Space Station, LEDs glow brighter than the orange lights in the suburbs. Satellites can't detect the bluer LED light pollution.

SAMANTHA CRISTOFORETTI, NASA, ESA

Atop Mount Säntis in Switzerland, researchers beamed a powerful infrared laser (a green laser marks its path in this photo) into the sky to redirect lightning bolts to a rod on a telecom tower.

PHYSICS

Infrared laser can channel lightning

The technology may improve lightning protection, test hints

BY MARIA TEMMING

Like Thor's hammer Mjölnir, a powerful laser can grab hold of a lightning bolt and reroute its path through the sky.

In a mountaintop experiment, the laser bent lightning toward a lightning rod, researchers report January 16 in *Nature Photonics*. Scientists have previously used lasers to wrangle electricity in the lab, but this is the first demonstration that the technique works in real-world storms. The finding could someday lead to better protection against lightning.

Today's most common anti-lightning tech is the classic lightning rod, a meters-long metal pole rooted to the ground. The metal's conductivity lures in lightning that might otherwise strike nearby buildings or people, feeding that electricity safely into the earth. But the area shielded by a lightning rod is limited by the rod's height.

"If you want to protect some large infrastructure, like an airport or a launching pad for rockets or a wind farm … then you would need, for good protection, a lightning rod of kilometer size, or hundreds of meters," says physicist Aurélien Houard of the Polytechnic Institute of Paris in Palaiseau, France.

Such a tall metal pole would be impractical. But a laser could reach that far, intercepting distant lightning bolts and ushering them to grounded metal rods.

Houard and colleagues tested this idea atop Mount Säntis in northeastern Switzerland. They set up a high-power laser near a telecommunications tower tipped with a lightning rod that is struck by lightning around 100 times every year. The team beamed the laser at the sky for about six hours total during thunderstorms from July to September 2021.

The laser blasted short, intense bursts of infrared light at the clouds about 1,000 times per second. This train of light pulses ripped electrons off of air molecules and knocked some air molecules out of its way, carving a channel of charged low-density plasma.

Sort of like clearing a path through the woods and laying down pavement, the combination of effects made it easier for electric current to flow along this route. That created a path of least resistance for lightning to follow through the sky.

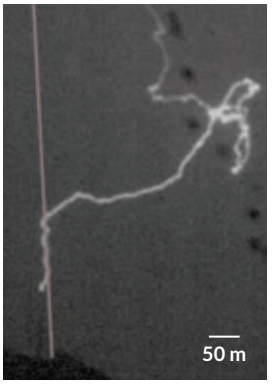
Houard's team tuned the laser so that this electrically conductive pathway formed just above the tip of the tower. That allowed the tower's lightning rod to intercept a bolt snagged by the laser before it zipped all the way down to the laser equipment.

Lightning hit the tower four times while the laser was on. One of those strikes happened when the sky was fairly clear, allowing two high-speed cameras to capture the moment. The images showed lightning zigzagging from the clouds, following the laser light for some 50 meters toward the tower's lightning rod.

To track the paths of the three bolts that cameras could not observe, the researchers looked at radio waves that the lightning bolts shed. Those waves showed that the three strikes followed the path of the laser much more closely than other strikes that happened when the laser was off, hinting that the laser guided the three strikes to the lightning rod.

"It's a real achievement," says Howard Milchberg, a physicist at the University of Maryland in College Park who was not involved in the work. "People have been trying to do this for many years."

Scientists' main goal in bending lightning to their will is to increase safety, Milchberg says. But "if this thing ever became really, really efficient, and the probability of guiding a discharge was increased way beyond what it is now, it could potentially even be useful for charging things."



On July 24, 2021, a high-speed camera captured the moment that a laser bent a lightning bolt's path between the sky and a lightning rod atop a tower.

Atmospheric and space scientist Robert Holzworth of the University of Washington in Seattle is more cautious about imagining any potential applications. "They only showed 50 meters of [guiding] length, and most lightning channels are kilometers long," Holzworth says. So scaling up the laser system to have a useful reach may take a lot of work.

Using a higher-frequency, higher-energy laser could extend its reach, Houard says. "This is a first step toward a kilometric-range lightning rod." ■

FROM TOP: TRUMPF, MARTIN STOLLBERG; A. HOUARD *ET AL*/*NATURE PHOTONICS* 2023

CLIMATE

Arctic cyclones grow more intense

More destructive storms threaten people and sea ice

BY NIKK OGASA

CHICAGO — In January 2022, a cyclone blitzed a large expanse of ice-covered ocean between Greenland and Russia. Frenzied gusts galvanized 8-meter-tall waves that pounded sea ice, while a bombardment of warm rain and a surge of southerly heat laid siege from the air.

Six days after the assault began, about a quarter of the area's sea ice, equaling roughly 400,000 square kilometers, had disappeared, leading to a record weekly loss for this stretch of ocean.

The storm is the strongest Arctic cyclone ever documented. But it may not hold that title for long. Cyclones in the Arctic have become more frequent and intense in recent decades, posing risks to both sea ice and people, researchers reported December 13 at the American Geophysical Union's fall meeting.

"This trend is expected to persist as the region continues to warm rapidly in the future," says climate scientist Stephen Vavrus of the University of Wisconsin–Madison.

The Arctic Circle is warming about four times as fast as the rest of Earth (SN: 9/10/22, p. 5). The major driver is human-caused climate change, which has led to the loss of sea ice. Floating ice reflects far more solar radiation back into space than naked seas do, influencing the global climate (SN: 11/6/21, p. 16). During August, the heart of the sea ice melting season, cyclones have been observed to amplify sea ice losses on average, exacerbating warming.

In addition to harming sea ice, boreal vortices can threaten people living and traveling in the Arctic (SN: 1/18/20, p. 6). As the storms intensify, Vavrus says, "stronger winds pose a risk for marine navigation by generating higher waves and for coastal erosion, which has already become a serious problem throughout much of the Arctic and forced some communities to consider relocating inland."

While climate change is intensifying storms to the south, for a long time it had been unclear how Arctic cyclones might change as the world warms (SN: 12/5/20, p. 14). Some previous research suggested that pressures, on average, in Arctic cyclones' cores have dropped in recent decades. That would be bad news because lower pressures generally mean more intense storms, with "stronger winds, larger temperature variations and heavier rainfall [and] snowfall," says atmospheric scientist Xiangdong Zhang of the University of Alaska Fairbanks.

But inconsistencies between analyses had prevented a clear trend from emerging, Zhang said at the meeting. So he and colleagues aggregated a comprehensive record of Arctic cyclone frequency, intensity and duration from 1950 through 2021.

Arctic cyclone activity has intensified in strength and frequency over recent decades, Zhang reported. Pressures in the hearts of today's boreal vortices are on average about nine millibars lower than in the 1950s. For context, such a pressure shift would be roughly equivalent to bumping a strong Category 1 hurricane well into Category 2 territory.

Vortices also became more frequent during winter in the North Atlantic Arctic and during summer in the Arctic north of Eurasia.

What's more, August cyclones appear to be damaging sea ice more than in the past, said Peter Finocchio, a meteorologist at a U.S. Naval Research Laboratory facility in Monterey, Calif. He and colleagues compared how northern sea ice responded to summer cyclones in the 1990s and the 2010s.

August vortices in the latter decade were followed by a local 10 percent loss of sea ice area on average, up from the earlier decade's 3 percent loss on average. This may be due in part to warmer water upwelling from below, which can melt the ice pack's underbelly, and from winds pushing the thinner, easier-to-move ice around, Finocchio said.

With climate change, cyclones may continue intensifying in the spring too, climate scientist Chelsea Parker said at the meeting. That's a problem because spring vortices can prime sea ice for later summer melting.

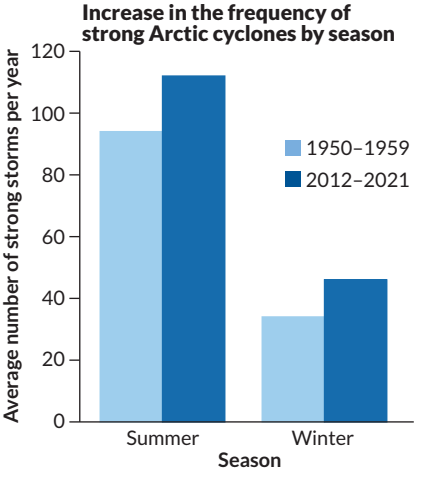
Parker, of NASA's Goddard Space Flight Center in Greenbelt, Md., and colleagues ran computer simulations of spring cyclone behavior in the Arctic under past, present and projected climate conditions. In the worst-case scenario, by the end of the century, the maximum near-surface wind speeds of spring cyclones — around 11 kilometers per hour today — could reach 60 km/h, the researchers found. And future spring cyclones may swirl at peak intensity for up to a quarter of their life spans, up from around 1 percent today. The storms will probably travel farther too, the team says.

"The diminishing sea ice cover will enable the warmer Arctic seas to fuel these storms and probably allow them to penetrate farther into the Arctic," says Vavrus, who was not involved in any of the research.

Parker's team plans to investigate the future evolution of Arctic cyclones in other seasons to capture a broader picture of how climate change affects the storms.

For now, it seems certain that Arctic cyclones aren't going anywhere. Less clear is how humankind will contend with these storms' growing fury. ■

Storm surge In the last decade, strong Arctic cyclones — with central pressures lower than 990 millibars — occurred more often, on average, than in the 1950s, up about 20 percent in summer and 35 percent in winter. SOURCE: X. ZHANG/UNIV. OF ALASKA FAIRBANKS



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ANIMALS

Diving water birds risk extinction

Adaptations may be trapping the birds in their environments

BY JAKE BUEHLER

Birds that dive underwater, such as penguins, loons and grebes may be more likely to go extinct than their nondiving kin, a new study finds.

Many water birds have evolved highly specialized bodies and behaviors that facilitate diving. An analysis of the evolutionary history of more than 700 water bird species shows that once a bird group gains the ability to dive, the change is irreversible. That inflexibility could help explain why diving water birds have an elevated extinction rate compared with nondiving water birds, scientists report in the Dec. 21 *Proceedings of the Royal Society B*.

"There are substantial morphological adaptations for diving," says evolutionary biologist Catherine Sheard of the University of Bristol in England, who was not involved in the work. For example, birds that plunge into the water from the air such as gannets and pelicans may have tweaks to neck muscles and chest bones.

Some diving birds may be evolving under an evolutionary "ratchet," where adaptations to exploit a certain food source or habitat unlock new opportunities, but also encourage ever more specialized evolutionary tailoring. The birds become trapped in their ways, increasing their risk of extinction. That's especially true if their habitat rapidly changes in some negative way, for example due to human-caused climate change.

Evolutionary biologists Josh Tyler and Jane Younger investigated the evolution of diving in 727 living water bird species across 11 bird groups. The scientists divided species into either nondiving birds, or one of three diving types: foot-propelled pursuit (such as loons and grebes), wing-propelled pursuit (like penguins and auks) and the plunge divers.

Diving has evolved about 14 separate times in the water birds, phylogenetic analyses showed, but there were no instances where diving birds reverted to a nondiving form.

Tyler and Younger also explored the link between diving and the development or demise of new species in various water bird lineages. Among 236 diving species, 75, or 32 percent, were part of lineages in which 0.02 more species go extinct per million years than arise. This elevated extinction rate was more common in wing-propelled and foot-propelled pursuit

ANIMALS

Chicken DNA runs amok in wild birds

Interbreeding reduces the genetic diversity of red jungle fowl

BY JAKE BUEHLER

Today's red jungle fowl, the wild forebears of the domesticated chicken, are becoming more chickenlike. A large proportion of the wild fowl's DNA has been inherited from chickens, and relatively recently, new research suggests.

Ongoing interbreeding between the two birds may threaten wild jungle fowl populations' future, and even hobble humans' ability to breed better chickens, scientists report January 19 in *PLOS Genetics*.

Wild red jungle fowl (one shown) in southern Asia are interbreeding with domesticated chickens, reducing the birds' genetic diversity.

JASON THOMPSON/FLICKR (CC BY 2.0)

Red jungle fowl (*Gallus gallus*) are forest birds native to Southeast Asia and parts of South Asia. Thousands of years ago, humans domesticated the fowl, possibly in the region's rice fields (SN: 7/2/22, p. 16).

"Chickens are arguably the most important domestic animal on Earth," says evolutionary biologist Frank Rheindt of the National University of Singapore. He points to their global ubiquity, abundance and affordability as a food source.

Domesticated chickens (*G. gallus domesticus*) are known to interbreed with jungle fowl near human settlements in South and Southeast Asia. Given the unknown impact of interbreeding on jungle fowl, the importance of chickens to humankind, and the possibility that jungle fowl genetic diversity could be a crucial resource for breeding hardier chickens, Rheindt and colleagues set out to gather more details.

The team analyzed and compared the genomes — an organism's full complement of DNA — of 63 jungle fowl and 51 chickens from across South and Southeast Asia. Some of the jungle fowl samples came from museum specimens collected from 1874 through 1939, which let the team see how the jungle fowl genome has changed over time.

Over the last century, wild jungle fowl's genomes have become increasingly similar to chickens'. About 20 to 50 percent of the genomes of modern jungle fowl originated in chickens, the team found. In contrast, many of the roughly 100-year-old jungle fowl had a chicken-ancestry share in the range of a few percent.

The rapid change probably comes from human communities expanding into wilderness, Rheindt says. Most modern jungle fowl live close to humans' free-ranging chickens, with which they interbreed.

Wild populations that interbreed with their domesticated counterparts could pick up physical or behavioral traits that change how the hybrids function in their ecosystem, says Claudio Quilodrán, a conservation geneticist at the University of Geneva who was not involved in the work.

The effect is probably negative since some of the traits coming into the wild population have been honed for human uses, not for survival, Quilodrán says.

divers than in plunge divers. Nondiving lineages generated 0.1 more new species than they lost to extinction per million years.

"The more specialized you become, the more reliant you are on a particular diet, foraging strategy or environment," says Tyler, of the University of Bath in England. Because they have a much larger range of environments in which to forage than specialist divers, nondiving water birds may have a greater ability to adapt and thrive.

If some diving water birds are trapped in their environments by their adaptations, that doesn't bode well for their long-term survival, say Tyler and Younger, who is at the University of Tasmania in Hobart, Australia. About one-fifth of the 727 water bird species is listed as vulnerable, endangered or critically endangered. The situation is more dire for the 75 species from lineages with heightened extinction rates: Nearly one-third is listed as threatened. ■

Jungle fowl have lost their genetic diversity as they've interbred too—it is now just a tenth of what it was a century ago. "This result is initially counterintuitive," Rheindt says. "If you mix one population with another, you would generally expect a higher genetic diversity."

But domesticated chickens have such low genetic diversity that interbreeding is sweeping certain versions of jungle fowl genes out of the population. The whittling down of these wild animals' genetic toolkit may leave them vulnerable to environmental changes, diseases and other threats.

A shallower jungle fowl gene pool could also mean diminished resources for breeding better chickens. The genetics of wild relatives are sometimes used to bolster the disease or pest resistance of crops. Jungle fowl genomes could be similarly valuable.

If the trend continues, "future human generations may only be able to access the entirety of ancestral genetic diversity of chickens in the form of museum specimens," Rheindt says, which could hamper chicken breeding efforts using the wild fowl genes. Singapore and some other countries have started managing jungle fowl populations to reduce interbreeding, he says. ■

THE YOMIURI SHIMBUN VIA AP IMAGES

The elusive Amami rabbit looks similar to ancient rabbits and is found only on two of Japan's Ryukyu Islands.

ANIMALS

Rare rabbit propagates parasitic plant

Japan's mysterious Amami rabbit disperses seeds through poop

BY DARREN INCORVAIA

A crucial link in the life cycle of one parasitic plant may be found in a surprising place—the bellies of rabbits.

Given the animals' propensity for nibbling on gardens and darting across suburban lawns, it can be easy to forget that rabbits are wild animals. But a living reminder of their wildness can be found on two of Japan's Ryukyu Islands, if you have the patience to look for it: the endangered Amami rabbit, a "living fossil" that looks strikingly similar to ancient Asian rabbits.

The lives of Amamis (*Pentalagus furnessi*) are shrouded in mystery due to their rarity—there may be fewer than 5,000 of the animals left in the wild—but they seem to play a surprising ecological role as seed dispersers, researchers report January 23 in *Ecology*.

Seed dispersal is the main point in a plant's life cycle when it can move to a new location. So dispersal is crucially important for understanding how plant populations are maintained and how species will respond to climate change, says Haldre Rogers, a biologist at Virginia Tech in Blacksburg. Despite this, seed dispersal hasn't received much attention, she says. "We don't know what disperses the seeds of most plants in the world."

Locals from the Ryukyu Islands were the first to notice that the "iconic yet endangered" Amami rabbit was nibbling on the fruit of a local plant, *Balanophora yuwanensis*, says biologist Kenji Suetsugu of Kobe University in Japan.

Rabbits generally like to eat vegetative tissue from plants, like leaves and stems, and so haven't been thought to contribute much to spreading seeds, which are often housed in fleshy fruits.

To catch the rabbits in the act, Suetsugu and graduate student Hiromu Hashiwaki set up camera traps. The researchers recorded rabbits munching on *B. yuwanensis* fruits 11 times but still needed to check whether the seeds can survive a trip through a bunny tummy.

So the team scooped up rabbit poop, finding *B. yuwanensis* seeds inside that could still be grown. By swallowing the seeds and pooping them out elsewhere, the Amami rabbits clearly act as seed dispersers, Suetsugu and Hashiwaki say.

B. yuwanensis plants don't have chlorophyll, so they can't use photosynthesis to make food. Instead, these parasitic plants suck energy away from a host plant. This means that where their seeds end up matters.

The Amami rabbits "may facilitate the placement of seeds near the roots of a compatible host" by pooping in underground burrows, Suetsugu says. "Thus, the rabbits likely provide a crucial link between *Balanophora* and its hosts" that remains to be further explored, he says.

Understanding the ecology of an endangered species like the Amami rabbit can help conserve both the animals and the plants that depend on them, Rogers says. ■

ARCHAEOLOGY

Ice Age cave art may be a calendar

Cryptic marks might have been an early notational system

BY ANNA GIBBS

As far back as roughly 25,000 years ago, Ice Age hunter-gatherers may have jotted down markings to communicate information about the behavior of their prey, a new study finds.

These markings include dots, lines and the symbol "Y," and often accompany images of animals. Over the last 150 years, the ancient, mysterious depictions have been found in hundreds of caves across Europe.

Some archaeologists have speculated that the markings might relate to keeping track of time. Now, a statistical analysis, published January 5 in the *Cambridge Archaeological Journal*, presents evidence that past people may have recorded the mating and birthing schedule of fauna.

By comparing the marks with animals' life cycles, researchers showed that, across all the analyzed examples, the number of dots or lines in a given image correlate to the month of mating. This included images of aurochs (an extinct species of wild cattle), bison, horses, mammoths and fish. The position of the symbol "Y" in a sequence was predictive of birth month, suggesting that "Y" signifies "to give birth."

It's one of the earliest records of a coherent notational system, the researchers claim. It indicates that people at the time could interpret the meaning of an item's position in a sequence and plan ahead for the distant future using a calendar of sorts.

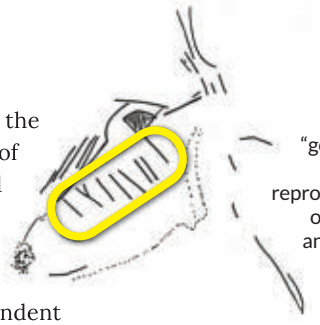
"This is a really big deal cognitively," says Ben Bacon, an independent researcher based in London. "We're dealing with a system that has intense organization, intense logic to it."

A furniture conservator by day, Bacon spent years poring through scientific articles to compile over 800 instances of these cave markings. From his research and reading the literature, he reasoned that the dots correspond to the 13 lunar cycles in a year.

In the new paper, he and colleagues argue that rather than pinning a calendar to astronomical events like the equinox, hunter-gatherers started their calendar year with the snowmelt in the spring. Not only would the snowmelt be a clear point of origin, but the meteorological calendar would also account for differences in timing across locations. For example, though snowmelt would start on different dates in different latitudes, bison would always mate approximately four lunar cycles — or months — after that region's snowmelt, as indicated by four dots or lines.

"This is why it's such a clever system, because it's based on the universal," Bacon says. "If you migrate from the Pyrenees to Belgium, you can just use the same calendar."

After compiling the markings, he worked with university and other researchers to identify the timing of migration, mating and birth for common Ice Age animals targeted by hunter-gatherers. The team used archaeological data or comparisons with similar modern animals. Next, the researchers determined if the marks aligned with important life events based on this calendar. A statistical analysis supported Bacon's theory.



In a cave painting of a "goat-antelope" (shown in this line-drawing reproduction), the position of the "Y" suggests the animal gave birth in the second month after the snowmelt.

"We've argued for notational systems before, but it's always been fairly speculative as to what the people were counting and why they were counting," says Brian Hayden, an archaeologist at Simon Fraser University in Burnaby, Canada, who peer-reviewed the paper. "This adds a lot more depth and specificity to why people were keeping calendars and how they were using them."

Some linguistic experts argue that, given the lack of conventional syntax and grammar, the marks wouldn't be considered writing. But that doesn't make the finding less exciting, says Genevieve von Petzinger, a paleoanthropologist at the Polytechnic Institute of Tomar in Portugal. Writing systems are often mistakenly considered a pinnacle of achievement, when in fact writing would be developed only in cultural contexts where it was useful, she says. Instead, it's significant that the marks provide a way to keep records outside of the mind.

"In a way, that was the huge cognitive leap," she says. "Suddenly, we have the ability to preserve [information] beyond the moment. We have the ability to transmit it across space and time. Everything starts to change."

But there's still debate over the marks' meanings. Archaeologist April Nowell doesn't buy many of the team's assumptions. "It boggles my mind why one would need a calendar … to predict that animals were going to have offspring in the spring," says Nowell, of the University of Victoria in Canada. "The amount of information that this calendar is providing, if it really is a calendar, is quite minimal." ■

In this French cave painting, the four dots on the torso of this aurochs indicate that the animal mated in the fourth month after the spring snowmelt, new research suggests.

FROM TOP: B. BACON *ET AL/CAMBRIDGE ARCHAEOLOGICAL JOURNAL* 2023; JOJAN/WIKIMEDIA COMMONS (CC BY 4.0)

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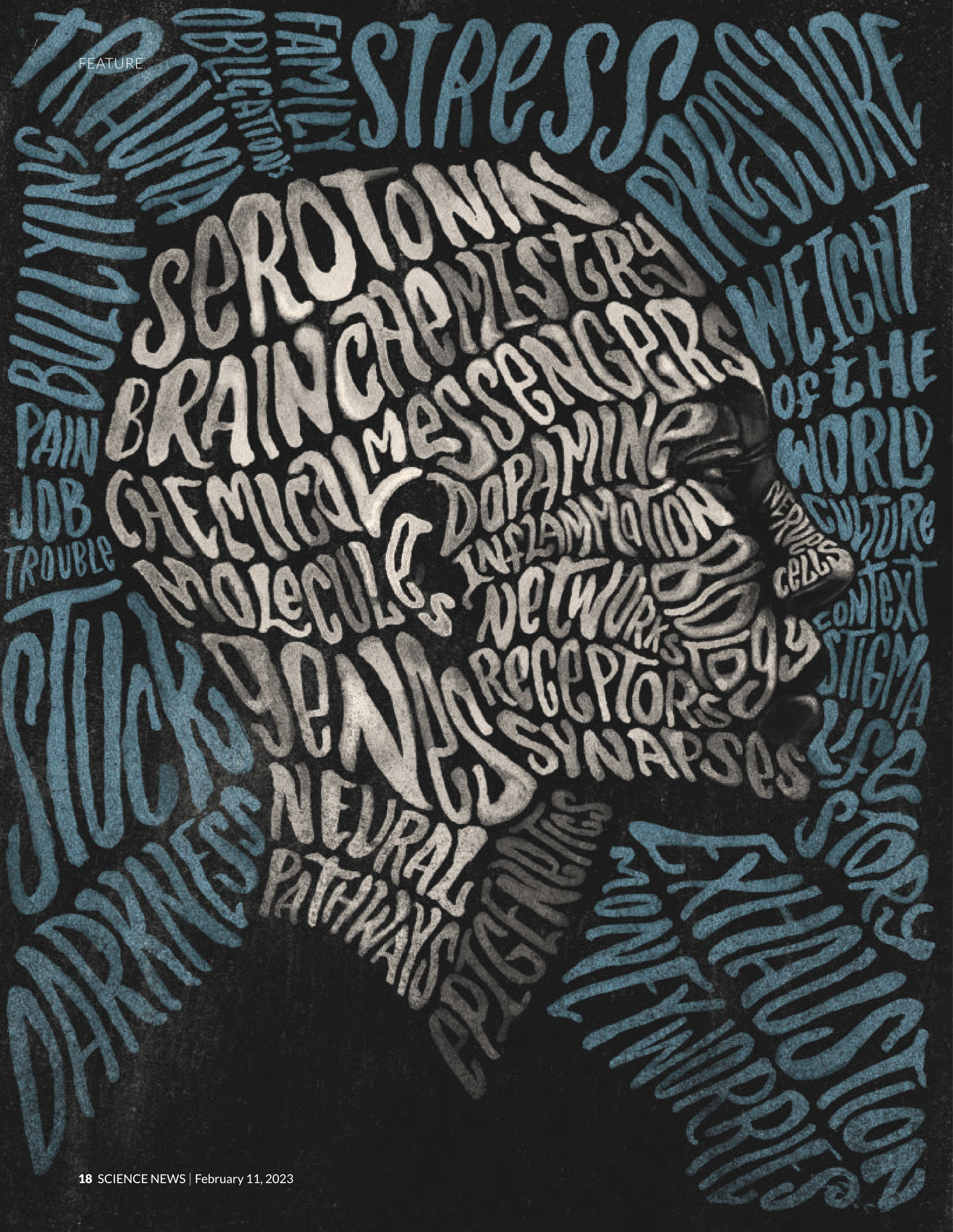
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NEURAL PATHWAYS
EPIGENETICS
DARKNESS
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MONEY WORRIES

No simple answers

Why has depression eluded scientific explanation?

By Laura Sanders

You'd be forgiven for thinking that depression has a simple explanation.

The same mantra — that the mood disorder comes from a chemical imbalance in the brain — is repeated in doctors' offices, medical textbooks and pharmaceutical advertisements. Those ads tell us that depression can be eased by tweaking the chemicals that are off-kilter in the brain. The only problem — and it's a big one — is that this explanation isn't true.

The phrase "chemical imbalance" is too vague to be true or false; it doesn't mean much of anything when it comes to the brain and all its complexity. Serotonin, the chemical messenger often tied to depression, is not the one key thing that explains depression. The same goes for other brain chemicals.

The hard truth is that despite decades of sophisticated research, we still don't understand what depression is. There are no clear descriptions of it, and no obvious signs of it in the brain or blood.

The reasons we're in this position are as complex as the disease itself. Commonly used measures of depression, created decades ago, neglect some important symptoms and overemphasize others, particularly among certain groups of people. Even if depression could be measured perfectly, the disorder exists amid myriad levels of complexity, from biological confluences of minuscule molecules in the brain all the way out to the influences of the world at large. Countless combinations of genetics, personality, history and life circumstances may all conspire to create the disorder in any one person. No wonder the science is stuck.

It's easy to see why a simple "chemical imbalance" explanation holds appeal, even if it's false, says Awais Aftab, a psychiatrist at Case Western Reserve University in Cleveland. What causes depression is nuanced, he says — "not something that can easily be captured in a slogan or buzzword."

So here, up front, is your fair warning: There will be no satisfying wrap-up at the end of this story. You will not come away with a scientific explanation for depression, because one does not exist. But there is a way forward for depression researchers, Aftab says. It requires grappling with nuances, complexity and imperfect data.

Those hard examinations are under way. "There's been some really interesting and exciting scientific and philosophical work," Aftab says. That forward motion, however slow, gives him hope and may ultimately benefit the millions of people around the world weighed down by depression.

How is depression measured?

Many people who feel depressed go into a doctor's office and get assessed with a checklist. "Yes" to trouble sleeping, "yes" to weight loss and "yes" to a depressed mood would all yield points that get tallied into a cumulative score. A high enough score may get someone a diagnosis. The process seems straightforward. But it's not. "Even basic issues regarding measurement of depression are actually still quite open for debate," Aftab says.

That's why there are dozens of methods to assess depression, including the standard description set by the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders*, or DSM-5. This manual is meant to standardize categories of illness.

Variety in measurement is a real problem for the field and points to the lack of understanding of the disease itself, says Eiko Fried, a clinical psychologist at Leiden University in the Netherlands.

OPPOSITE PAGE: PETER STRAIN

Current ways of measuring depression "leave you with a really impoverished, tiny look," Fried says.

Scales can miss important symptoms, leaving people out. "Mental pain," for instance, was described by patients with depression and their caregivers as an important feature of the illness, researchers reported in 2020 in *Lancet Psychiatry*. Yet the term doesn't show up on standard depression measurements.

One reason for the trouble is that the experience of depression is, by its nature, deeply personal, says clinical psychologist Ioana Alina Cristea of the University of Pavia in Italy. Individual patient complaints are often the best tool for diagnosing the disorder, she says. "We can never let these elements of subjectivity go."

In the middle of the 20th century, depression was diagnosed through subjective conversation and psychoanalysis, and considered by some to be an illness of the soul. In 1960, psychiatrist Max Hamilton attempted to course-correct toward objectivity. Working at the University of Leeds in England, he published a depression scale. Today, that scale, known by its acronyms HAM-D or HRSD, is one of the most widely used depression screening tools, often used in studies measuring depression and evaluating the promise of possible treatments.

"It's a great scheme for a scale that was made in 1960," Fried says. Since the HRSD was published, "we have put a man on the moon, invented the internet and created powerful computers small enough to fit in people's pockets," Fried and his colleagues wrote in April in *Nature Reviews Psychology*. Yet this 60-year-old tool remains a gold standard.

Hamilton developed his scale by observing patients who had already been diagnosed with depression. They exhibited symptoms such as weight loss and slowed speech. But those mixtures of symptoms don't apply to everyone with depression, nor do they capture nuance in symptoms.

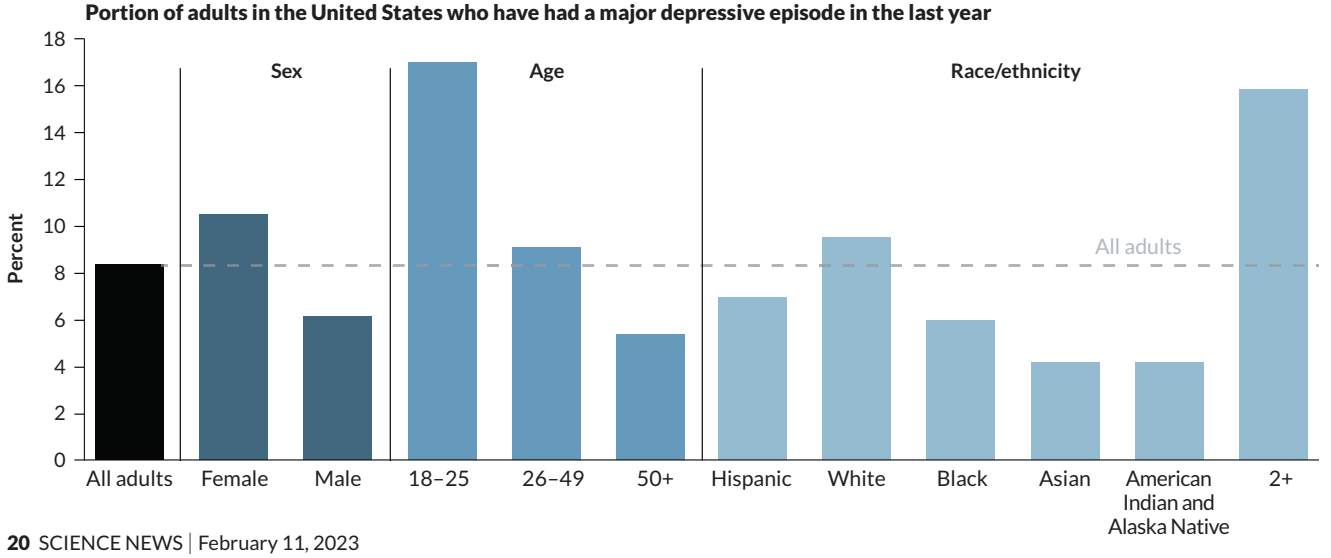
To spot these nuances, Fried looked at 52 depression symptoms across seven different scales for depression, including Hamilton's scale. On average, each symptom appeared in three of the seven scales. A whopping 40 percent of the symptoms appeared in only one scale, Fried reported in 2017 in the *Journal of Affective Disorders*. The only specific symptom common to all seven scales? "Sad mood."

In a study that examined depression symptoms reported by 3,703 people, Fried and Randolph Nesse, an evolutionary psychiatrist at the University of Michigan Medical School in Ann Arbor, found 1,030 unique symptom profiles. Roughly 14 percent of participants had combinations of symptoms that were not shared with anyone else, the researchers reported in 2015 in the *Journal of Affective Disorders*.

Before reliable thermometers, the concept of temperature was murky. How do you understand the science of hot and cold without the tools to measure it? "You don't," Fried says. "You make a terrible measurement, and you have a terrible theory of what it is." Depression presents a similar challenge, he says. Without good measurements, how can you possibly diagnose depression, determine whether symptoms get better with treatments or even prevent it in the first place?

Who is depressed? According to data from 2020, an estimated 21 million adults in the United States have had a major depressive episode in the last year, putting the overall prevalence at 8.4 percent. Rates are notably higher among females, people ages 18 to 25 and people who reported belonging to two or more races. But the widely varied scales used to diagnose depression may not accurately capture the true rates among some populations.

SOURCE: SAMHSA



T. TIBBITTS

The role of gender, race and culture

The story gets murkier when considering who these depression scales were made for. Symptoms differ among groups of people, making the diagnosis even less relevant for certain groups.

Behavioral researcher Leslie Adams of Johns Hopkins Bloomberg School of Public Health studies depression in Black men. "It's clear that [depression] is negatively impacting their work lives, social lives and relationships. But they're not being diagnosed at the same rate" as other groups, she says. For instance, white people have a lifetime risk of major depression disorder of almost 18 percent; Black people's lifetime risk is 10.4 percent, researchers reported in 2007 in *JAMA Psychiatry*. This discrepancy led Adams to ask: "Could there be a problem with diagnostic tools?"

Turns out, there is. Black men with depression have several characteristics that common scales miss, such as feelings of internal conflict, not communicating with others and feeling the burdens of societal pressure, Adams and colleagues reported in 2021 in *BMC Public Health*. A lot of depression measurements are based on questions that don't capture these symptoms, Adams says. "'Are you very sad?' 'Are you crying?' Some people do not emote in the same way," she says. "You may be missing things."

American Indian women living in the Southeast United States also experience symptoms that aren't adequately caught by the scales, Adams and her team found in a separate study. These women also reported experiences that do not necessarily signal depression for them but generally do for wider populations.

On common scales, "there are some items that really do not capture the experience of depression for these groups," Adams says. For instance, a common question asks how well someone agrees with the sentence: "I felt everything I did was an effort." That "can mean a lot of things, and it's not necessarily tied to depression," Adams says. The same goes for items such as, "People dislike me." A person of color faced with racism and marginalization might agree with that, regardless of depression, she says.

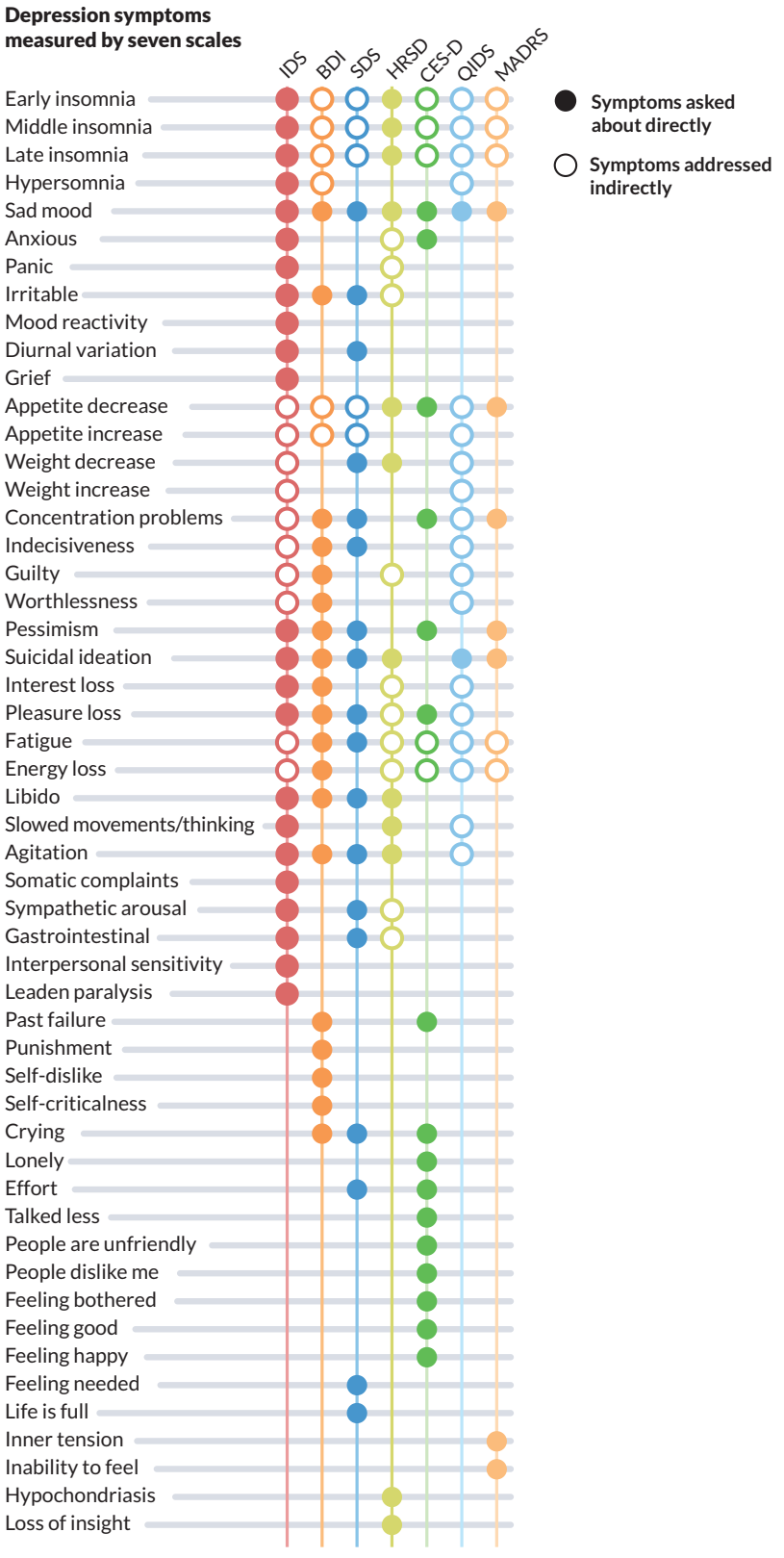
Our ways to measure depression capture only a tiny slice of the big picture. The same can be said about our understanding of what's happening in the brain.

The flawed serotonin hypothesis

Serotonin came into the spotlight in part because of the serendipitous discovery of drugs that affected serotonin receptors, called selective serotonin reuptake inhibitors, or SSRIs. After getting its start

Scale by scale Seven common rating tools for depression measure a wide variety of symptoms. When researchers reviewed the 52 symptoms measured by these scales, only one specific symptom appeared in all seven — sad mood.

SOURCE: E.I. FRIED, J.K. FLAKE AND D.J. ROBINAUGH/*NATURE REVIEWS PSYCHOLOGY* 2022



in the late 1960s, the "serotonin hypothesis" flourished in the late '90s, as advertisers ran commercials that told viewers that SSRIs fixed the serotonin deficit that can accompany depression. These messages changed the way people talked and thought about depression. Having a simple biological explanation helped some people and their doctors, in part by easing the shame some people felt for not being able to snap out of it on their own. It gave doctors ways to talk with people about the mood disorder.

But it was a simplified picture. A recent review of evidence, published in July in *Molecular Psychiatry*, finds no consistent data supporting the idea that low serotonin causes depression. Some headlines declared that the study was a grand takedown of the serotonin hypothesis. To depression researchers, the findings weren't a surprise. Many had already realized this simple description wasn't helpful.

There's plenty of data suggesting that serotonin, and other chemical messengers such as dopamine and norepinephrine, are somehow involved in depression, including a study by neuropharmacologist Gitte Moos Knudsen of the University of Copenhagen. She and colleagues recently found that 17 people who were in the midst of a depressive episode released, on average, less serotonin in certain brain areas than 20 people who weren't depressed. The study is small, but it's one of the first to look at serotonin release in living human brains of people with depression.

But Knudsen cautions that those results, published in October in *Biological Psychiatry*, don't mean that depression is fully caused by low serotonin levels. "It's easy to defer to simple explanations," she says.

SSRIs essentially form a molecular blockade, stopping serotonin from being reabsorbed into nerve cells and keeping the levels high between the cells. Those high levels are thought to influence nerve cell activity in ways that help people feel better.

> "We need to be honest with patients, to say that we don't know everything about this."
>
> GITTE MOOS KNUDSEN

Because the drugs can ease symptoms in about half of people with depression, it seemed to make sense that depression was caused by problems with serotonin. But just because a treatment works by doing something doesn't mean the disease works in the opposite way. That's backward logic, psychiatrist Nassir Ghaemi of Tufts University School of Medicine in Boston wrote in October in a *Psychology Today* essay. Aspirin can ease a headache, but a headache isn't caused by low aspirin.

"We think we have a much more nuanced picture of what depression is today," Knudsen says. The trouble is figuring out the many details. "We need to be honest with patients, to say that we don't know everything about this," she says.

The brain contains seven distinct classes of receptors that sense serotonin. That's not even accounting for sensors for other messengers such as dopamine and norepinephrine. And these receptors sit on a wide variety of nerve cells, some that send signals when they sense serotonin, some that dampen signals. And serotonin, dopamine and norepinephrine are just a few of dozens of chemicals that carry information throughout a multitude of interconnected brain circuits. This complexity is so great that it renders the phrase "chemical imbalance" meaningless.

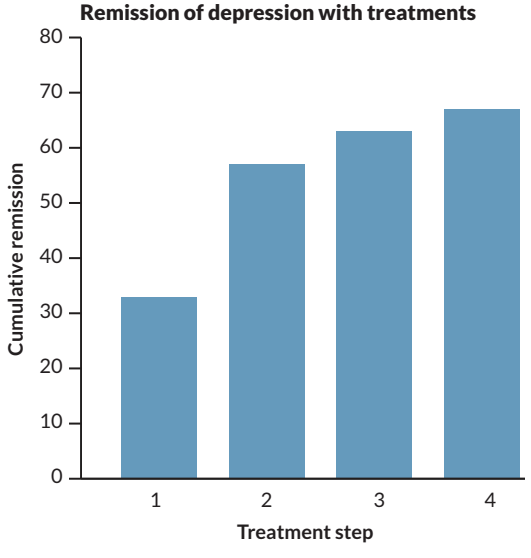
Overly simple claims — low serotonin causes depression, or low serotonin isn't involved — serve only to keep us stymied, Aftab says. "[It] just keeps up that unhelpful binary."

We can't ignore the world

In the 1990s, Aftab says, depression researchers got intensely focused on the brain. "They were trying to find the broken part of the brain

Finding relief A large study called STAR*D enrolled more than 4,000 people with depression across the United States and offered a window into how well treatment works. In the study, volunteers who didn't respond to one treatment were switched to a second and so on. At each step, the number of people in remission increased, though gains were smaller for later steps.

SOURCE: B.N. GAYNES *ET AL/PSYCHIATRIC SERVICES* 2009



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that causes depression." That limited view "really hurt depression research," Aftab says. In the last 10 years or so, "there's a general recognition that that sort of mind-set is not going to give us the answers."

Reducing depression to specific problems of biology in the brain didn't work, Cristea says. "If you were a doctor 10 years ago, the dream was that the neuroscience would give us the markers. We would look at the markers and say, 'OK. You [get] this drug. You, this kind of therapy.' But it hasn't happened." Part of that, she says, is because depression is an "existentially complicated disorder" that's tough to simplify, quantify and study in a lab.

Our friendships, our loves, our setbacks and our stress can all influence our health. Take a recent study of first-year doctors in the United States. The more these doctors worked, the higher the rate of depression, scientists reported in October in the *New England Journal of Medicine*. Similar trends exist for caregivers of people with dementia and health care workers who kept emergency departments open during the COVID-19 pandemic. Their high-stress experiences may have prompted depression in some way.

"Depression is linked to the state of the world—and there is no denying it," Aftab says.

Today's research on depression ought to be more pluralistic, Adams says. "There are so many factors at play that we can't just rest on one solution," she says. Research from neuroscience and genetics has helped identify brain circuits, chemical messengers, cell types, molecules and genes that all may be involved in the disorder. But researchers aren't satisfied with that. "There is other evidence that remains unexplored," Adams says. "With our neuroscience advances, there should be similar advances in public health and psychiatric work."

That's happening. For her part, Adams and colleagues have just begun a study looking at moment-to-moment stressors in the lives of Black adolescents, ages 12 to 18, as measured by cell phone questionnaires. Responses, she hopes, will yield clues about depression and risk of suicide.

Other researchers are trying to fit together all of these different ways of seeing the problem. Fried, for example, is developing new concepts of depression that acknowledge the interacting systems. You tug on one aspect of it—using an antidepressant for instance, or changing sleep patterns—and see how the rest of the system reacts.

Approaches like these recognize the complexity of the problem and aim to figure out ways to handle it. We will never have a simple explanation for depression; we are now learning that one cannot possibly exist.

That may sound like cold comfort to people in depression's grip. But seeing the challenge with clear eyes may be the thing that moves us forward. ■

What isn't asked In a concept mapping study, descriptions of depression symptoms provided by Black men and key individuals supporting Black men's health, including Black women and doctors, were clustered into six categories (example statements are included below). Some of the categories weren't consistently reflected in three commonly used depression assessments. SOURCE: L.B. ADAMS *ET AL/BMC PUBLIC HEALTH* 2021

Reflected in three assessments:	Reflected in just one assessment:
Physical states •High blood pressure •Self-harm or suicidal behavior •Binge eating •Insomnia •Oversleeping/sleeping frequently •Heart palpitations •Weight loss/gain	**Communication with others** •Unable to communicate properly, such as ignoring emails and calls •Isolation from others •Blunted emotional expression •Withdrawal from everyday activities •Volatile behavior toward others •Not able to maintain romantic relationships •Ignoring support from others
Emotional states •Not able to "get up and go" •Lack of motivation •Anger •Feeling "sick" •Low self-esteem •Being stagnant or stuck in life •Feeling fatigued •Feeling hopeless •Feeling frustrated •Bursts of crying •Worry •Feeling out of control	**Internal conflict** •Having a pessimistic outlook •Feeling guilty •Feeling unqualified •Heightened sense of fear or dread •Not feeling supported by the Black community •Feeling attacked/defensiveness •Feeling helpless due to aging
	Not reflected in the assessments:
Diminished drive •Untidy appearance, including home and personal hygiene •Not able to complete tasks •Not being able to provide for your family •Not able to complete life goals, such as finishing school, getting a job, traveling •Excessive substance use, such as marijuana, cigarettes, alcohol	**Social pressures** •Not able to keep up appearances •Fear of unknown consequences of today's political environment •Adherence to cultural norms of success and power •Increased attendance at religious institution •Lack of work/life balance •Seeking happiness through accumulated materials

Explore more

- E.I. Fried, J.K. Flake and D.J. Robinaugh. "Revisiting the theoretical and methodological foundations of depression measurement." *Nature Reviews Psychology*. June 2022.
- A. Aftab. "The case for antidepressants in 2022." Substack. November 20, 2022.

TED SHAFFREY/ASSOCIATED PRESS

FOSSILS FOR SALE

Science can suffer when *T. rex* skulls and skeletons go to the highest bidder

A *T. rex* skull dubbed Maximus sold at a Sotheby's auction in December for about $6.1 million.

By Carolyn Gramling

Tyrannosaurus rex isn't just a king to paleontologists. The dinosaur increasingly reigns over the world of art auctions. A nearly complete skeleton known as Stan the *T. rex* smashed records in October 2020 when a bidding war drove its price to $31.8 million, the highest ever paid for a fossil. Before that, Sue the *T. rex* held the top spot; it went for $8.36 million in 1997.

That kind of publicity — and cachet — means that *T. rex*'s value is sky-high, and the dinosaur continues to have its teeth firmly sunk into the auction world.

Two more *T. rex* fossils were the centerpieces of auctions in late 2022 — though one was withdrawn just before the sale's onset. That fossil, dubbed Shen, was supposed to be the highlight of a Christie's auction in Hong Kong and was expected to sell for between $15 million and $25 million. Christie's pulled the lot on November 20 due to

concerns over the number of replica bones used in the fossil.

In December, auction house Sotheby's in New York City sold a *T. rex* skull known as Maximus for $6.1 million to an anonymous buyer. That sale, well short of an anticipated $15 million auction price, may have been hurt by the Shen controversy.

"These are astronomical sums of money, really surprising sums of money," says Donna Yates, a criminologist at Maastricht University in the Netherlands who studies high-value collectibles.

Stan's final price "was completely unexpected," Yates says. The fossil was originally appraised at about $6 million — still a very large sum, though nothing like the final tally, which was the result of a three-way bidding war.

But the staggering amounts of money *T. rex* fossils now fetch at auction can mean a big loss for science. At those prices, the public institutions that might try to claim these glimpses into the deep past are unable to compete with deep-pocketed private buyers, researchers say.

One reason for the high prices may be that *T. rex* fossils are increasingly being treated more like rare works of art than bits of scientific evidence, Yates says. The bones might once have been bought and sold at dusty "cowboy fossil" dealerships. But nowadays these fossils are on display in shiny gallery spaces and are being appraised and marketed as rare objets d'art. That's appealing to collectors, she adds: "If you're a high-value buyer, you're a person who wants the finest things."

But fossils' true value is the information they hold, says Thomas Carr, a paleontologist at Carthage College in Kenosha, Wis. "They are our only means of understanding the biology and evolution of extinct animals."

Keeping fossils of *T. rex* and other ancient animals in public repositories, such as museums, ensures that scientists have consistent access to study the objects, including being able to replicate or reevaluate previous findings. But a fossil sold into private or commercial hands is subject to the whim of its owner — which means anything could happen to it at any time, Carr says.

"It doesn't matter if [a *T. rex* fossil] is bought by some oligarch in Russia who says scientists can come and study it," he says. "You might as well take a sledgehammer to it and destroy it."

A *T. rex* of one's own

There are known specimens from only about 120 *T. rex* individuals in the world, Carr estimates. At least half of them are owned privately and aren't available to the public. That loss is "wreaking havoc on our dataset. If we don't have a good sample size, we can't claim to know anything about [*T. rex*]," Carr says.

For example, to be able to tell all the ways that *T. rex* males differed from females, researchers need between 70 and 100 good specimens for statistically significant analyses, an amount scientists don't currently have.

Similarly, scientists know little about how *T. rex* grew, and studying fossils of youngsters could help (SN: 2/1/20, p. 15). But only a handful of juvenile *T. rex* specimens are publicly available to researchers. That number would double if private specimens were included, Carr says.

Museums and academic institutions typically don't have the kind of money it takes to compete with private bidders in auctions or any such competitive sales. That's why, in the month before Stan went up for auction in 2020, the Society of Vertebrate Paleontology, or SVP, wrote a letter to Christie's asking the auction house to consider restricting bidding to public institutions. The hope was that this would give scientists a fighting chance to obtain the specimens.

But the request was ignored — and may have only increased publicity for the sale, says Stuart Sumida, a paleontologist at California State University, San Bernardino and SVP's current vice president. That's why SVP didn't issue a public statement ahead of the auctions for Shen and Maximus, Sumida says, though the organization continues to strongly condemn fossil sales — whether of large, dramatic specimens or less well-known creatures. "All fossils are data. Our position is that selling fossils is not scientific and it damages science."

Sumida is particularly appalled at statements

Shen was slated to be the first *T. rex* fossil ever sold at auction in Asia, with an expected price of $15 million to $25 million. That auction was withdrawn due to questions over the number of replica bones in the skeleton.

MARCUS MÜLLER-WITTE, M.A./COURTESY OF CHRISTIE'S

made by auction houses that suggest the skeletons have already been studied, an attempt to reassure researchers that the data contained in that fossil won't be lost, regardless of who purchases it. That's deeply misleading, he says, because of the need for reproducibility, as well as the always-improving development of new analytical techniques. "When they make public statements like that, they are undermining not only paleontology, but the scientific process as well."

The high prices earned by Stan and Sue are not only helping to drive up the market for fossils of *T. rex*, but also of less famous species. "It creates this ripple effect that is incredibly damaging to science in general," Sumida says.

Sotheby's, for example, auctioned off the *T. rex* relative *Gorgosaurus* in July for $6.1 million. In May, a *Deinonychus antirrhopus* — the inspiration for *Jurassic Park*'s velociraptor — was sold by Christie's for $12.4 million.

Protecting *T. rex* from collectors

Compounding the problem is the fact that the United States has no protections in place for fossils unearthed from the backyards or dusty fields of private landowners. The United States is home to just about every *T. rex* skeleton ever found. Stan, Sue and Maximus hail from South Dakota. Shen was found in Montana.

As of 2009, U.S. law prohibits collecting scientifically valuable fossils, particularly fossils of vertebrate species like *T. rex*, from public lands without permits. But fossils found on private lands are still considered the landowner's personal property. And landowners can grant digging access to anyone.

Before the discovery of Sue (*SN: 9/20/14, p. 28*), private owners often gave scientific institutions free access to hunt for fossils on their land, says Bridget Roddy, a researcher at the legal news company Bloomberg Law in Washington, D.C. But in the wake of Sue's sale in 1997, researchers began to have to compete for digging access with commercial fossil hunters.

These hunters can afford to pay landowners large sums for the right to dig, or even a share of the profits from fossil sales. And many of these commercial dealers sell their finds at auction houses.

Lack of federal protections for paleontological resources found on private land — combined with the large available supply of fossils — is a situation unique to the United States, Roddy says. Fossil-rich countries such as China, Canada, Italy and France consider any such finds to be under government protection, part of a national legacy.

In the United States, seizing such materials from private landowners — under an eminent domain argument — would require the government to pay "just compensation" to the landowners. But using eminent domain to generally protect such fossils wouldn't be financially sustainable for the government, Roddy says, not least because most fossils dug up aren't of great scientific value anyway.

There may be other, more grassroots ways to at least better regulate fossil sales, she says. In May, while still a law student at DePaul University in Chicago, Roddy outlined some of those ideas in an article published in *Texas A&M Journal of Property Law*.

One option, she suggests, is for states to create a selective sales tax attached to fossil purchases, specifically for buyers who intend to keep their purchases in private collections that are not readily available to the public. It's "similar to if you want to buy a pack of cigarettes, which is meant to offset the harm that buying cigarettes does to society in general," Roddy says. That strategy could be particularly effective in states with large auction houses, like New York.

Another possibility is to model any new, expanded fossil preservation laws on existing U.S. antiquities laws, intended to preserve cultural heritage. After all, Roddy says, fossils aren't just bones, but they're also part of the human story. "Fossils have influenced our folklore; they're a unifier of humanity and culture rather than a separate thing."

Though fossils from private lands aren't protected, many states do impose restrictions on

Sue the *T. rex*, shown here in May 2000, was acquired by the Field Museum in Chicago in 1997 for $8.36 million.

TIM BOYLE/HULTON ARCHIVE/GETTY IMAGES

Stan the *T. rex* went on display at Christie's in September 2020. Its estimated value was between $6 million and $8 million, but the fossil ultimately sold for $31.8 million, the highest price ever for a fossil.

SPENCER PLATT/GETTY IMAGES NEWS

searches for archaeological and cultural artifacts, by requiring those looking for antiquities to restore excavated land or with fines for excavation of certain antiquities that occur without state permission. Expanding those restrictions to fossil hunting, perhaps by requiring state approval through permits, could give states the opportunity to track or even purchase any significant finds before they're lost to private buyers.

Fossils for science and the public

Such protections could be a huge boon to paleontologists, who may not even know what's being lost. "The problem is, we'll never know" all the fossils that are being sold, Sumida says. "They're shutting scientists out of the conversation."

And when it comes to dinosaurs, "so many of the species we know about are represented by a single fossil," says Steve Brusatte, a paleontologist at the University of Edinburgh. "If that fossil was never found, or disappeared into the vault of a collector, then we wouldn't know about that dinosaur."

Or, he says, sometimes a particularly complete or beautifully preserved dinosaur skeleton is found, and without it, "we wouldn't be able to study what that dinosaur looked like, how it moved, what it ate, how it sensed its world, how it grew."

The point isn't to put restrictions on collecting fossils so much as to make sure they remain in public view, Brusatte says. "There's nothing as magical as finding your own fossils, being the first person ever to see something that lived millions of years ago." But, he adds, unique and scientifically invaluable fossils such as dinosaur skeletons should be placed in museums "where they can be conserved and studied and inspire the public, rather than in the basements or yachts of the oligarch class."

After its record-breaking sale, Stan vanished for a year and a half, its new owners a mystery. Then in March 2022, news surfaced that the fossil had been bought by the United Arab Emirates, which stated it intends to place Stan in a new natural history museum. Sue, too, is on public view. The fossil is housed at Chicago's Field Museum, thanks to the pooled financial resources of the Walt Disney World Resort, the McDonald's Corporation, the California State University System and others. That's the kind of money it took to get the highest bid on a *T. rex* 25 years ago. And those prices could continue to go up. Researchers may have gotten lucky with Sue, and possibly Stan.

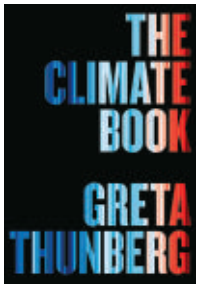
As for Shen, the fossil's fate remains in limbo: It was pulled from auction not over outcry from paleontologists but concerns about intellectual property. The fossil, at 54 percent complete, may have been supplemented with a polyurethane cast of bones from Stan, according to representatives of the Black Hills Institute of Geological Research in Hill City, S.D. That organization, which excavated Stan, retains a copyright over the skeleton.

In response to those concerns, Christie's pulled the lot and says the fossil's current owner now intends to loan the fossil to a museum. But this move doesn't reassure paleontologists. "A lot of people are pleased that the sale didn't go through," Sumida says. "But it sort of just kicks the can down the road.... It doesn't mean they're not going to try and sell it in another form, somewhere down the road."

Ultimately, scientists simply can't count on every important fossil finding its way to the public, Carr says. "Those fossils belong in a museum; it's right out of *Indiana Jones*," he says. "It's not like they're made in a factory somewhere. Fossils are nonrenewable resources. Once Shen is gone, it's gone." ■

Explore more

- B. Roddy. "Can you dig it? Yes, you can! But at what cost?: A proposal for the protection of domestic fossils on private land." *Texas A&M Journal of Property Law*. May 2022.



The Climate Book
Greta Thunberg
PENGUIN PRESS, $30

BOOKSHELF

A new guide to the climate crisis calls for action now

The best shot we have at minimizing the future impacts of climate change is to limit global warming to 1.5 degrees Celsius. Since the Industrial Revolution began, humankind has already raised the average global temperature by about 1.1 degrees. If we continue to emit greenhouse gases at the current rate, the world will probably surpass the 1.5-degree threshold by the end of the decade.

That sobering fact makes clear that climate change isn't just a problem to solve someday soon; it's an emergency to respond to now. And yet, most people don't act like we're in the midst of the greatest crisis humans have ever faced—not politicians, not the media, not your neighbor, not myself, if I'm honest. That's what I realized after finishing *The Climate Book* by Greta Thunberg.

The urgency to act now, to kick the addiction to fossil fuels, practically jumps off the page to punch you in the gut. So while not a pleasant read—it's quite stressful—it's a book I can't recommend enough. The book's aim is not to convince skeptics that climate change is real. We're well past that. Instead, it's a wake-up call for anyone concerned about the future.

A collection of bite-size essays, *The Climate Book* provides an encyclopedic overview of all aspects of the climate crisis, including the basic science, the history of denialism and inaction, and what to do next. Thunberg, who became the face of climate activism after starting the Fridays For Future protests as a teenager (SN: 12/21/19 & 1/4/20, *p.* 25), assembles an all-star roster of experts to write the essays.

The first two sections of the book lay out how a small amount of warming can have major, far-reaching effects. For some readers, this will be familiar territory. But as each essay builds on the next, it becomes clear just how delicate Earth's climate system is. What also becomes clear is the significance of 1.5 degrees (SN: 12/22/18 & 1/5/19, *p.* 18). Beyond this point, scientists fear, various aspects of the natural world might reach tipping points that usher in irreversible changes, even if greenhouse gas emissions are later brought under control. Ice sheets could melt, raise sea levels and drown coastal areas. The Amazon rainforest could become a dry grassland.

The cumulative effect would be a complete transformation of the climate. Our health and the livelihood of other species and entire ecosystems would be in danger, the book shows. Not surprisingly, essay after essay ends with the same message: We must cut greenhouse gas emissions, now and quickly.

Repetition is found elsewhere in the book. Numerous essays offer overlapping scientific explanations, stats about emissions, historical notes and thoughts about the future. Rather than being tedious, the repetition reinforces the message that we know what the climate change threat is, we know how to tackle it and we've known for a long time.

Thunberg's anger and frustration over the decades of inaction, false starts and broken pledges are palpable in her own essays that run throughout the book. The world has known about human-caused climate change for decades, yet about half of all human-related carbon dioxide emissions ever released have occurred since 1990. That's the year the Intergovernmental Panel on Climate Change released its first report and just two years before world leaders met in Rio de Janeiro in 1992 to sign the first international treaty to curb emissions.

Perversely, the people who will bear the brunt of the extreme storms, heat waves, rising seas and other impacts of climate change are those who are least culpable. The richest 10 percent of the world's population accounts for half of all carbon dioxide emissions while the top 1 percent emits more than twice as much as the bottom half. But because of a lack of resources, poorer populations are the least equipped to deal with the fallout. "Humankind has not created this crisis," Thunberg writes, "it was created by those in power."

That injustice must be confronted and accounted for as the world addresses climate change, perhaps even through reparations, Olúfẹ́mi O. Táíwò, a philosopher at Georgetown University, argues in one essay.

So what is the path forward? Thunberg and many of her coauthors are generally skeptical that new tech alone will be our savior. Carbon capture and storage, or CCS, for example, has been heralded as one way to curb emissions. But less than a third of the roughly 150 planned CCS projects that were supposed to be operational by 2020 are up and running. Progress has been impeded by expenses and technology fails, science writer Ketan Joshi explains. An alternative might be "rewilding," restoring damaged mangrove forests, seagrass meadows and other ecosystems that naturally suck CO_2 out of the air, suggest environmental activists George Monbiot and Rebecca Wrigley.

Fixing the climate problem will not only require transforming our energy and transportation systems, which often get the most attention, but also our economies (endless growth is not sustainable), political systems and connection to nature and with each other, the book's authors argue.

The last fifth of the book lays out how we could meet this daunting challenge. What's needed is a critical mass of individuals who are willing to make lifestyle changes and be heard. This could trigger a social movement strong enough to force politicians to listen and create systemic and structural change. In other words, it's time to start acting like we're in a crisis.

Thunberg doesn't end the book by offering hope. Instead, she argues we each have to make our own hope. "To me, hope is not something that is given to you, it is something you have to earn, to create," she writes. "It cannot be gained passively, through standing by and waiting for someone else to do something. Hope is taking action." —*Erin Wayman*

SPLATOON INK IS INSPIRED BY REAL OCTOPUSES AND SQUIDS

In Nintendo's *Splatoon* games, rising sea levels have killed off most land dwellers, and sea creatures now reign. Kids known as Inklings and Octolings can transform into squids and octopuses that duke it out with weapons that spew ink. This thick, colorful goo paints over buildings and the ground. Real-life squids and octopuses shoot out ink, too. But how does their ink compare with that of *Splatoon*'s rowdy kids?

Science News Explores, our award-winning website and magazine for young people, set out to find out.

For one thing, *Splatoon* players splat each other with ink-loaded weapons as they go on the offensive. In contrast, most true cephalopods use ink for self-defense (with the Japanese pygmy squid as one notable exception). Another difference: The ink of cephalopods doesn't share the technicolor hues of the Inklings' and Octolings' splatterings.

Philadelphia-based squid biologist Sarah McAnulty appreciates the *Splatoon* series for bringing squid awareness to a broad audience. "There isn't enough squid in art depicted in the United States," she says. *—Aaron Tremper, editorial assistant,* Science News Explores

DECEMBER 17, 2022 & DECEMBER 31, 2022

SOCIAL MEDIA

Back to life

A species of clam called *Cymatioa cooki* (shown below) that scientists thought had been extinct for about 30,000 years was found alive off the coast of California, **Allison Gasparini** reported in "Clam discovery resurrects a long-dead species" (*SN: 12/17/22 & 12/31/22, p. 4*). "This is what I love about science," Facebook user **Debra Chugg** wrote. "There's always the 'unexpected' out there that can rewrite our learning. [Every day], there's the possibility of yet another wonderful discovery."

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On the rise

A thinning, accelerating ice stream in Greenland's interior could contribute nearly 16 millimeters to global sea level rise by 2100, more than six times as much as previously thought, ***Nikk Ogasa*** *reported in "Greenland is hemorrhaging ice" (*SN: 12/17/22 & 12/31/22, p. 7*).*

Reader **Leslie Hruby** wondered how local sea levels will be affected as an ice sheet melts and the land underneath rebounds.

"The immense weight of the ice can depress the Earth's crust, just like a heavy object placed on a soft mattress," **Ogasa** says. When the ice retreats, the unburdened ground rises back up. What's more, as the ice loses mass, its gravitational pull on the nearby ocean also wanes. When polar ice retreats, these changes can compound to lower the local sea level but raise the sea level farther off. "Projections indicate that sea level rise will be most severe along the coastal areas farthest from the polar regions, such as South and Southeast Asia," **Ogasa** says. "These regions are home to large, low-income populations who bear the least responsibility for climate change, but they will face the worst of it."

Keeping ethics in mind

In the lab, brain implants can translate internal speech into external signals, technology that could help people who are unable to speak or type, ***Laura Sanders*** *reported in "Brain implants 'read' thoughts" (*SN: 12/17/22 & 12/31/22, p. 8*).*

Reader **J Morley** rejoiced that the technology might one day help people but worried about what it means for privacy.

Morley raises a common concern. In 2020, *Science News* asked readers about their views on brain technology that can read—and perhaps influence—brain activity. Concerns about privacy rose to the top of the list (SN: *2/13/21, p.* 24).

Sanders says many of the scientists she spoke to in her reporting emphasized the flip side. "They feel a moral imperative to move research forward so that they can help people by restoring the ability to communicate, for instance, or relieving symptoms of a distressing mental illness," she says. "It's a complex area that defies simple black-and-white thinking; there is room here for lots of different perspectives and priorities."

JUST WONDERING

Science News *readers often ask questions that are unrelated to our journalism but are fascinating nonetheless. We're indulging our nerdy impulses to try to answer those questions.*

Reader **Steve Ostrom** asked if the James Webb Space Telescope needs to be pointed in a particular direction to look for the first generation of stars after the Big Bang.

"To get a glimpse of the first stars, JWST needs a clear view beyond our galaxy, so it must not be pointed at the Milky Way's center or at any impenetrable walls of dust in our galaxy," says associate news editor **Christopher Crockett**, who has a Ph.D. in astronomy. "But the direction itself doesn't matter."

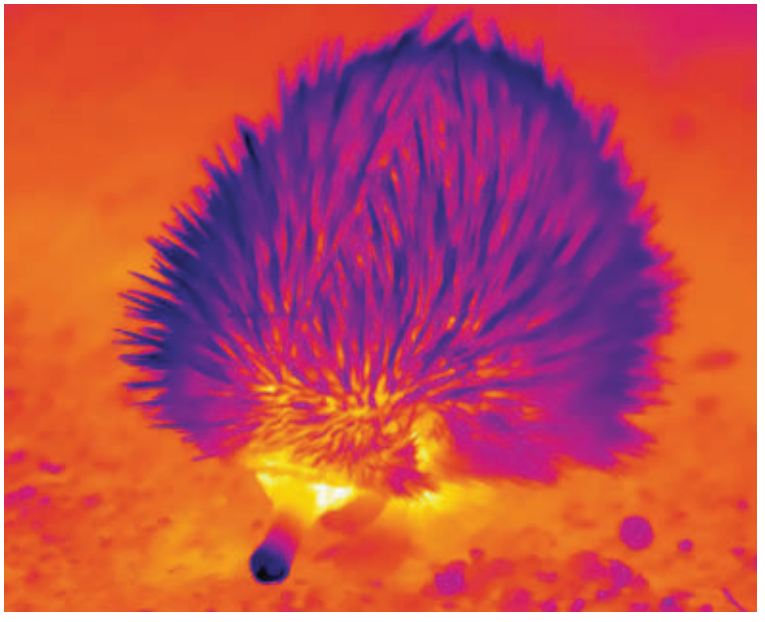
This is because the Big Bang happened everywhere all at once, **Crockett** says. "It is less of a place in space and more of an event imprinted everywhere if we look far enough out."

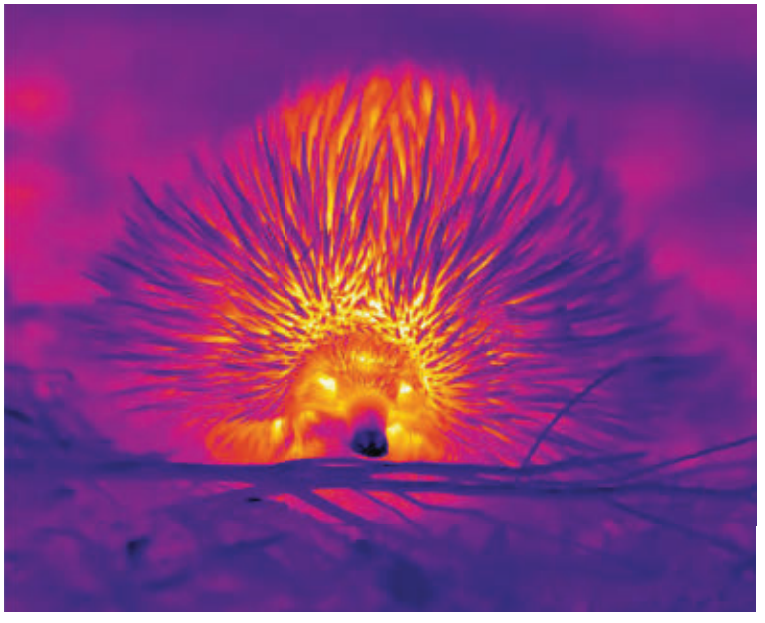
Think of it this way: Roughly 13 billion years ago, a first generation of stars was coming to life all around Earth's current location in space. Back then, if someone stood where we are now, they might have seen brand-new stars forming in all directions. Fast forward to the present, and it's kind of the same idea, **Crockett** says. Look in one direction with JWST, and you might see a bunch of first-generation stars that were once relatively close to Earth's current location. Turn the telescope around, and you might see another bunch of first-gen stars.

That doesn't mean that the first stars were born everywhere at the exact same moment, **Crockett** says. The first stars were born over millions of years due to local variations in things like the density and temperature of hydrogen clouds. It was "an epoch when conditions throughout the universe were finally right to allow hydrogen clouds to collapse and ignite fusion for the first time."

Send your science questions to feedback@sciencenews.org.

JEFF GODDARD





Adorable spike-balls beat the heat with snot bubbles

Animals cover themselves in all kinds of unsavory fluids to keep cool. Humans sweat, kangaroos spit and some birds urinate on themselves to survive hot days. It turns out that short-beaked echidnas do something much cuter to beat the heat — though perhaps just as sticky (and slightly icky).

The spiny insectivore (one shown at left) stays cool by blowing snot bubbles, researchers report in the January *Biology Letters*. The bubbles pop, keeping the critter's nose moist. As this moisture evaporates, it seems to draw heat away from a blood-filled sinus in the echidna's beak, helping to cool the blood.

Short-beaked echidnas (*Tachyglossus aculeatus*) look like hedgehogs but are actually monotremes, egg-laying mammals found only in Australia and New Guinea (SN: *11/26/16, p. 4*). Lab studies have shown that air temperatures above 35° Celsius should kill echidnas. But the animals don't seem to have gotten the memo. They live everywhere from tropical rainforests to deserts to snow-capped peaks, leaving scientists with a physiological puzzle.

Mammals evaporate water to keep cool when body temperatures start to climb, says environmental physiologist Christine Cooper of Curtin University in Perth, Australia. "Lots of mammals do that by either licking, sweating or panting," she says. "Echidnas weren't believed to be able to do that." But it's known that the critters blow snot bubbles when it gets hot.

So, armed with a heat-vision camera and a telephoto lens, Cooper and a colleague drove through nature reserves in Western Australia once a month for a year to film echidnas.

In infrared, the warmest parts of the spiny echidna body glowed in oranges, yellows and whites (shown in the bottom two images of two different echidnas). But the tip of the nose appeared as a dark purple blob, presumably kept cool as moisture from snot bubbles evaporated. Echidnas might also lose heat through the belly and legs, the researchers report, while the spikes could act as an insulator.

Monotremes parted evolutionary ways with other mammals between 250 million and 160 million years ago, around the time the supercontinent Pangaea broke apart. "They have a whole lot of traits that are considered to be primitive," Cooper says. "Understanding how they might thermoregulate can give us some ideas about how thermal regulation…might have evolved in mammals." — *Elise Cutts*

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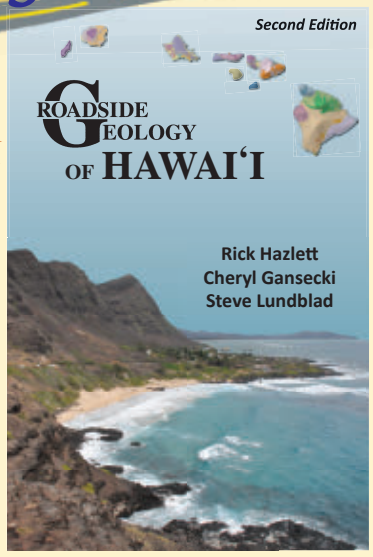

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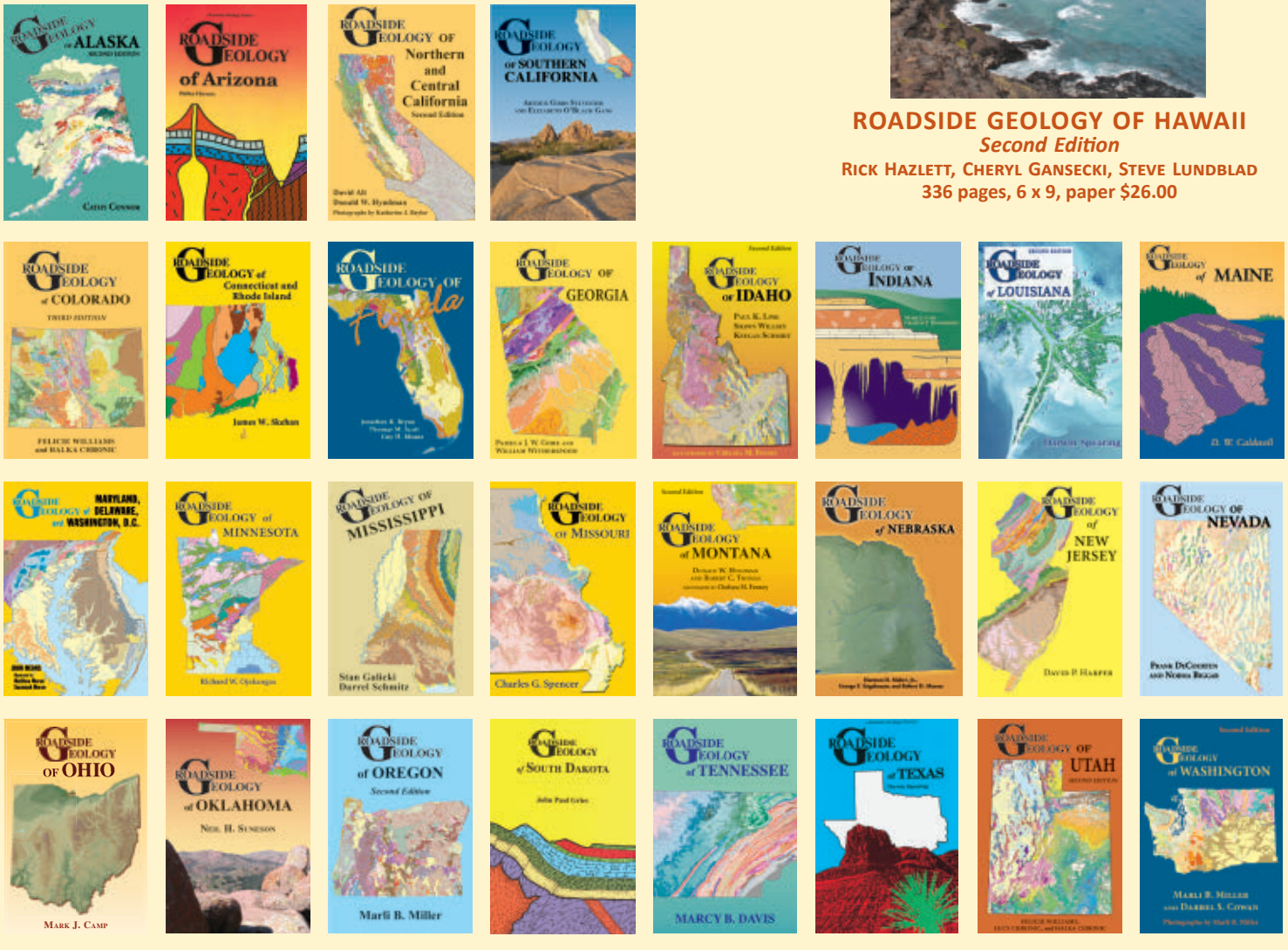

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At Michigan Tech, researchers turn plastic into protein powder.

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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