Triceratops Fight Club | Sound Gets Strange on Mars

ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ MAY 7, 2022 & MAY 21, 2022

The Future of Food

Experiments in what we eat and how we grow it will help us weather climate change

Congratulations and best of luck to the Regeneron ISEF 2022 finalists!

At Regeneron, science powers our mission to repeatedly bring important new medicines to patients living with serious diseases. Science is key to tackling many of the threats facing humanity, and we believe today's ISEF finalists will play a critical role in finding solutions, today and in the future.

We are proud to partner with the Society for Science to celebrate and inspire the next generation of scientists.

REGENERON ISEF
A PROGRAM OF SOCIETY FOR SCIENCE

REGENERON SCIENCE TALENT SEARCH
A program of SOCIETY FOR SCIENCE
Since 1942

REGENERON
SCIENCE TO MEDICINE®

VOL. 201 | NO. 9

ScienceNews

28

Special Report

THE FUTURE OF FOOD

News


14


4

Departments

COVER A farmer in western India's Dhundi village harvests rice. Solar panels power his water pump and bring in extra income. *IWMI-TATA Program, Shashwat Cleantech and Dhundi Saur Urja Utpadak Sahkari Mandali (DSUUSM)*

FROM TOP: JOE SOHM/VISIONS OF AMERICA/UNIVERSAL IMAGES GROUP VIA GETTY IMAGES; D. KOZLOWSKI/UGA; JPL-CALTECH/NASA, MSSS

A changing climate means changes on the plate

Food has always been complicated, not the least because we can't live without it. Throughout human history, the hunt for food has fueled migration, war and exploration. Changing tastes in food can change history. Europeans came upon the Americas while trying to break the Ottoman Empire's monopoly on the spice trade. And Europeans' yen for sugar in the 17th century sparked the development of Caribbean sugar plantations and the transatlantic trade of enslaved people.

In this issue, we consider the future of food through the lens of climate change. Currently, one-third of human-caused global greenhouse gas emissions are related to food. And there's growing focus on how to shrink food's climate footprint.

Agriculture is one big opportunity. In India, experiments in climate-smart agriculture include planting trees that boost soil nutrients and keep carbon out of the atmosphere (Page 36). Freelance writer Sibi Arasu talked with Pravinbhai Parmar, a farmer in the state of Gujarat who switched from using diesel fuel to electricity from solar panels to pump irrigation water. He no longer has to pay for diesel and has income from selling excess electricity. Around the world, people are identifying foods that can thrive despite increasingly volatile weather, such as millet and Bambara groundnuts, our intern Anna Gibbs reports (Page 34).

But as you might imagine, the calculus on food and climate gets complicated quickly. Six economies contribute more than half of Earth's food-related greenhouse gases, according to reporting by freelancer Betsy Ladyzhets (Page 22). But the sources of those emissions vary widely. China and India are high emitters largely due to their big populations, while bulldozing forests to clear land for farming is a big driver in Brazil and Indonesia. And in Europe and the United States, it's our penchant for meat-heavy meals and reliance on industrial-scale farming, which is dependent on fossil fuels and chemicals.

Not all efforts to make for a greener food system require changing the habits of entire countries, continents or global industries. Individuals like me who appreciate a good burger every now and then will be heartened to learn that dining meat-free one day a week takes a bite out of greenhouse gas production. Other changes, such as eating vegan for two out of three meals a day, can have an even bigger impact. So I could have my occasional burger and help the planet, too.

I grew up in the Midwest. Each fall, my family stocked the freezer with a side of beef and a side of pork to get us through the winter. But we also grew vegetables and put them by. Over the years, I have found myself enjoying vegetables more and craving meat less, and I'm sure I'm not alone. Given that food is so entwined with culture, family and identity, researchers are keenly interested in how cultural and personal food preferences can change, as social sciences writer Sujata Gupta reports (Page 28). Sometimes it's as simple as being more inclusive: For many, "flexitarian" sounds much less restrictive than "vegetarian."

And sometimes the planet-friendly food choice is no sacrifice at all. I cook up a mushroom risotto so luscious I'd happily choose it over a burger. In fact, it's a treat. —*Nancy Shute, Editor in Chief*








BROADCOM®
FOUNDATION

Salutes 10 years of the Broadcom MASTERS International








Excerpt from the May 6, 1972 issue of *Science News*

50 YEARS AGO

Comet hints at a new planet

There have been suggestions that our solar system might have a tenth planet.... In the April *Publications of the Astronomical Society of the Pacific*, a mathematician ... presents what he says is "some very interesting evidence of a planet beyond Pluto." The evidence comes from calculations of the orbit of Halley's comet.

UPDATE: The 1972 evidence never yielded a planet, but astronomers haven't stopped looking — though it became a search for Planet 9 with Pluto's 2006 switch to dwarf status. In the mid-2010s, scientists hypothesized that the tug of a large planet 500 to 600 times as far from the sun as Earth could explain the peculiar orbits of some objects in the solar system's debris-filled Kuiper Belt (*SN: 7/23/16, p. 7*). But that evidence might not stand up to further scrutiny (*SN: 3/13/21, p. 9*). Researchers using the Atacama Cosmology Telescope in Chile to scan nearly 90 percent of the Southern Hemisphere's sky had no luck finding the planet, the team reported in December 2021.

Female jorō spiders (one shown) are hard to miss, while males are extremely small. The arachnids are spreading in the U.S. Southeast, but how far north they'll go is unclear.

IT'S ALIVE

Calling Jorō spiders 'giant' tells only half the story

Some fingertip-sized, brown male spiders in Georgia could be miffed if they paid the least attention to humans and our news obsessions.

Recent stories have made much of "giant" jorō spiders, some large enough to span your palm, reaching North America from eastern Asia. Lemon yellow bands cross their backs. Bright red bits can add drama, and a cheesecake yellow highlights the joints on long black legs. So far, only a few tests on basic physiology have addressed the arachnid's ability to expand its territory.

The showy giants are just the females of *Trichonephila clavata*. Males hardly get mentioned except for what they're not: colorful or big. At 8 millimeters, hulkier males aren't quite half the length of small females. Even the species's nickname ignores the guys. The word jorō, borrowed from Japanese, translates to such terms as "courtesan" and "lady-in-waiting."

Mismatched sexes are nothing new for spiders. The group shows the most extreme size differences between the sexes known among land animals, says evolutionary biologist Matjaž Kuntner of the Evolutionary Zoology Lab in Ljubljana, Slovenia. And those differences can lead to violent mating conflicts, such as females eating males (*SN: 11/13/99, p. 312*). Jorō spiders don't engage in such behavior, Kuntner says, maybe because the size difference isn't extreme enough.

When it comes to humans, these spiders don't bother anybody who doesn't bother them. But what a spectacle they make. "I've got dozens and dozens in my yard," says ecologist Andy Davis of the University of Georgia in Athens. "One big web can be 3 or 4 feet in diameter." Jorō spiders have lived in northeastern Georgia since at least 2014.

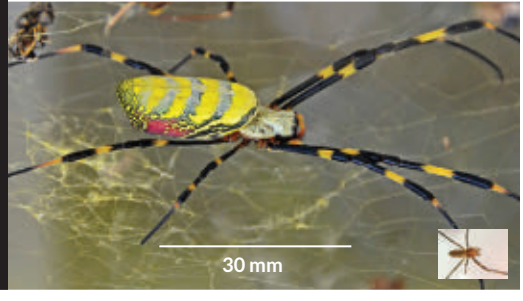
The recent arrivals inspired Davis and undergraduate Benjamin Frick to see if the spiders withstand chills better than *T. clavipes* — a more tropical relative that hasn't left the comfy U.S. Southeast since the species invaded at least 160 years ago.

To figure out the jorō's hardiness, Davis wanted to take its pulse. Spider hearts aren't lumps circulating blood through a closed system. The jorō sluices its blood-like fluid through a long tube open at both ends. "Think of a garden hose," Davis says. He found a spot on a spider's back where a keen-eyed observer can count throbs.

Female jorō spiders packed in ice to simulate cold stress kept their heart rates some 77 percent higher than *T. clavipes* females, tests showed. Metabolic rates of jorō females were about double. And in two minutes of freezing cold, jorō females showed better survival (74 percent versus 50 percent). Lab tests used only females, though male ability to function in cold snaps also could matter in how far north jorō spiders spread.

Sightings now stretch into the Carolinas and Tennessee. Jorō spiders appear to reproduce in less time than *T. clavipes*, a potential boon should the newcomers move farther north, Davis and Frick reported February 17 in *Physiological Entomology*. Adults don't need to survive winter as long as their eggs sacs can. But how far jorō parents will go and when, we'll just have to wait and see. — *Susan Milius*

A female *Trichonephila clavata* spider looms so large that it's easy to overlook males of the species (inset, shown to scale) that hang out in her web.



FROM TOP: D. KOZLOWSKI/UGA; J. HOWELL (FEMALE), B.J. FREEMAN (INSET MALE), E.R. HOEBEKE, W. HUFFMASTER AND B.J. FREEMAN/*PEERJ* 2015

THE EVERYDAY EXPLAINED

Upbringing may influence wayfinding ability

Score one for the country mouse. People who grow up outside of cities are better at finding their way around than those who grow up as urbanites, a large study suggests. The results, described in the April 7 *Nature*, hint that learning to handle environmental complexity as a child strengthens mental muscles for spatial skills.

Nearly 400,000 people from 38 countries played a video game called *Sea Hero Quest*, in which they piloted a boat in search of various targets. On average, people who reported growing up outside of cities, where they would have presumably encountered lots of meandering paths, were better at finding the targets than people who were raised in cities. What's more, the difference between city dwellers and outsiders was most prominent in countries where cities tend to have simple, gridlike layouts. The simpler the cities, the bigger the advantage for people outside of them, cognitive scientist Antoine Coutrot of CNRS, who is based in Lyon, France, and colleagues report. From these data, the team can't definitively say that childhood environment is behind the differences. But it's plausible. Other bits of demography, including age, gender and education, as well as sense of smell have been linked to navigational performance. —*Laura Sanders*

A newfound possible star (arrow) is from the universe's first 900 million years, scientists say. It's visible because a galaxy cluster magnifies the light of this object and a background galaxy (red arc).

THE –EST

'Earendel' might be the farthest known star

A chance alignment may have revealed a star from the universe's first billion years. If confirmed, this star would be the most distant one ever seen, obliterating the previous record. Light from the object, dubbed "Earendel" from the Old English word meaning "morning star," traveled for about 12.9 billion years on its journey toward Earth. That's about 4 billion years longer than the former record holder, astronomer Brian Welch and colleagues report in the March 31 *Nature*.

The team found the object in Hubble Space Telescope images of a cluster of galaxies nearer to Earth. Such clusters are so massive that they bend and focus the light from more distant background objects. Earendel's light originates from 900 million years after the Big Bang, which took place about 13.8 billion years ago. Welch, of Johns Hopkins University, and colleagues think the object has at least 50 times the mass of the sun. But the team can't pin down that value or confirm that the object is a star without more data. Welch plans to examine Earendel using the James Webb Space Telescope, and perhaps uncover objects from even earlier in the universe's history. "I'm hoping that this record won't last very long." —*Liz Kruesi*

TEASER

Cellulose helps ice cream go down smooth

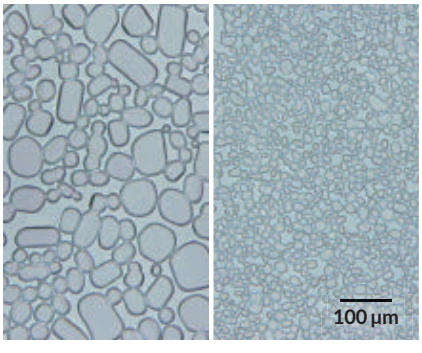
You can never have too much ice cream, but you can have too much ice in your ice cream. Adding plant-based nanocrystals to the frozen treat could help solve the problem, food scientist Tao Wu of the University of Tennessee in Knoxville and colleagues reported March 20 at the American Chemical Society spring meeting in San Diego.

Small ice crystals in ice cream grow bigger when temperature fluctuations in freezers cause the crystals to melt and reform. Stabilizers such as guar gum slow crystal growth, but don't stop it. Once ice crystals hit 50 micrometers across, ice cream takes on a grainy texture.

Plant-derived cellulose nanocrystals, or CNCs, have properties similar to guar gum. An experiment with a sucrose solution—an ice cream proxy—and CNCs showed that after 24 hours, ice crystals stopped growing and remained at 25 micrometers after a week, well under the graininess threshold. In a test with guar gum, ice crystals grew to over 50 micrometers in just three days.

The finding suggests "nanocrystals are a lot more potent than the gums," says food engineer Richard Hartel of the University of Wisconsin–Madison. —*Anna Gibbs*

When compared with ice crystals in an unadulterated ice cream–like solution (left), ice crystals in solution with cellulose particles added (right) stopped growing after 24 hours and stayed at a desirable size for a week.



FROM TOP: AMERICAN HERITAGE CHOCOLATE/UNSPLASH; NASA, ESA, B. WELCH/JHU, DAN COE/STSCI (SCIENCE); NASA, ESA, ALYSSA PAGAN/STSCI (IMAGE PROCESSING); MIN LI

HUMANS & SOCIETY

How Ukrainian identity solidified

Social scientists have tracked the rise in national pride

BY SUJATA GUPTA

Before Russia invaded Ukraine, many military analysts feared that the capital of Kyiv would fall within days of any attack, undermining any further resistance. Instead, the war has now dragged on for more than two months.

What these analysts and Russian President Vladimir Putin missed, social scientists say, is research showing that people who live in Ukraine have identified more and more as Ukrainian — and less as Russian — since Ukraine's independence from the former Soviet Union in 1991.

That trend intensified after Russia seized the Crimean Peninsula in 2014 and started backing separatists in the Donbas region, political and ethnic studies scholar Volodymyr Kulyk said in a virtual talk organized by Harvard University in February. "'Russians' came to mean people in Russia," said Kulyk, of the National Academy of Sciences of Ukraine.

Ukrainian loyalists are now fighting tooth and nail for their country. "Putin underestimated Ukrainians' attachment to their country and overestimated [their] connection to Russia," says political scientist Lowell Barrington of Marquette University in Milwaukee. "One of his biggest mistakes was not reading social science research on Ukraine."

Historic divide

The common refrain is that Ukraine is a country divided along both linguistic and regional lines. While the country's official language is Ukrainian, most people speak both Ukrainian and Russian. People living in western cities primarily speak Ukrainian, and those in eastern cities closer to the Russian border primarily speak Russian.

The origins of those divisions are complicated but trace back, in part, to when western Ukraine was part of the Austro-Hungarian Empire and eastern Ukraine was part of the Russian Empire, between the late 18th and early 20th centuries. After the Russian Empire's collapse in 1917, Ukraine was briefly an independent state before being incorporated into the Soviet Union in the early 1920s.

Putin seems to believe that national identities stay relatively fixed across time, says political scientist Henry Hale of George Washington University in Washington, D.C. Social scientists refer to that idea as primordialism, the belief that individuals have a single nationalistic or ethnic identity that they pass on to subsequent generations. In other words, once a Russian, always a Russian.

That rigid mentality shows up in the framing of official documents and censuses conducted in the Soviet Union starting in 1932. That's when officials began recording people's *natsionalnist*, essentially a conflation of nationality with ethnicity. People in the Soviet Union fell into one of over 180 possible ethnic categories, including Russian, Chechen, Tatar, Jewish and Ukrainian.

"Nationality was transformed into a characteristic of a person that was inherited from his parents, rather than chosen consciously," says political scientist Oksana Mikheieva of the European University Viadrina in Frankfurt and the Ukrainian Catholic University in Lviv.

The Kremlin's goal was to unite multiple ethnicities under a single Soviet label, but those with a Russian ethnicity remained at the top of the social ladder, Mikheieva and political scientist Oxana Shevel of Tufts University in Medford, Mass., wrote in a chapter of the 2021 book *From 'the Ukraine' to Ukraine*. Paradoxically, one's nationality both provided a sense of belonging and deepened ethnic divides.

Putin, who served in the Soviet-era KGB, may have either directly or indirectly been counting on people to still view their nationality in this way. "He's stuck in his formative years from the Soviet period," says Elise Giuliano, a political scientist at Columbia University.

Shifting identity

Primordialism has largely fallen out of favor among social scientists, Hale says. Most researchers see ethnic and nationalistic identities as fluid, or dependent on the political and social environment.

Some of that shift in thinking comes from the study of Ukraine itself. Its relatively recent independence means that social scientists can track Ukrainian people's evolving sense of identity in real time.

At the time of independence, Ukraine made the unusual move of granting citizenship to nearly everyone living

Three weeks after Russia's invasion of Ukraine, volunteers in Lviv sew Ukrainian flags. Ukrainian nationalism has been steadily growing since the country gained independence in 1991.

BERNAT ARMANGUE/AP PHOTO

within its borders. When passports were issued, officials stopped the Soviet practice of stamping them with a person's *natsionalnist*. In the 2000s, that category disappeared from birth certificates.

These practices contrasted with those of other former Soviet countries, such as Latvia and Estonia, where ethnic Russians were denied automatic citizenship, says Barrington, the Marquette political scientist. Consequently, Ukraine paved the way for the emergence of a civic, or chosen, identity. So, researchers wondered, would people in Ukraine, even those with a non-Ukrainian *natsionalnist*, shed their Soviet identity and become Ukrainian?

> "In some paradoxical twist, Putin is basically unifying the Ukrainian nation."
>
> **OXANA SHEVEL**

Official censuses from before and after independence hinted that the percentage of people living in Ukraine who identified as Ukrainian did increase after 1991. In 1989, about 73 percent of people identified as Ukrainian. By 2001, about 78 percent did. In contrast, about 22 percent of people identified as Russian in 1989, while only about 17 percent did by 2001. Migration out of Ukraine cannot fully account for that change.

Since 2001, no national censuses have been held. So scientists have relied on smaller but often more detailed surveys. Initially, those surveys continued to use Soviet terminology. Censuses and surveys shoehorn people into categories, Hale says, but understanding how people's interpretation of those categories change over time, particularly when the social context changes, is essential (SN: 3/14/20, p. 16).

For understanding Ukrainian identity, researchers have looked to the "native language" question, which even in Soviet times was hard to interpret. Asking people to choose their native language was meant to capture their language of everyday use. But people often selected the language that aligned with their ethnicity.

About 12 percent of Ukrainians selected Russian as their native language in the 1989 census, Kulyk said in his talk. But other surveys from around that time that distinguished between native and everyday language revealed that over 50 percent of Ukrainians spoke Russian in everyday life.

Confusion over the native language question carried over to post-Soviet Ukraine. Surveys in the 1990s and 2000s showed that many people selecting Ukrainian as their native language did not necessarily speak it, Kulyk reported in 2011 in *Nations and Nationalism*.

In a more recent analysis of three nationwide surveys — in 2012, 2014 and 2017, and each with some 1,700 to 2,000 respondents — Kulyk studied responses to this question: What language do you consider your native language? In 2012, some 60 percent of respondents said Ukrainian; 24 percent said Russian. By 2017, over 68 percent chose Ukrainian and just under 13 percent chose Russian, Kulyk reported in 2018 in *Post-Soviet Affairs*.

Those numbers say little about actual language use, Hale says. Instead, the native language question gauges shifting views of national identity. The growing number of Ukrainian "speakers" and decreasing number of Russian "speakers" suggests that people select an answer in line with their Ukrainian civic identity, Hale says. "Knowing Russian isn't any kind of predictor for supporting the Russian state. Instead, what is [becoming] more important is the civic identification with the Ukrainian state."

Choosing Ukraine

Researchers have also been investigating responses to the question, What is your *natsionalnist*? It still occasionally appears on official paperwork.

Ukrainians filling out those forms can interpret the term as asking about their ethnic background in the Soviet sense, their chosen identity or some combination of both. What social scientists want to understand is how Ukrainians no longer under Soviet rule perceive themselves.

To that end, the three nationwide surveys Kulyk evaluated all asked multiple questions about nationality. In one, people were told: "…some people consider themselves belonging to several nationalities at the same time. Please look at this card and tell which statement reflects more than the others your opinion about yourself." People could select a single nationality or some combination of Russian and Ukrainian. The percentage of people selecting only Ukrainian went up from 67.8 percent in 2012 to 81.5 percent in 2017.

The greatest rise occurred among people in the historically Russian strongholds of eastern and southern Ukraine. In 2012, some 40 percent of Ukrainians from those regions selected "only Ukrainian" compared with almost 65 percent in 2017. Meanwhile, the percentage of eastern and southern Ukrainians identifying as "only Russian" decreased from roughly 17 percent to less than 5 percent. (Those figures might be out of date as researchers have been unable to collect more recent data from the Russian-controlled Crimean Peninsula and the disputed Donbas region.)

More recent work also suggests that Ukrainian people are shedding their Soviet understanding of identity. In a 2018 survey, some 70 percent of the more than 2,000 respondents said their Ukrainian citizenship constituted at least part of their identity, Barrington reported in 2021 in *Post-Soviet Affairs*. That's due, in part, to Ukrainian leaders' efforts to shift away from ethnic nationalism and toward civic nationalism. Deprioritizing ethnicity weakens the linguistic and regional divides, while civic nationalism bonds people through "feelings of solidarity, sympathy and obligation," Barrington wrote.

Broadly speaking, researchers say, these surveys show that identification with the Ukrainian state began right after the country got independence and accelerated following Russian aggression in 2014.

The current war is almost certainly cementing many Ukrainians' loyalty to their country, everyone interviewed for this story said. "In some paradoxical twist," says Shevel, the political scientist at Tufts, "Putin is basically unifying the Ukrainian nation."

Identity grows stronger, and internal divisions weaker, when nations are under attack, says Giuliano, the political scientist at Columbia. During an invasion, "you are going to rally around the flag. You're going to support the country in which you live." ■

EARTH & ENVIRONMENT

U.N. report calls for climate action now

Strategies exist to halve greenhouse gas emissions by 2030

BY CAROLYN GRAMLING AND NIKK OGASA

The world already has the know-how and tools to dramatically reduce greenhouse gas emissions, and we need to use those tools immediately if we hope to forestall the worst impacts of climate change. That's the message of the latest installment of the sixth assessment of climate science by the United Nations' Intergovernmental Panel on Climate Change, which was released on April 4.

Global warming is fueling extreme weather events around the world, and Earth is on track to warm by an average of about 3.2 degrees Celsius above preindustrial levels by the end of the century (SN: 9/11/21, p. 8; SN: 3/26/22, p. 7). Altering that course and limiting warming to 1.5 degrees or even 2 degrees C means global greenhouse gas emissions should peak no later than 2025, the report states.

Right now, meeting that goal looks extremely unlikely. National and corporate pledges to reduce greenhouse gas emissions to date amount to "a litany of broken climate promises," said U.N. Secretary-General António Guterres at a news event announcing the report's release.

But there is reason for hope, says forest ecologist Bronson Griscom of Conservation International, an environmental organization based in Arlington, Va. "This report is basically saying, 'Look, if we don't do anything, it's increasingly grim.' But the reasons to do something are incredibly powerful and the tools in the toolbox are very powerful," says Griscom, who was not an author of the report.

Those tools are strategies that governments, industries and individuals can use to cut emissions immediately in multiple sectors of the global economy, including transportation, energy, urban development, agriculture and forestry. Taking immediate action to reduce emissions in each sector could halve global emissions by 2030, the report states.

Consider the transportation sector, which contributed 15 percent of human-related greenhouse gas emissions in 2019. Globally, electric vehicle sales have surged over the last few years, driven by government policies and tougher emissions laws (SN: 12/18/21 & 1/1/22, p. 28).

If the surge continues, "electric vehicles offer us the greatest potential [to reduce transportation emissions on land], as long as they're combined with low- or zero-carbon electricity sources," Diana Ürge-Vorsatz, vice chair of the climate change panel's Working Group III, said at the news event. For aviation and long-haul shipping, which are difficult to electrify, reduced carbon emissions could be achieved with low-carbon hydrogen fuels or biofuels.

Urban areas contributed 67 to 72 percent of global greenhouse gas emissions in 2020, the report notes. To cut emissions, buildings in established cities could be retrofitted with systems that capture greenhouse gases and repurposed to make the cities more walkable and public transportation more accessible. Cities that are just getting established could incorporate energy-efficient infrastructure and construct buildings using low- or zero-emissions materials.

As for agriculture and forestry, these and other land use sectors contribute about 22 percent of the world's greenhouse gas emissions, with about half coming from deforestation (SN: 7/3/21 & 7/17/21, p. 24). Reforestation and reduced deforestation are key to flipping the balance between carbon dioxide emissions and removal from the atmosphere. Other strategies at the world's fingertips include more sustainable management of ecosystems, livestock, crops and soil.

The report also includes a chapter on the "untapped potential" of lifestyle changes to reduce emissions (SN: 5/9/20 & 5/23/20, p. 34). Such changes include shifting toward plant-based diets and walking, cycling and using public transportation in lieu of driving. If these and other changes are enabled by policies, infrastructure and technology, they could cut emissions by 40 to 70 percent by 2050.

Government policies are key to financing these transformational changes. Global investment in climate-related technologies needs to ramp up fast to limit warming, the report states. By 2030, investments and other financial transactions to support these transitions need to be three to six times as high as they are now.

Reducing emissions alone isn't enough to keep planetary warming below 2 degrees C, the report notes. Technologies that capture CO_2 from the air and store the gas underground could help. But these options are in their infancy, and we don't yet know how much of an impact they'll have, says Simon Nicholson, co-director of the Institute for Carbon Removal Law and Policy at American University in Washington, D.C., who was not involved in the report. "We need massive investment now in research," he says. ■

Solar panels float on a lake in western Germany on April 1. A new United Nations climate report outlines numerous changes the world can make now, including shifting to solar and other sources of renewable energy, that would halve global greenhouse gas emissions by 2030.

MARTIN MEISSNER/AP IMAGES

Can a student protect our Nation?

When you intern at CIA, you can.

If you're looking to experience more than a traditional internship and jump in right away, then CIA is the place for you.

CIA has internship opportunities in several fields of study, some of which might surprise you. Discover where your skills could help us protect our national security.

Central Intelligence Agency

cia.gov/careers/student-programs

An equal opportunity employer and a drug-free workforce.

HUMANS & SOCIETY

U.S. medical records show racial bias

Notes on Black patients inordinately contain negative terms

BY AIMEE CUNNINGHAM

When health care providers enter notes into a patient's electronic health record, they are more likely to portray a Black patient negatively than a white patient, two recent studies found. The unfavorable descriptions may perpetuate bias and stigma, and influence the care that patients receive.

"The first impression is the chart," says Gracie Himmelstein, a physician training in internal medicine at the UCLA David Geffen School of Medicine. "That narrative is going to shape your views of the patient, even if you think you're just looking for the clinical data."

Himmelstein and colleagues analyzed more than 48,000 hospital admission notes from a Boston medical center. Stigmatizing language overall, and about diabetes and substance use disorder in particular, was more often used in Black patients' notes than in white patients' notes, the team reports in the January *JAMA Network Open*.

> "The first impression is the chart. That narrative is going to shape your views of the patient."
>
> **GRACIE HIMMELSTEIN**

Another group of researchers combed through more than 40,000 medical notes from a Chicago medical center. Black patients were more likely than white patients to be described as not complying with or resistant to treatment, among other unfavorable terms, that team reports in the February *Health Affairs*.

The studies appear to be the first to quantify racial bias in U.S. electronic health records. Bias can drive health disparities — differences in health tied to social, environmental or economic disadvantages — that occur between different racial and ethnic groups (SN: 11/23/19, p. 6). For example, Black infants have a higher mortality rate than white infants due to health disparities.

In the study in *Health Affairs*, scientists designed a computer program to look for phrases with negative connotations — such as "not compliant," "not adherent" and "refused" — in medical notes written from January 2019 to October 2020 for nearly 18,500 patients. Overall, about 8 percent of patients had at least one negative term in their health records.

Black patients were 2.5 times as likely to have such words in their medical notes as white patients, the team found. This language "has a potential for targeted harm," says coauthor Michael Sun, a medical student at the University of Chicago's Pritzker School of Medicine.

In the other study, Himmelstein and colleagues scrutinized electronic medical notes for negative language like "nonadherent" and "unwilling," along with stigmatizing words such as "abuse" that label or place blame on the patient. The notes were written from January to December 2018.

Overall, around 1,200, or 2.5 percent, of the notes contained unfavorable language. Notes about substance use disorder and diabetes had more of that language woven in, at 3.4 percent and 7 percent. In the full sample, Black patients were nearly 1.3 times as likely as white patients to have stigmatizing terms in their notes. That factor was about the same for diabetes notes. For records about substance use disorder, Black patients were 1.7 times as likely to have negative descriptions.

The studies didn't assess what impact biased notes had on patients' medical care. But other research has found that when short descriptions of a patient include stigmatizing language, the negative terms influenced physicians' treatment decisions, for example, making doctors less likely to offer sufficient pain medication.

Bias in medical notes may also sour patients' perceptions of their providers. Patients now have the right to read their electronic health records, as mandated in the 21st Century Cures Act. Notes that include stigmatizing or biased depictions can "potentially undermine trust," says Leonor Fernández, a primary care doctor and health equity adviser at Beth Israel Deaconess Medical Center in Boston.

In a survey of nearly 23,000 patients, 10.5 percent felt offended or judged, or both, after reading their own notes, Fernández and colleagues reported in the *Journal of General Internal Medicine* in September 2021. Many respondents explained what prompted their feelings. One participant wrote, "Note said I wasn't doing everything I could to lose weight which was untrue and very upsetting to see my Dr. thought of me like that."

Other researchers have written about ways to remove stigma from descriptions of substance use disorder and diabetes, among other conditions. This guidance encourages language that does not identify the patient by their illness and that focuses on the efforts a patient is making. For example, instead of describing a patient as "noncompliant" with their medication, the researchers suggest explaining why, as in, the patient takes insulin "50 percent of the time because of cost concerns."

Accounting for challenges patients face can make health care providers more effective and patients less likely to feel blamed, Fernández says.

Sun hopes health care providers "think about what other context and what other story" can be told about their patients.

In the study that Sun coauthored, an encouraging change occurred over time. From March to October 2020, Black patients were no longer more likely to have negative terms in their notes than white patients. That time period coincided with the start of the COVID-19 pandemic and a ramping up of Black Lives Matter protests.

Sorting out what's behind the drop will take more work, Sun says. Providers may have considered patients with COVID-19 less responsible for their illness, in contrast to other conditions, he and his team note. But perhaps the drop has to do with how impactful that time period was in raising awareness of racial health disparities, Sun says. Perhaps the shift was "out of empathy." ■

مؤسسة الملك عبدالعزيز ورجاله للموهبة والإبداع
King Abdulaziz & his Companions Foundation for Giftedness & Creativity

موهبة

"Mawhiba
where you belong"

At Mawhiba we seek to enable Giftedness & Creativity as the main contributions to the advancement of humanity. Therefore, our mission is to provide an inspirational environment for giftedness & creativity, and promote passion for science & knowledge in the development of future leaders nationally and internationally.

Learn More

mawhiba.org

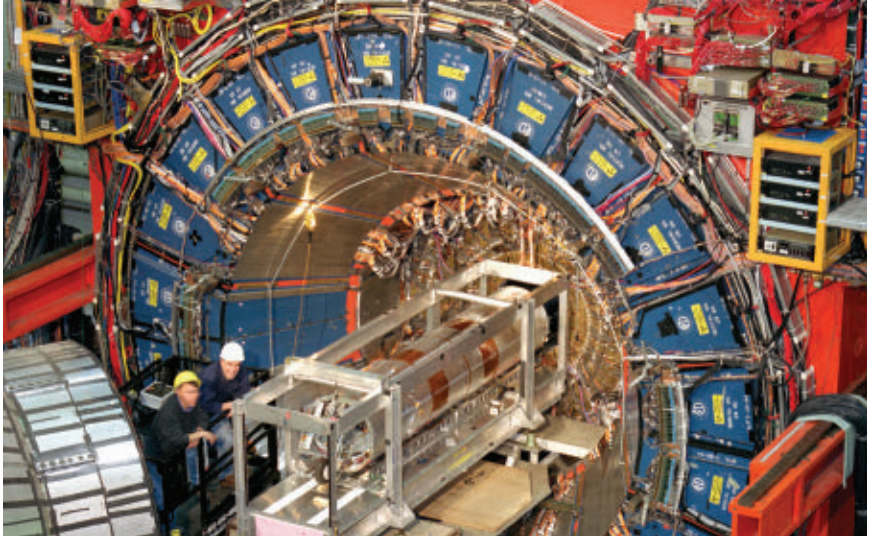
Mawhiba

ATOM & COSMOS

Subatomic particle may be extra hefty

Measurement of W boson's mass hints at new physics

BY EMILY CONOVER



The Collider Detector at Fermilab experiment (shown) found hints that an elementary particle called the W boson has a higher mass than predicted by the standard model of particle physics.

FERMILAB

There's something amiss with a mass.

A new measurement of the mass of an elementary particle, the W boson, has defied expectations. The result hints at a possible flaw in physicists' otherwise stalwart theory of the fundamental bits and bobs of our world, known as the standard model.

That theory predicts a W boson with a mass of about 80,357 million electron volts. But the new measured mass is larger, at 80,433.5 MeV, physicists with the Collider Detector at Fermilab, or CDF, collaboration report in the April 8 *Science*.

The finding could hint at new particles or other mysteries of physics yet to be discovered. "If confirmed, this would clearly mean very interesting new physics that we can explore," says theoretical physicist Sven Heinemeyer of the Institute for Theoretical Physics in Madrid.

Still, several earlier, less precise measurements found W boson masses more closely aligned with the standard model, including a measurement from the ATLAS experiment at the Large Hadron Collider at CERN near Geneva. So physicists are awaiting further confirmation before declaring their prized theory incorrect.

"CDF's new result seems barely compatible with the previous ones, including its own previous result, which prompts questions," says ATLAS physicist Maarten Boonekamp of the Institute of Research into the Fundamental Laws of the Universe at the University of Paris-Saclay.

Discovered in 1983, the W boson plays an important role in the standard model (SN: 2/5/83, *p.* 84). The particle comes in two varieties, with either positive or negative electric charge. Together with their uncharged partner, the Z boson, the particles carry the weak nuclear force, which is responsible for certain types of radioactive decay and is a key player in the nuclear reactions that power the sun.

Using data collected from 2002 to 2011, the CDF team looked for W bosons produced in collisions of protons and their antimatter counterparts, antiprotons, in the now-shuttered Tevatron particle collider at Fermilab in Batavia, Ill. (SN: 9/24/11, *p.* 22). The analysis was designed so that researchers couldn't tell what the end result was until they were done.

The moment of the unveiling was striking, says experimental particle physicist Ashutosh Kotwal of Duke University. "When the answer popped up … we were awestruck about what we might have just learned."

The new W boson mass estimate, measured to within 0.01 percent, is about twice as precise as the previous record. "This is a very special measurement; this is a true legacy," says experimental particle physicist Rafael Coelho Lopes de Sá of the University of Massachusetts Amherst, who worked on measuring the W boson mass for another Tevatron experiment. "The level of dedication and care and detail … is amazing."

The new measurement disagrees with the standard model expectation by seven sigma, a measure of the statistical significance of a result. That's well above the five sigma that physicists usually require to claim a discovery.

Still, "before getting too excited," says ATLAS physicist Guillaume Unal of CERN, "I would like to see an independent measurement that confirms the CDF measurement." In addition to the ATLAS measurement, described in 2018 in the *European Physical Journal C*, another measurement of the W boson's mass from the CERN experiment LHCb was also in line with the standard model prediction, researchers reported in the January *Journal of High Energy Physics*.

"The W boson mass is notoriously difficult to measure," says LHCb physicist Mika Vesterinen of the University of Warwick in Coventry, England. That explains why it took CDF so long to wrap up this analysis, published more than 10 years after the experiment ended.

Hopefully scientists won't have to wait that long for another measurement. The ATLAS and LHCb collaborations are already working on improved W boson mass analyses. CMS, another experiment at CERN, could also size up the particle.

If the new measurement holds up, it's not yet clear what secrets of physics might be at play. New particles — such as those predicted by the theory of supersymmetry, which posits that each known particle has a heavier partner — could help shift the W boson mass upward. Those same particles, Heinemeyer says, might also help explain another recent mystery — the faster-than-predicted magnetic gyrations of muons reported by the Muon g–2 experiment (SN: 5/8/21 & 5/22/21, *p.* 6).

Whatever physicists uncover, they'll gain a new grasp on the particulars of the W boson, says theoretical physicist Nathaniel Craig of the University of California, Santa Barbara. "At the end of the day, the added energy and attention devoted to the W mass measurement … will be an immensely positive thing." ■

SCIENCE TAKES HARD WORK AND DEDICATION

SO DOES THE CITADEL

Every college promises a top-notch STEM education. But only The Citadel combines a state-of-the-art curriculum with 180 years of experience in developing principled leaders for the military, government, and private sector.

If you're ready to focus on academics in an environment that will develop your mind, body and spirit, The Citadel is ready for you.

BEST COLLEGES U.S.News & WORLD REPORT BEST VALUE SCHOOLS 2022

THE CITADEL

Learn more at
citadel.edu

ATOM & COSMOS

Sound on Mars travels at two speeds

Carbon dioxide drives the differing paces, spacecraft data show

BY LIZ KRUESI

On Mars, the speed of sound depends on its pitch.

All sound travels slower through Mars' air compared with Earth's. But the higher-pitched clack of a laser zapping rocks travels slightly faster in the thin Martian atmosphere than the lower-pitched hum of the Ingenuity helicopter, researchers report April 1 in *Nature*.

These sound speed measurements from NASA's Perseverance rover are part of a broader effort to monitor minute-by-minute changes in atmospheric pressure and temperature, like during wind gusts, on the Red Planet.

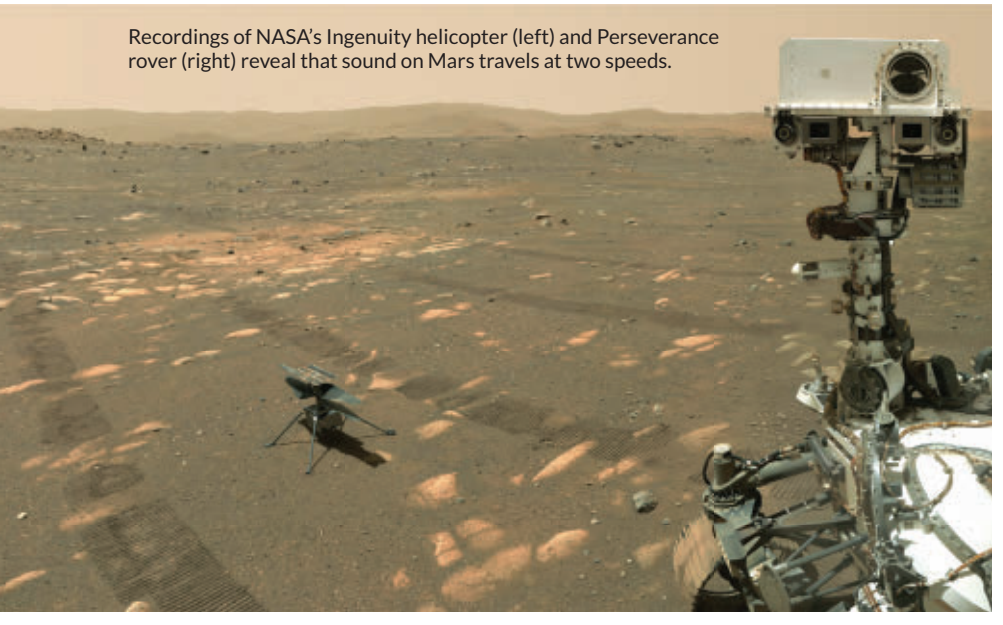
"The wind is the sound of science for us," says astrophysicist Baptiste Chide of Los Alamos National Laboratory in New Mexico.

Perseverance listens to the wind with two microphones. One was meant to record audio during the mission's complex entry, descent and landing, and while it didn't work as hoped, it is now turned on occasionally to listen to the rover's vitals. The other microphone is part of the rover's SuperCam instrument, a mast-mounted mishmash of cameras and other sensors used to understand the properties of materials on the planet's surface.

These microphones also pick up other sounds such as those made by Perseverance itself as its wheels crunch the surface, and by the rover's flying companion Ingenuity. SuperCam, for example, has a laser, which Perseverance fires at interesting rocks for further analysis. The microphone on SuperCam captures sounds from those laser shots, which help researchers learn about the hardness of the target material, says Naomi Murdoch, a planetary scientist at the Institut Supérieur de l'Aéronautique et de l'Espace in Toulouse, France.

Murdoch, Chide and colleagues listened to the laser's clack as it zapped rocks. When the laser hits a target, that blast creates a sound wave. Because scientists know when the laser fires and how far away a target is, they can measure the speed at which that sound wave travels through the air toward the SuperCam microphone.

The speed of this sound is about 250 meters per second, the team reports. That's slower than on Earth, where sound travels through the air at about 340 m/s.



Recordings of NASA's Ingenuity helicopter (left) and Perseverance rover (right) reveal that sound on Mars travels at two speeds.

JPL-CALTECH/NASA, MSSS

The slower speed isn't surprising. Sound is composed of pressure waves traveling through a medium like air, and the speed of those waves depends on the medium's density, composition and temperature (SN: 11/7/20, *p.* 9). Atmospheric pressure at Earth's surface is 160 times greater than the atmospheric pressure at the Martian surface. And Earth's air is mostly nitrogen and oxygen, whereas Martian air is predominately carbon dioxide and on average 80 degrees Celsius colder. So sound on Mars travels slower in that different air.

SuperCam's microphone also picked up the lower-pitch whir of Ingenuity's blades (SN: 1/15/22, *p.* 12). From this lower-pitched sound and previous studies of CO_2, the team found a second speed of sound at the Martian surface at frequencies below 240 hertz, or slightly deeper than middle C on a piano: 240 m/s.

In contrast, sound at Earth's surface moves through the air at only one speed, no matter the pitch. The two speeds on Mars, the team says, are because of the planet's carbon dioxide–rich atmosphere. CO_2 molecules behave differently when sound waves above 240 Hz move through the air compared with waves below 240 Hz, affecting the waves' speed.

"We've proved that we can do science with a microphone on Mars," Chide says.

The SuperCam microphone captures thousands of sound snippets per second. Those sounds are affected by air pressures, so researchers can use that acoustic data to track detailed changes in air pressures over short timescales, and, in turn, learn more about Martian climate. While other Mars rovers have carried wind, temperature and pressure sensors, those could sense changes only over longer periods of several minutes to hours.

Now the team is focusing on collecting acoustic data at different times of day and during different seasons on Mars.

"The pressure changes a lot on Mars throughout the year with the seasons," says Melissa Trainer, a planetary scientist at NASA's Goddard Space Flight Center in Greenbelt, Md., who was not part of this work. "I'm really excited to see how the data might change as it gets collected through proceeding seasons." ■

Listen to spacecraft on Mars at **bit.ly/SN_MarsSounds**

ARE YOU 15-17 YEARS OLD?

APPLY TO RISE

RISE

Rise is a program that finds **brilliant** people who need opportunity and **supports them for life** as they work to serve others.

The program starts at ages 15-17 and offers access to benefits that last a lifetime, including scholarships, mentorship, access to career development opportunities, funding, and more as Global Winners work toward solving humanity's most pressing problems.

www.riseforthe world.org

ATOM & COSMOS

Violent origin proposed for baby planet

Young world's location supports alternative formation scenario

BY ALLISON GASPARINI

A young, massive planet is orbiting in an unusual place in its star system, and it's reviving a long-debated view of how giant planets can form.

The protoplanet, nine times the mass of Jupiter, is too far from its star to have formed by accreting matter piece by piece, as most giant planets are thought to get built. Instead, the massive world probably formed all at once in a violent implosion of gas and dust, researchers report April 4 in *Nature Astronomy*.

"My first reaction was, there's no way this can be true," says Thayne Currie, an astrophysicist at the Subaru Telescope headquartered in Hilo, Hawaii.

Astronomers have debated for years how giant planets form. In the "core accretion" story, a planet starts out as small bits of matter within a disk of gas, dust and ice swirling around a young star. The clumps accrete other matter, growing to become the core of a planet. Up to a certain distance from the star, that core accumulates a thick blanket of hydrogen and helium, becoming a bloated, gassy world.

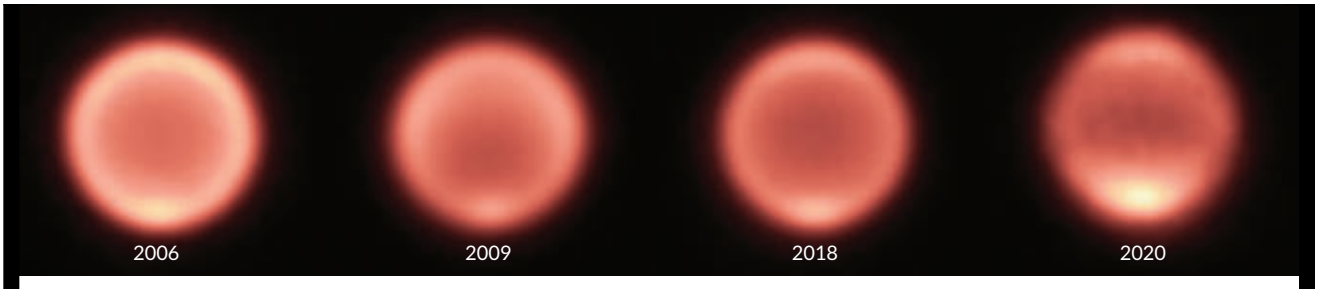
The new planet, orbiting a star called AB Aurigae, is in the outskirts of its system, where there's less matter to gather into a core, and the core can't get massive enough to create a gaseous envelope. The remote location, Currie and colleagues argue, makes it more likely the planet formed via "disk instability," where the disk around the star breaks into planet-sized fragments. Drawn together by their own gravity, the fragments then rapidly collapse in on themselves and clump together, forming a giant planet.

Using the Subaru Telescope, Currie and colleagues observed AB Aurigae periodically from 2016 to 2020. They also looked at images of the star taken by the Hubble Space Telescope. The researchers observed a bright spot next to the star. The bright clump was a clear protoplanet, dubbed AB Aur b, orbiting nearly 14 billion kilometers from its star — roughly three times as far as Neptune is from the sun.

The images of AB Aur b look like they're from a simulation of disk instability, except they're real, Currie says. "For the longest time, I never believed that planet formation by disk instability could actually work."

Because AB Aur b is still in the early stages of formation, embedded in the young star's disk, it could help to explain how the handful of known massive planets orbiting far from their stars formed. "We only know maybe a few dozen total of these types of planets," says astrophysicist Quinn Konopacky of the University of California, San Diego. "Every single one that we find is basically precious."

It's difficult to distinguish whether a planet formed by core accretion or disk instability through observations alone, Konopacky says. The fact that AB Aur b is so widely separated from its star is "good evidence" for disk instability, she says. Still, "there's a lot more work to be done and other ways that we can try to assess if that's what's going on." ■



M. ROMAN/ESO, COMICS/SUBARU/NOAJ

ATOM & COSMOS

Temperature swings on Neptune

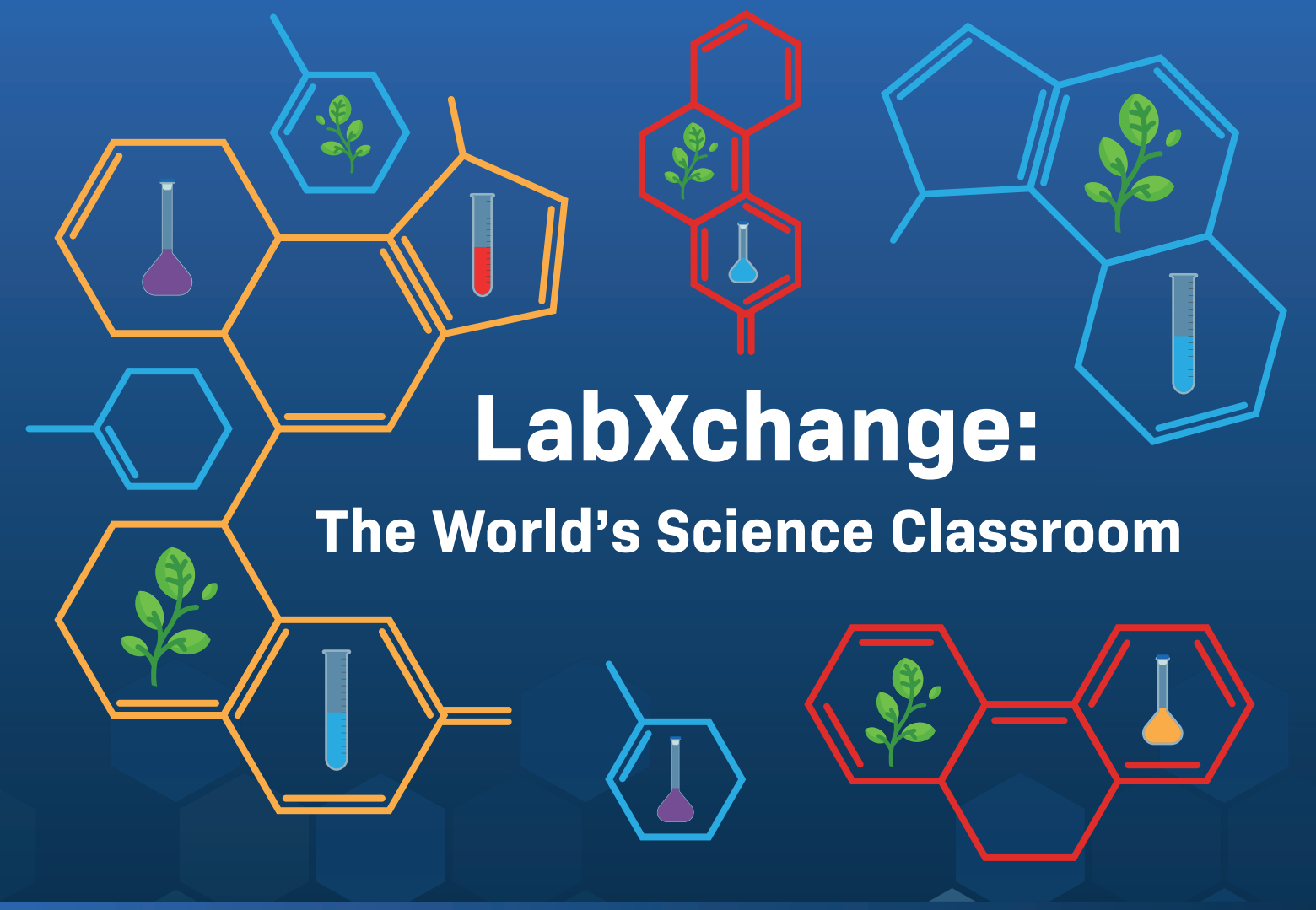
Neptune's atmospheric temperature is on an unexpected roller coaster ride. From 2003 to 2012, at the start of summer in the ice giant's southern hemisphere, the global temperature dropped about 8 degrees Celsius, as indicated by dimming in thermal images (shown above). Then from 2018 to 2020, Neptune's south pole brightened dramatically, indicating a spike of 11 degrees C, researchers report in the April *Planetary Sciences Journal*.

The scientists looked at 17 years of mid-infrared data collected by telescopes. The team used infrared light to pierce Neptune's top cloud layer and peer at its stratosphere, where the atmospheric chemistry comes into view.

Each Neptune year lasts 165 Earth years, so the study's data cover the equivalent of five weeks on Earth. The wildest temperature shift occurred when the south pole's average temperature rose from −121° C in 2018 to −110° C in 2020.

"We weren't expecting any seasonal changes to happen in this short time period, because we're not even seeing a full season," says Naomi Rowe-Gurney, a planetary scientist at NASA Goddard Space Flight Center in Greenbelt, Md.

Rowe-Gurney and colleagues don't know what's causing the changes. The sun's ultraviolet rays break up methane molecules in the stratosphere, which then form other combinations. That chemistry or even the sun's activity cycle could be a trigger. "We need to keep observing over the next 20 years to see a full season and see if something else changes," Rowe-Gurney says. — *Liz Kruesi*



LabXchange:

The World's Science Classroom

A PLACE WHERE YOU BELONG

Whether you're passionate about space exploration, biotechnology, or championing underrepresented voices in STEM, LabXchange has something for you.

LEARN SCIENCE YOUR WAY

When it comes to learning, one size does not fit all. Explore our library, connect with mentors, and prepare for college or careers - all in one place, for free.

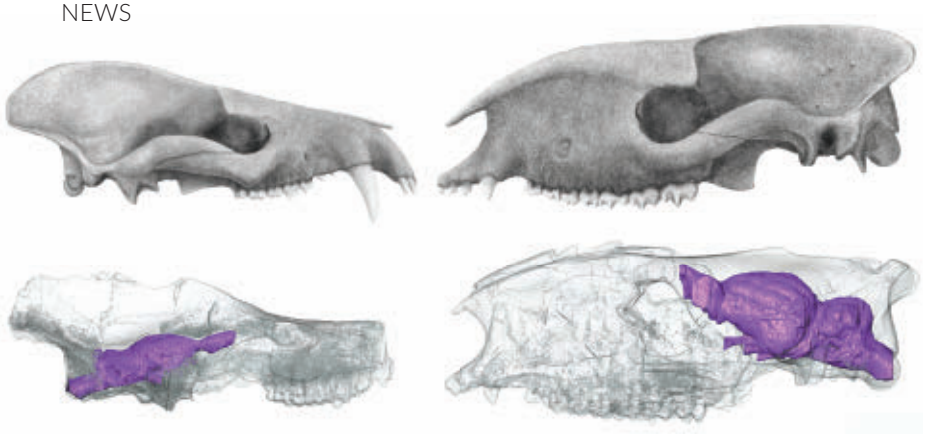
Start your journey in science today.

LABXCHANGE.ORG

AMGEN® Foundation

HARVARD
Faculty of Arts and Sciences

LabXchange™
Learning without limits.



To follow changes in brain size through time, researchers used CT scans to trace the braincases (purple) inside mammal skulls. Here, a Paleocene mammal (left) is compared with a later Eocene species (right).

LIFE & EVOLUTION

Mammals grew big and then got smart

After the dino extinction, body and brain size evolved separately

BY CAROLYN GRAMLING

Modern mammals are known for their big brains. But new analyses of skulls from mammals that lived shortly after the dinosaur mass extinction show that braininess wasn't always a foregone conclusion. For at least 10 million years after the dinosaurs disappeared, mammals got a lot brawnier but not brainier, researchers report in the April 1 *Science*.

That conclusion bucks conventional wisdom. "I thought, 'It's not possible. There must be something that I did wrong,'" says Ornella Bertrand, a mammal paleontologist at the University of Edinburgh. "It really threw me off. How am I going to explain that they were not smart?"

Modern mammals have the largest brains in the animal kingdom relative to body size. How and when that brain evolution happened is a mystery. One idea has been that the disappearance of all nonbird dinosaurs following an asteroid impact at the end of the Mesozoic Era 66 million years ago left a vacuum for mammals to fill (SN: 2/4/17, p. 22). Recent discoveries of fossils from the Paleocene — the postextinction epoch spanning 66 million to 56 million years ago — do reveal a flourishing menagerie of weird and wonderful mammal species, many much bigger than their Mesozoic predecessors (SN: 12/7/19, p. 32). It was the dawn of the Age of Mammals.

Before those fossil finds in Colorado and New Mexico, the prevailing wisdom was that in the wake of the mass extinction, the brains of mammals most likely grew apace with their bodies, everything increasing together like an expanding balloon, Bertrand says.

But the Paleocene fossil troves, plus reexaminations of fossils previously found in France, offered scientists the chance to actually measure mammalian brain size over time.

Bertrand and colleagues used CT scanning to create 3-D images of the braincases of different types of ancient mammals from both before and after the extinction event. Those specimens included mammals from 17 groups dating to the Paleocene and 17 to the Eocene, the epoch that spanned 56 million to 34 million years ago.

What the team found was a shock: Relative to their body sizes, Paleocene mammals had brains that were smaller than those of Mesozoic mammals. It wasn't until the Eocene that brains began to grow in many different groups of mammals, particularly in certain sensory regions, the team reports.

To assess how the sizes and shapes of those sensory regions changed over time, Bertrand looked for the edges of different parts of the brains within the 3-D models, tracing them like a sculptor working with clay. The size of the olfactory bulb, responsible for the sense of smell, didn't change over time. That makes sense, because even Mesozoic mammals were good sniffers, Bertrand says.

The really big brain changes came in the neocortex, which is responsible for visual processing, memory and motor control, among other skills. Those kinds of changes are metabolically costly, Bertrand says. "To have a big brain, you need to sleep and eat, and if you don't do that, you get cranky, and your brain just doesn't function."

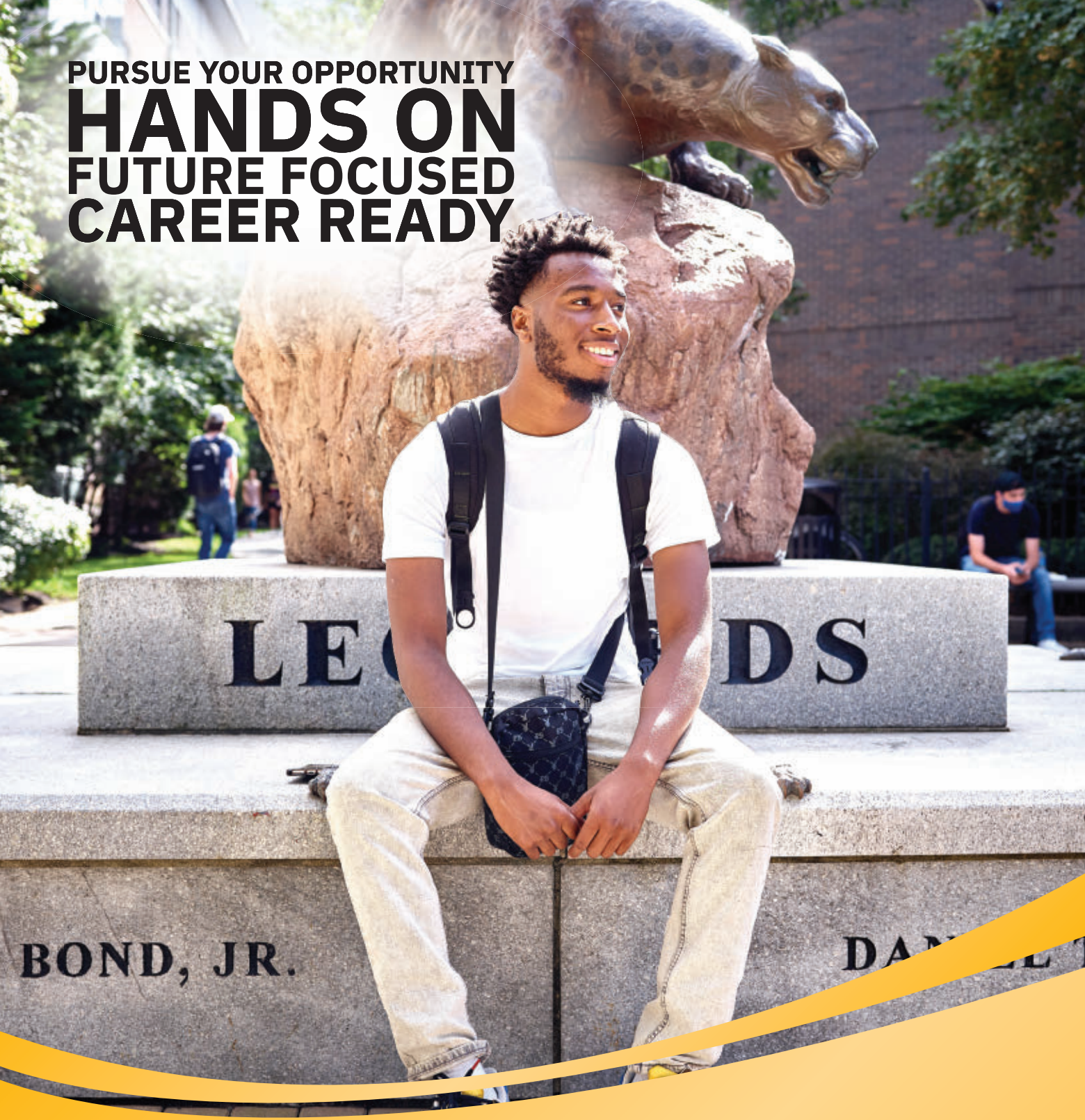
So as the world shook off the dust of the mass extinction, brawn was the priority for mammals, helping them swiftly spread out into newly available ecological niches, Bertrand and colleagues propose. But after 10 million years or so, the metabolic calculations had changed, and competition within those niches was ramping up. As a result, mammals began to develop new skills that could help them snag hard-to-reach fruit from a branch, escape a predator or catch prey.

Other factors — such as social behavior or parental care — have probably been important to the overall evolution of mammals' big brains. But these new findings suggest that, at least at the dawn of the Age of Mammals, ecology gave a big push to brain evolution, paleoecologist Felisa Smith of the University of New Mexico in Albuquerque wrote in a commentary in the same issue of *Science*.

"An exciting aspect of these findings is that they raise a new question: Why did large brains evolve independently and concurrently in many mammal groups?" says David Grossnickle, an evolutionary biologist at the University of Washington in Seattle.

Most modern mammals have relatively large brains, so studies that examine only modern species might conclude that large brains evolved once in mammal ancestors, Grossnickle says. But what this study uncovered is a "much more interesting and nuanced story," that these brains evolved separately in many different groups, he says. And that shows just how important fossils can be to stitching together an accurate tapestry of evolutionary history. ■

O. BERTRAND, SARAH SHELLEY



Wentworth

INSTITUTE OF TECHNOLOGY

wit.edu | admissions@wit.edu | 800.556.0610

LEARN MORE!

LIFE & EVOLUTION

Triceratops hole may be a combat injury

Healing wound hints that the dinosaurs fought each other

BY ANNA GIBBS

A gaping hole in the bony frill of a *Triceratops* dubbed "Big John" may be a battle scar from one of his peers.

The frill that haloes the head of *Triceratops* is an iconic part of the dinosaur's look. Equally iconic, at least to paleontologists, are the holes that mar the headgear. For over a century, researchers have debated various explanations for the holes, called fenestrae — from battle scars to natural aging processes. Now, a microscopic analysis suggests that Big John's hole is a partially healed lesion that could be from a traumatic injury from a fight with another *Triceratops*, researchers report April 7 in *Scientific Reports*.

In summer 2021, Flavio Bacchia, director of Zoic LLC in Trieste, Italy, was reconstructing the skeleton of Big John, the largest known *Triceratops* skeleton, when he noticed a keyhole-shaped fenestra on the right side of the frill. Bacchia then reached out to Ruggero D'Anastasio, a paleopathologist at the "G. D'Annunzio" University of Chieti-Pescara in Italy.

"When I saw, for the first time, the opening, I realized that there was something strange," D'Anastasio says. In particular, the irregular margins of the hole were odd. He had never seen anything like it.

To analyze the fossilized tissues around the fenestra, he obtained a piece of bone about the size of a nine-volt battery, cut from the bottom of the keyhole. (The rest of Big John sold at an auction for $7.7 million — the most expensive non–*Tyrannosaurus rex* dinosaur fossil ever.)

Looking at the bone under a scanning electron microscope, D'Anastasio and his team found evidence consistent with the formation processes of new bone that are usually observed in mammals. New bone growth is typically supported by blood vessels, and in the bone near the border of the hole, the tissue was porous and strewn with vascular canals. Farther from the fenestra, the bone showed little evidence of blood vessels.

> "Pathology is a great tool to understand the behavior of dinosaurs."
>
> **FILIPPO BERTOZZO**

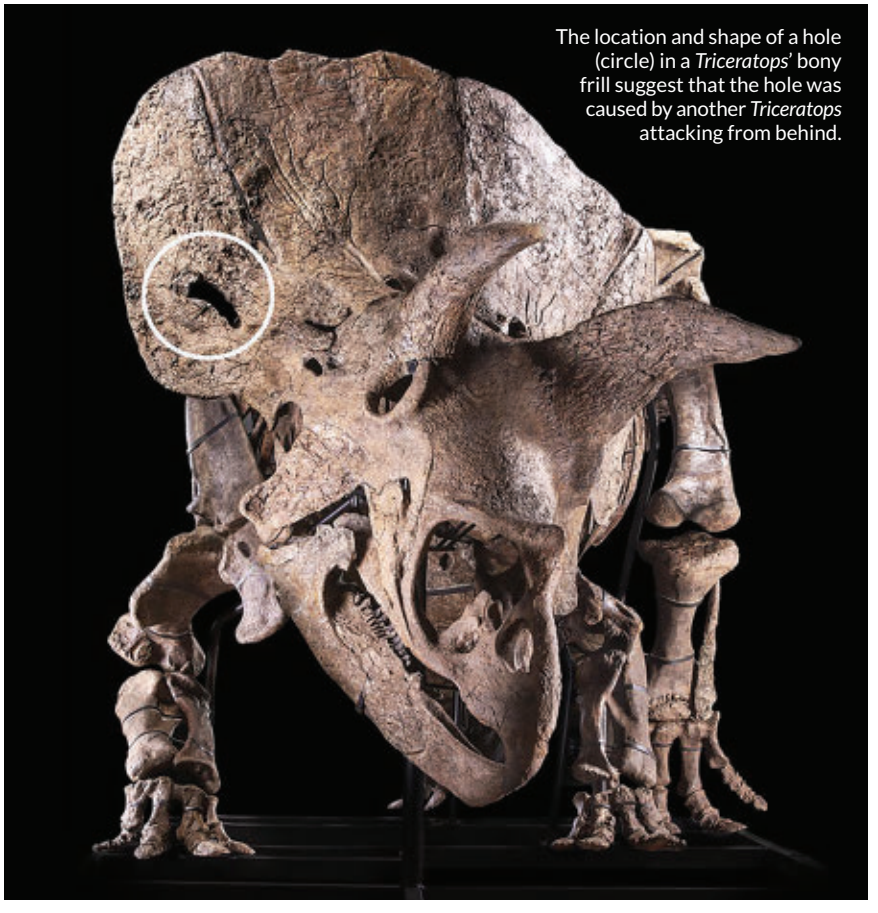
The irregularity of the hole margins that D'Anastasio had initially observed was also present at the microscopic level. The border was dappled with dimples called Howship lacunae that form during bone healing when bone cells erode away existing bone to make way for new healthy bone. The researchers also observed primary osteons, formations that occur during new bone growth.

In addition, a chemical analysis revealed high levels of sulfur, indicative of proteins involved in new bone formation. In mature bones, sulfur is present only in low quantities.

Taken all together, the evidence told the team that this particular fenestra was a partially healed wound. "The presence of healing bone is typical of a response to a traumatic event," D'Anastasio says.

The location and shape of the wound suggest that Big John's frill was impaled from behind by a *Triceratops* rival, adding evidence to the idea that these dinosaurs fought with one another. An initial puncture that was pulled downward probably created the keyhole shape, the team says.

"Pathology is a great tool to understand the behavior of dinosaurs," says Filippo Bertozzo, a paleontologist at the Royal Belgian Institute of Natural Sciences in Brussels who was not involved in the study. Dinosaur behavior has long been in the realm of speculation, he says, but analyses like these can provide a glimpse into the lifestyle of these animals. But this particular wound is "not a Rosetta stone," he adds, because it's unlikely that all fenestrae are battle injuries. "Fenestration is still a big mystery." ■



The location and shape of a hole (circle) in a *Triceratops*' bony frill suggest that the hole was caused by another *Triceratops* attacking from behind.

COURTESY OF A. FERRARA, I. BRIANO, R. D'ANASTASIO *ET AL/SCIENTIFIC REPORTS* 2022

SIEGEL FAMILY ENDOWMENT

Did you know that you can pursue a career in science and technology while also radically shaping the way our society works together?

The growing field of Public Interest Technology holds massive opportunities for people excited to use technology and digital solutions to tackle the world's most pressing challenges. From creating software that connects real time public health data to hospital systems, to building data models to map municipal climate impact, public interest technology elevates our digital infrastructure through cutting edge solutions designed to address today's biggest problems in ways that are equitable, inclusive, and accountable to the public.

Discover your path into Public Interest Technology

Include public interest technology in your studies at college. The **Public Interest Technology University Network** is a partnership between 48 colleges, universities, and HBCUs around the country that are committed to growing a new generation of civic-minded technologists.

There are also a number of fellowship and internship opportunities for technologists looking to apply their skills to the benefit of the public sector. Through **TechCongress**, you could work on Capitol Hill directly with members of Congress to inform and shape federal technology policy. The **Day One Project**, hosted by the Federation of American Scientists, solicits big ideas for public technology projects and runs an accelerator program to help entrepreneurial technologists get those ideas off the ground.

Even some of the world's largest platform companies are pursuing goals related to public interest technology. **Mozilla** is creating products, technologies, and platforms that build a healthier internet and more trustworthy AI. **Wikimedia** is made up of a team of technologists working to make knowledge free and accessible to all.

Whether you enter into the public, private, or nonprofit sector, you can find a rewarding career in using technology and science to make our collective future brighter.

Siegel Family Endowment proudly supports this growing movement and the people - like you - who will make up our future

Learn more at siegelendowment.org/public-interest-technology/

Food choices

What we eat plays an outsize role in greenhouse gas emissions

By Betsy Ladyzhets

The food we eat is responsible for an astounding one-third of global greenhouse gas emissions caused by human activities, according to two comprehensive studies published in 2021.

"When people talk about food systems, they always think about the cow in the field," says statistician Francesco Tubiello, lead author of one of the reports, appearing in last June's *Environmental Research Letters*. True, cows are a major source of methane, which, like other greenhouse gases, traps heat in the atmosphere. But methane, carbon dioxide and other planet-warming gases are released from several other sources along the food production chain.

Before 2021, scientists like Tubiello, of the Food and Agriculture Organization of the United Nations, were well aware that agriculture and related land use changes made up roughly 20 percent of the planet's greenhouse gas emissions. Such land use changes include cutting down forests to make way for cattle grazing and pumping groundwater to flood fields for the sake of agriculture.

But new modeling techniques used by Tubiello and colleagues, plus a study from a group at the European Commission Tubiello worked with, brought to light another big driver of emissions: the food supply chain. All the steps that take food from the farm to our plates to the landfill—transportation, processing, cooking and food waste—bring food-related emissions up from 20 percent to 33 percent.

To slow climate change, the foods we eat deserve major attention, just like fossil fuel burning, says Amos Tai, an environmental scientist at the Chinese University of Hong Kong. The fuller picture of food-related emissions demonstrates that the world needs to make drastic changes to the food system if we are to reach international goals for reducing global warming.

Change from developing countries

Scientists have gained a clearer understanding of global human-related emissions in recent years through databases like EDGAR, or Emissions Database for Global Atmospheric Research,

Special Report: The Future of Food

MARIO TAMA/GETTY IMAGES PLUS

developed by the European Union. The database covers every country's human-emitting activities, from energy production to landfill waste, from 1970 to the present. EDGAR uses a unified methodology to calculate emissions for all economic sectors, says Monica Crippa, a scientific officer at the European Commission's Joint Research Centre.

Crippa and colleagues, with help from Tubiello, built a companion database of food system–related emissions called EDGAR-FOOD. Using that database, the researchers arrived at the same one-third estimate as Tubiello's group.

Crippa's team's calculations, reported in *Nature Food* in March 2021, split food system emissions into four broad categories: land (including both agriculture and related land use changes), energy (used for producing, processing, packaging and transporting goods), industry (including the production of chemicals used in farming and materials used to package food) and waste (from unused food).

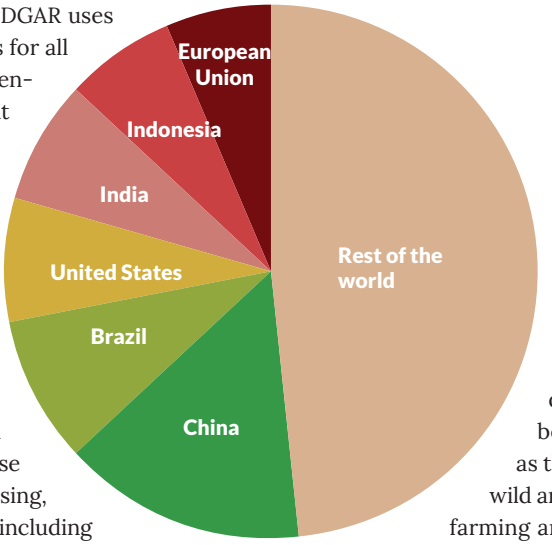
The land sector is the biggest culprit in food system emissions, Crippa says, accounting for about 70 percent of the global total. But the picture looks different across different nations. The United States and other developed countries rely on highly centralized megafarms for much of their food production; so the energy, industry and waste categories make up more than half of these countries' food system emissions.

In developing countries, agriculture and changing land use are far greater contributors. Emissions in historically less developed countries have also been rising in the last 30 years, as these countries have cut down wild areas to make way for industrial farming and started eating more meat, another major contributor to emissions with impacts across all four categories.

As a result, agriculture and related landscape shifts have driven major increases in food system emissions among developing countries in recent decades, while emissions in developed countries have not grown.

For instance, China's food emissions shot up by almost 50 percent from 1990 to 2018, largely due to a rise in meat-eating, according to the EDGAR-FOOD database. In 1980, the average Chinese person ate about 30 grams of meat a day, Tai says. In 2010, the average person in China ate almost five times as much, or just under 150 grams of meat a day.

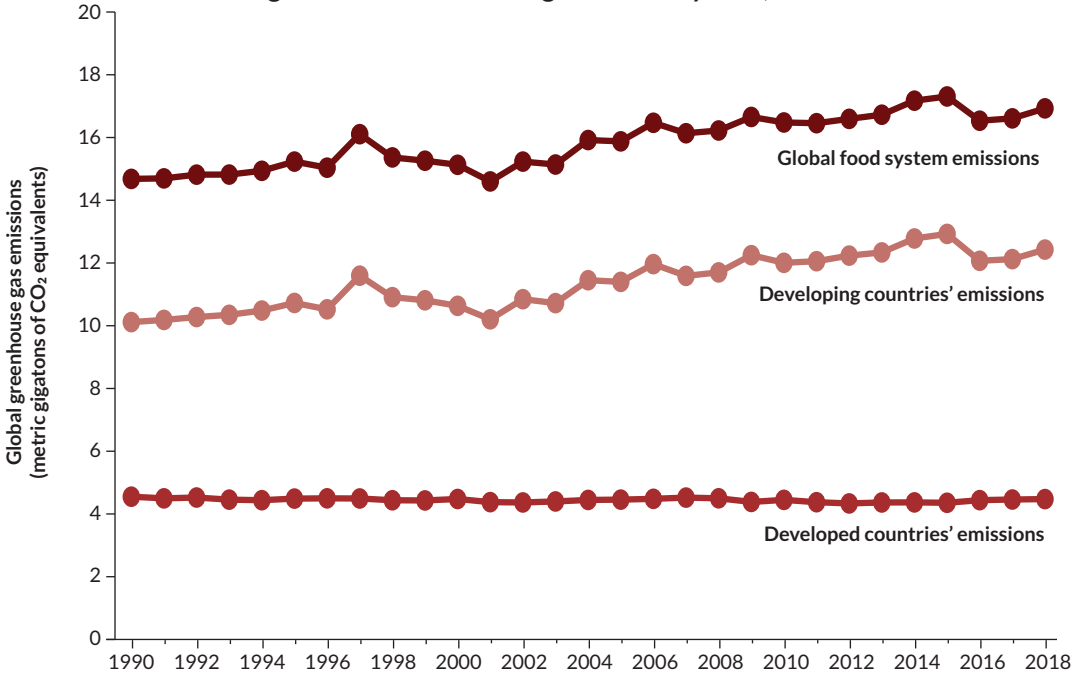
Six economies emit more than half of Earth's food system greenhouse gases



The world's food system produces about 17 metric gigatons of greenhouse gas emissions each year, measured in tons of CO_2 equivalents — a standardized unit that allows for comparisons between different gases. Emissions from China, Brazil, the United States, India, Indonesia and the European Union together account for 52 percent of this total.

SOURCE: M. CRIPPA *ET AL*/ *NATURE FOOD* 2021

Greenhouse gas emissions from the global food system, 1990–2018

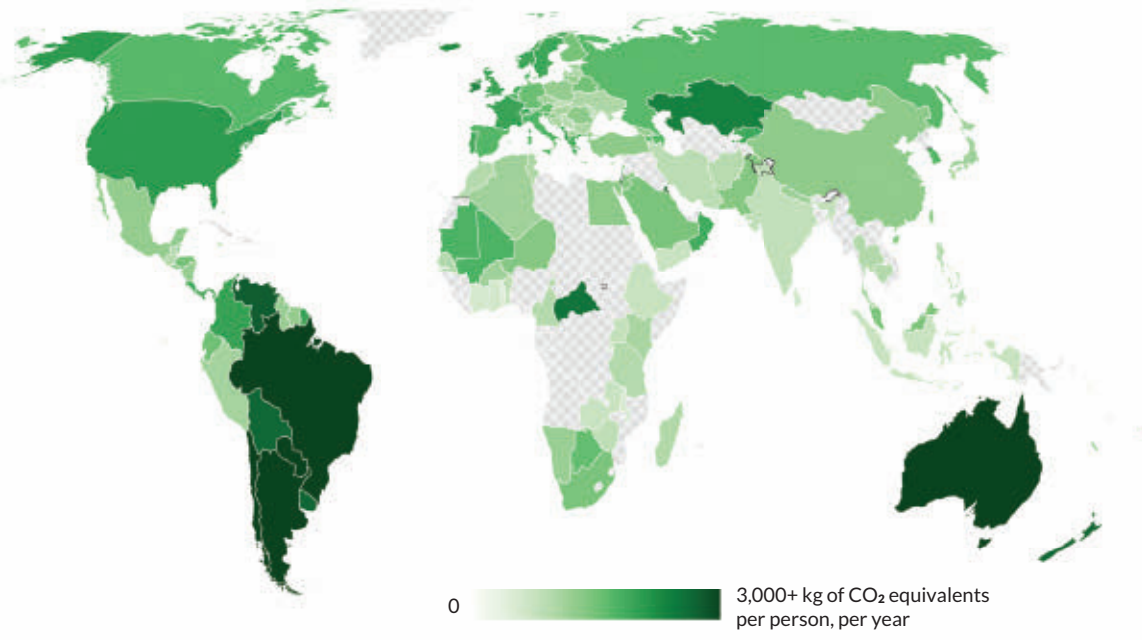


Developing countries' food-related greenhouse gas emissions have been rising as these countries have shifted to eating more meat and producing food at large, industrialized farms. This shift is driving an overall global increase in food-related emissions. In developed countries, emissions have remained relatively stable.

SOURCE: M. CRIPPA *ET AL*/ *NATURE FOOD* 2021

B. LADYZHETS AND T. TIBBITTS

Greenhouse gas emissions caused by the average person's diet, by country



The food produced for an average person's diet in a developed country results in more greenhouse gas emissions than the food produced for the average diet in a developing country. These food production emissions represent the largest share of food-related emissions, but do not include processing, transportation, retail or waste. Deforestation for food production has led to high emissions in Australia, Brazil, Argentina and several other South American countries. Data are not available for countries in gray.
SOURCE: B.F. KIM *ET AL/GLOBAL ENVIRONMENTAL CHANGE* 2020

Top-emitting economies

In recent years, Crippa says, six economies, the top emitters, have been responsible for more than half of total global food emissions. These economies, in order, are China, Brazil, the United States, India, Indonesia and the European Union. The immense populations of China and India help drive their high numbers. Brazil and Indonesia make the list because large swaths of their rainforests have been cut down to make room for farming. When those trees come down, vast amounts of carbon flow into the atmosphere (SN: 7/3/21 & 7/17/21, p. 24).

The United States and the European Union are on the list because of heavy meat consumption. In the United States, meat and other animal products contribute the vast majority of food-related emissions, says Richard Waite, a researcher at the World Resources Institute's food program in Washington, D.C.

Waste is also a huge issue in the United States: More than one-third of food produced never actually gets eaten, according to a 2021 report from the U.S. Environmental Protection Agency. When food goes uneaten, the resources used to produce, transport and package it are wasted. Plus, the uneaten food goes into landfills, which produce methane, carbon dioxide and other gases as the food decomposes.

Meat consumption drives emissions

Climate advocates who want to reduce food emissions often focus on meat consumption, as animal products lead to far greater emissions than plants. Animal production uses more land than plant production, and "meat production is heavily inefficient," Tai says.

"If we eat 100 calories of grain, like maize or soybeans, we get that 100 calories," he explains. All the energy from the food is delivered directly to the person who eats it. But if the 100 calories' worth of grain is instead fed to a cow or a pig, when the animal is killed and processed for food, just one-tenth of the energy from that 100 calories of grain goes to the person eating the animal.

Methane production from "the cow in the field" is another factor in meat consumption: Cows release this gas via their manure, burps and flatulence. Methane traps more heat per ton emitted than carbon dioxide, Tubiello says. So emissions from cattle farms can have an outsize impact (SN: 11/28/15, p. 22). These livestock emissions account for about one-third of global methane emissions, according to a 2021 U.N. report.

Shifting from meats to plants

U.S. residents should consider how they can shift to what Brent Kim calls "plant-forward" diets. "Plant-forward doesn't mean vegan. It means reducing animal product intake, and increasing the share of plant foods that are on the plate," says Kim, program officer at the Johns Hopkins Center for a Livable Future.

Kim and colleagues estimated food emissions by diet and food group for 140 countries and territories, using a similar modeling framework to EDGAR-FOOD. However, the framework includes only the food production emissions (i.e. agriculture and land use), not processing, transportation and other pieces of the food system incorporated in EDGAR-FOOD.

Producing the average U.S. resident's diet generates more than 2,000 kilograms of greenhouse gas emissions per year, the researchers reported in 2020 in *Global Environmental Change*. The group measured emissions in terms of "CO_2 equivalents," a standardized unit allowing for direct comparisons between CO_2 and other greenhouse gases like methane.

B. LADYZHETS AND T. TIBBITTS

To see interactive versions of the map and charts, visit **bit.ly/SN_FoodEmissions**

Imperial College London

THE TIMES THE SUNDAY TIMES GOOD UNIVERSITY GUIDE 2022

UNIVERSITY OF THE YEAR

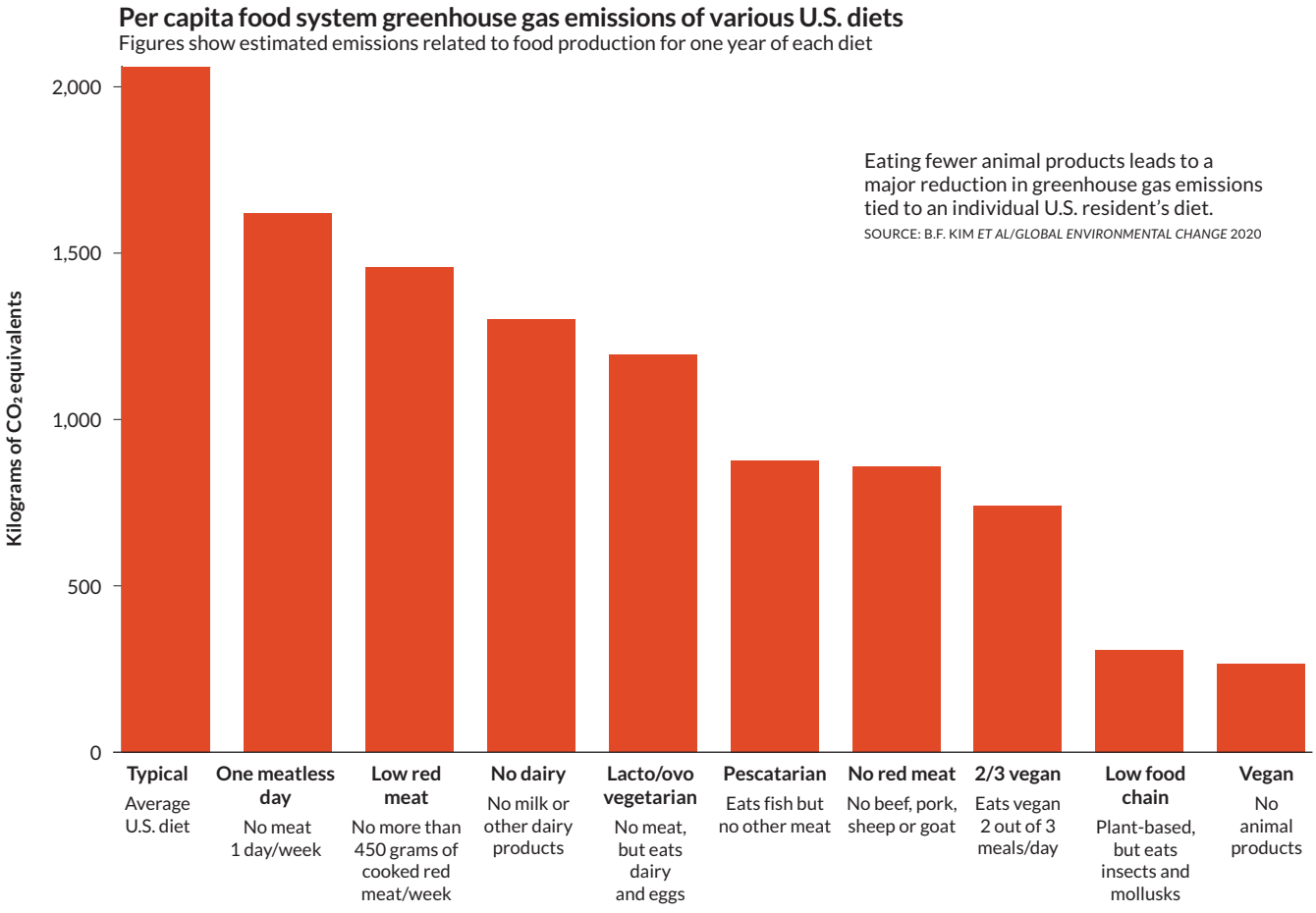
Attend a world top 10 university

THEN TAKE ON THE UNIVERSE

Top 10 best university in the world
QS World University Rankings 2022

1st for graduate employability
The Guardian University Guide 2022

Find out more:
imperial.ac.uk/study/ug



Going meatless one day a week brings down that figure to about 1,600 kilograms of CO_2 equivalents per year, per person. Going vegan — a diet without any meat, dairy or other animal products — cuts it by 87 percent to under 300. Going even two-thirds vegan offers a sizable drop to 740 kilograms of CO_2 equivalents.

Kim's modeling also offers a "low food chain" option, which brings emissions down to about 300 kilograms of CO_2 equivalents per year, per person. Eating low on the food chain combines a mostly plant-based diet with animal products that come from more climate-friendly sources that do not disturb ecological systems. Examples include insects, smaller fish like sardines, and oysters and other mollusks.

Tai agrees that not everybody needs to become a vegetarian or vegan to save the planet, as meat can have important cultural and nutritional value. If you want to "start from the biggest polluter," he says, focus on cutting beef consumption.

But enough people need to make these changes to "send a signal back to the market" that consumers want more plant-based options, Tubiello says. Policy makers at the federal, state and local levels can also encourage climate-friendly farming practices, reduce food waste in government operations and take other actions to cut down the resources used in food production, Waite says.

For example, the World Resources Institute, where Waite works, is part of an initiative called the Cool Food Pledge, in which companies, universities and city governments have signed on to reduce the climate impacts of the food they serve. The institutions agree to track the food they purchase every year to ensure they are progressing toward their goals, Waite says.

Developed countries like the United States — which have been heavy meat consumers for decades — can have a big impact by changing food choices. Indeed, a paper published in *Nature Food* in January shows that if the populations of 54 high-income nations switched to a plant-focused diet, annual emissions from these countries' agricultural production could drop by more than 60 percent. ■

Explore more

- Monica Crippa *et al.* "Food systems are responsible for a third of global anthropogenic GHG emissions." *Nature Food*. March 2021.
- Francesco Tubiello *et al.* "Greenhouse gas emissions from food systems: building the evidence base." *Environmental Research Letters*. June 2021.

Betsy Ladyzhets is a freelance science, health and data journalist based in Brooklyn, N.Y.

B. LADYZHETS AND T. TIBBITTS

We make the world smarter, more connected and more sustainable.

At Jacobs, we work every day to make the world better for all. Everything we do — from addressing water scarcity and aging infrastructure to ensuring access to life-saving therapies, protecting against sophisticated cyberattacks and exploring beyond our Earth — is more than our daily jobs: They're our challenges as human beings, too.

Proud sponsor of the 2022 ISEF Environmental Engineering Grand Awards category.

Follow us @JacobsConnects | jacobs.com

Jacobs

Challenging today.
Reinventing tomorrow.

NORMALIZING plant-based diets

How to get people to want to be part of the low-meat future

By Sujata Gupta

When my friend Julie Babulski was a freshman in high school in the mid-1990s, she decided to stop eating meat. "I loved animals. I couldn't see them suffering," Babulski says. "The fact that it pissed off my mom was an added, happy bonus."

For her meat-loving family of Polish immigrants, meals frequently featured kielbasa or bacon, Babulski says. Even the sauerkraut had meat. With such limited food options at home, teenage Babulski initially subsisted on starches and salads. Her mom, she says, thought she "was going to straight up die."

Babulski, now a biologist at Monroe Community College in Rochester, N.Y., eventually learned to eat a more balanced vegetarian diet, including beans, whole grains and the occasional neon orange veggie dog. But, Babulski remembers, her mom still wished she'd give up the madness.

Mom was probably reacting to the fact that eating is a social activity, uniting family, friends and even strangers. Her daughter could no longer enjoy the turkey at Thanksgiving, the traditional Polish meal of fish on Christmas Eve or even the family's "lazy pierogies"—dumplings filled with noodles, mushrooms and bits of bacon.

On a societal level, the decision by Babulski and others to go vegetarian can feel threatening to those who view eating animals as quintessentially American. Eating meat is the norm in the United States, says social psychologist Gregg Sparkman of Princeton University. "It's literally the center of that Norman Rockwell painting."

Yet Rockwell's vision of meat as the star of the American meal has big drawbacks. Besides

CLOCKWISE FROM TOP LEFT (ALL VIA GETTY IMAGES): KCLINE/E+; SAVANY/ISTOCK; BERNJUER/ISTOCK; RONDAKIMBROW/ISTOCK; YULIIA KORZHAN/ISTOCK; WESTEND61; YALCINSONAT1/ISTOCK; JENA ARDELL/MOMENT; PIDJOE/ISTOCK; DIANAZH/ISTOCK

concerns about animal welfare, medical experts have long encouraged people to eat less processed and red meat for health reasons (SN: 11/28/15, *p.* 9). What is becoming crystal clear is that a meat-heavy diet is also terrible for the planet (SN: 7/7/18, *p.* 10).

Shifting demand from meat to beans, whole grains, fruits, vegetables, nuts and seeds could have substantial benefits for the climate. In 2018, total greenhouse gas emissions worldwide were almost 49 billion metric tons. That same year, the United Nations Intergovernmental Panel on Climate Change, the IPCC, estimated that if everyone in the world went vegan, eating only plant-based foods, global emissions could drop by roughly 16 percent in a year, or 8 billion tons.

Meanwhile, going vegetarian, a plant-based diet that includes dairy, eggs and the very occasional meat or seafood allowed in IPCC's definition, resulted in a 6-billion-ton drop. For those reluctant to give up the bacon entirely, the IPCC says a less absolutist approach could still reap big benefits. The panel estimates that a flexitarian diet — reducing meat and dairy consumption by 75 percent — could cut emissions by 5 billion tons.

Individual behavior changes alone cannot fix a supply chain built around the mass production of meat and animal products. But a more recent April report from the IPCC (see Page 8) suggests that the world's wealthiest individuals could substantially decrease emissions through lifestyle changes, such as driving and flying less and eating less meat. That's because households with incomes in the top 10 percent generate roughly 36 to 45 percent of global emissions, while households with incomes in the bottom 50 percent contribute just 13 to 15 percent. Moreover, wealthier individuals serve as role models. So those who adopt a low-carbon lifestyle can help establish new, more sustainable social norms.

Social norms are unwritten rules for how to behave in a given group. Norms encourage conformity. If everyone in a group wears clothes, a single member is unlikely to wander outside naked. But if people think that shedding one's clothing is becoming the new norm, can this encourage others to follow suit? Yes, Sparkman says. "Actions you do … ripple outward and can change others."

The challenge, he and others say, is sorting out how to encourage that snowball effect to transform really strong social norms, such as eating meat. These scientists are, in a sense, trying to understand how to make the abnormal appear normal. What would it take, for instance, for people to mentally swap Rockwell's Thanksgiving turkey for something greener?

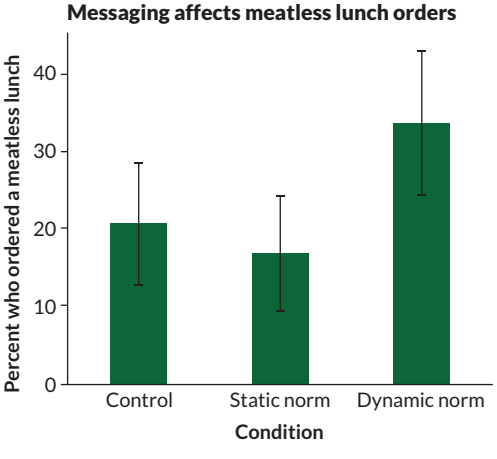
A meat-heavy diet is the norm in the United States, as this billboard in Ozark, Mo., shows. To reduce greenhouse gas emissions, researchers are trying to figure out how to get people to buck the norm and go for a diet that's richer in plants and beans.

Changing normal

Social norms, which by design remain relatively stable across time, typically hinder social change. But research shows that people conform not just to present norms but also to perceived future norms, what Sparkman calls "preconformity." That suggests that reframing the Julie Babulskis among us as trendsetters rather than social deviants could encourage others to conform to their plant-based vision of the future (SN: 2/26/22, *p.* 24).

In that vein, Sparkman and colleagues have been testing whether giving information on changing, or "dynamic," norms can shift people's food choices. In a pilot study, the team surveyed café-goers at Stanford University. When the 304 mostly faculty, staff and graduate students were waiting to order, researchers handed them one of three written statements.

Some participants received a static norm message: "Recent research has shown that 30 percent of Americans make an effort to limit their meat



Eye to the future
Café-goers who read that meat-eating is decreasing over time, the dynamic norm group, were more likely to order a vegetarian meal than those who read that some Americans limit their meat intake, a static norm, and the controls, who got an irrelevant message.
SOURCE: G. SPARKMAN AND G.M. WALTON/*PSYCHOLOGICAL SCIENCE* 2017

FROM TOP: JOE SOHM/VISIONS OF AMERICA/UNIVERSAL IMAGES GROUP VIA GETTY IMAGES; E. OTWELL

consumption." Some participants got a dynamic norm statement: "Recent research has shown that, over the last five years, 30 percent of Americans have started to make an effort to limit their meat consumption." Participants in a control group read that people are starting to limit the time they spend on Facebook. While the static statement emphasizes change in the present, the dynamic statement emphasizes changes happening over time and theoretically into the future, Sparkman says.

Roughly 20 percent of participants in the control and static norm groups went on to order a meatless lunch in the café compared with 34 percent of participants in the dynamic norm condition, the team reported in 2017 in *Psychological Science*. The results suggest people's values can shift, Sparkman says.

Group dynamics

As Babulski grew older, she learned about the health and environmental impacts of meat production. Her resolve to stay vegetarian solidified, and a once-impulsive decision became a way of life.

Babulski now shares her personal journey with students in her environmental science course. There's always that student who treats her dietary choices as a personal affront, Babulski says. One student told her: "I'm going to eat three more chickens because you're vegetarian to make up for the difference."

People have long used food restrictions as a proxy for group membership. Hindu and Muslim people live side by side in South Asia, for instance, but can identify members of their own group just by noting who eats pork and who eats beef. "Food taboos are to do with establishing both in and out groups," says Harriet Ritvo, an environmental historian at MIT.

Many fast food chains, including Burger King, now offer plant-based burgers. Someday, these changes to the food environment may make veggie options the norm.

Divisions around food can encourage tribal identities. For instance, Jewish people in Chicago who avoid leavened food during Passover often feel disconnected from their non-Jewish peers, Kaitlin Woolley, a behavioral scientist at Cornell University, and colleagues reported in 2020 in the *Journal of Personality and Social Psychology*. But that sense of alienation helps them forge stronger connections with their Jewish peers. In a way, the Passover tribe grows stronger.

"In the West … to become a vegetarian is a very conscious choice to deviate from what is socially normal," says social psychologist Daniel Rosenfeld of UCLA. "To form a community is often a way to buffer against that feeling of social alienation."

Strong food-based communities help those within the group, but can repel those outside the group, such as Babulski's chicken-eating student. Research shows that when people identify a certain diet, such as kosher or vegan, with an out-group, they can develop negative attitudes about the diet or avoid those "specialty" foods.

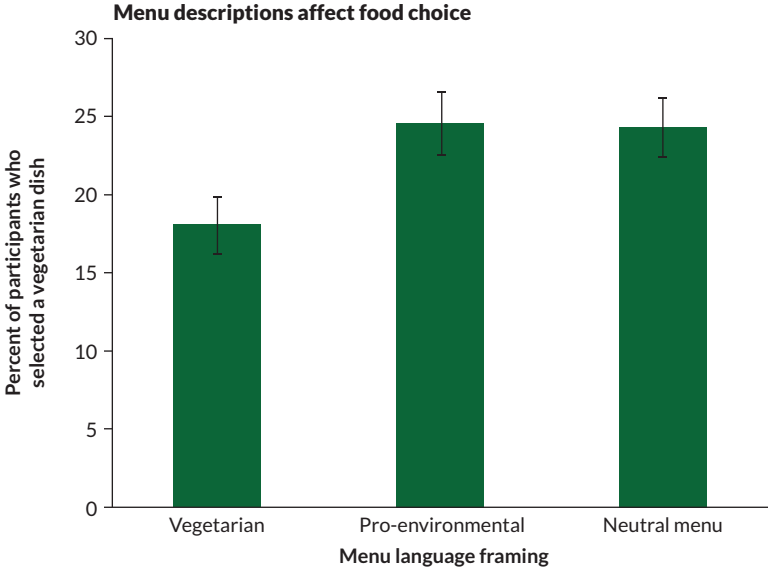
For instance, setting apart vegetarian items and labeling them "vegetarian" on a menu decreased the percentage of nonvegetarians who chose those entrées versus when the options were incorporated into the main menu, researchers reported in 2020 in the *Journal of Environmental Psychology*.

But there are ways to thwart that us-versus-them mentality, says Michael Schmitt, a social

Labeling decisions

Three groups of online participants who were meat eaters saw different menus: One menu set vegetarian choices apart and called them "vegetarian," one labeled them as good for the environment and a third listed vegetarian and nonvegetarian items together. The vegetarian framing was least likely to lead to veggie orders.

SOURCE: D. KRPAN AND N. HOUTSMA/*JOURNAL OF ENVIRONMENTAL PSYCHOLOGY* 2020



FROM TOP: YICHUAN CAO/NURPHOTO VIA GETTY IMAGES; E. OTWELL

At Lehigh University, you'll find hands-on, creative and interdisciplinary experiences that will challenge you and prepare you to solve complex problems in real-world situations. Our world-class faculty and rigorous academic programs will have you ready for success in whatever STEM field you choose.

COLLEGE OF ARTS AND SCIENCES
Astronomy
Astrophysics
Behavioral Neuroscience
Biochemistry
Biology
Chemistry (B.S. and B.A.)
Cognitive Science
Computer Science (B.S. and B.A.)
Earth & Environmental Sciences
Mathematics
Molecular Biology
Pharmaceutical Chemistry
Physics
Pre-med
Statistics

P.C. ROSSIN COLLEGE OF ENGINEERING AND APPLIED SCIENCE
Applied Science
Bioengineering
Chemical Engineering
Civil Engineering
Computer Engineering
Computer Science (B.S.)
Electrical Engineering
Engineering Mechanics
Engineering Physics
Environmental Engineering
Industrial & Systems Engineering
Materials Science & Engineering
Mechanical Engineering

COLLEGE OF HEALTH
Global and Community Health
Population Health

INTERCOLLEGIATE INTERDISCIPLINARY PROGRAMS
Computer Science and Business (CSB)
Integrated Degree in Engineering, Arts and Sciences (IDEAS)
Integrated Business and Engineering (IBE)

DUAL-DEGREE/ ACCELERATED PROGRAMS
Arts & Engineering

This is a partial list of Lehigh's majors and programs. For the full list, please scan the QR code.

LEHIGH UNIVERSITY

lehigh.edu/admissions | admissions@lehigh.edu

These posters promoted Meatless Mondays in New York City Public Schools. Former Mayor Bill de Blasio launched the program in 2019 to promote healthy eating and reduce the city's environmental footprint.

psychologist at Simon Fraser University in Burnaby, Canada. One option is for researchers and policy makers to promote more inclusive labels. For instance, highlighting movement toward a more flexitarian diet does not seem to trigger the same sort of backlash as highlighting movement toward a vegetarian diet, Schmitt says. "That offers people an identity that might be closer to existing norms."

Subtly changing the food environment to make veggie options, rather than meat, the default is another idea. For instance, simply increasing the availability of vegetarian meals in a university cafeteria from a quarter of the choices to half the choices increased sales of vegetarian entrées by almost 8 percent, researchers reported in 2019 in the *Proceedings of the National Academy of Sciences*.

Then there's the grocery store. Researchers reported in March in *PLOS Medicine* that moving Easter chocolates away from prominent locations, like the store entrance and end of aisles, in a chain of U.K. grocery stores caused sales of those items to plummet. Compared with 151 stores that stuck with business as usual, 34 stores that moved the candy sold, on average, 21 kilograms less chocolate per week. Assuming the average chocolate Easter bunny weighs about 100 grams, that equals roughly 200 fewer bunnies sold per store each week.

Imagine if U.S. grocery store operators shunted meat to hard-to-find locations, Schmitt says. Changing perceptions of normal requires first envisioning a new normal.

Ripple effects

Given the sheer scope of climate change, how can one person's actions make a difference?

Using dynamic norms to change behavior hinges on the simple premise that individual actions do, in fact, matter. Research from the sustainability field bears this out. From 2012 to 2015, officials in Connecticut sought to get more people to install solar panels through a program called Solarize Connecticut. At that time, only 0.4 percent of U.S. homeowners had solar panels, making their use outside the ordinary. So volunteers traveled to 58 towns to encourage residents to make the energy switch. Researchers reported in 2018 in *Nature* that volunteers who had invested in solar panels themselves convinced almost 63 percent more residents to go solar than volunteers who had made no such investment.

Conversely, individual inaction also matters. In a now classic study from the 1960s appearing in the *Journal of Personality and Social Psychology*, male undergraduate students sat in a room that slowly filled with smoke. When the students were alone, 75 percent of them reported the situation. But when others were in the room and failed to act, only 10 percent of students reported the problem. Doing nothing had become socially acceptable.

In essence, we live in a world filling with smoke and must choose between inaction and action. Why not choose action?

Babulski applies this philosophy to her own teaching. Minus a naysayer or two, many of her students come to realize the power of their individual choices. "You can actually see students over the course of the semester going, 'Wow, the little things I do actually do add up and make a difference,'" Babulski says.

Eventually, perhaps, a future Norman Rockwell will paint a less meat-heavy meal on that American dinner platter: beans, crickets or a plant-based turkey. Imagine that. ■

Explore more

- Gregg Sparkman, Lauren Howe and Greg Walton. "How social norms are often a barrier to addressing climate change but can be part of the solution." *Behavioural Public Policy*. October 2021.

MPI43/MEDIAPUNCH/IPX

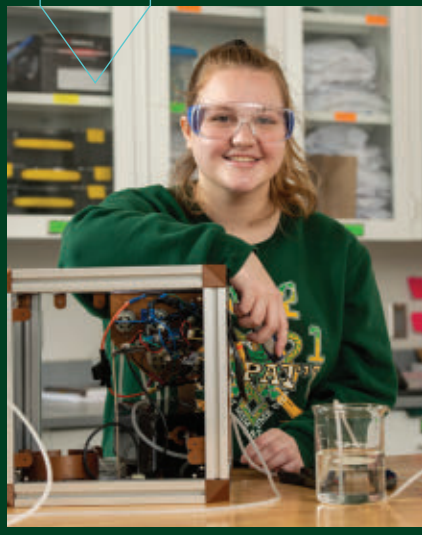
MISSOURI S&T

1

Choose your major. Build your future.

SOLVE FOR YOUR TOMORROW.

3



2

Missouri University of Science and Technology gives you options — over 100 degree programs in 40 different fields of study. But no matter what you study, you'll connect with other curious minds to create an experience — and a future — that's all your own.

1 Real-world research into the presence of arsenic in groundwater

2 S&T's ChemE Cube team's water purification system won a national award

3 S&T's hypersonic wind tunnel is one of many high-tech facilities at S&T

See how S&T can change your tomorrow at **futurestudents.mst.edu**.

SIX FOODS of the future

Each is full of nutrients and just might survive the changing climate

By Anna Gibbs

No matter how you slice it, climate change will alter what we eat in the future. Today, just 13 crops provide 80 percent of people's energy intake worldwide, and about half of our calories come from wheat, maize and rice. Yet some of these crops may not grow well in the higher temperatures, unpredictable rainfall and extreme weather events caused by climate change. Already, drought, heat waves and flash floods are damaging crops around the world (*SN: 9/25/21, p. 16*).

"We must diversify our food basket," says Festo Massawe. He's executive director of Future Food Beacon Malaysia, a group at the University of Nottingham Malaysia campus in Semenyih that studies the impact of climate change on food security.

That goes beyond what we eat to how we grow it. The trick will be investing in every possible solution: breeding crops so they're more climate resilient, genetically engineering foods in the lab and studying crops that we just don't know enough about, says ecologist Samuel Pironon of the Royal Botanic Gardens, Kew in London. To feed a growing population in a rapidly changing world, food scientists are exploring many possible avenues, while thinking about how to be environmentally friendly.

Consumer preferences are part of the equation as well. "It does have to be that right combination of: It looks good, it tastes good and it's the right price point," says Halley Froehlich, an aquaculture and fisheries scientist at the University of California, Santa Barbara.

Here are six foods that could check all those boxes and feature more prominently on menus and grocery shelves in the future.

Millet

SOURCE OF: Carbohydrates, protein, minerals (potassium, phosphorus and magnesium)

USES: Whole grain; gluten-free flour, pasta, chips, beer

The United Nations has declared 2023 the International Year of Millets (a handful of varieties exist). Quinoa earned the same honor in 2013, and its sales skyrocketed. First cultivated in Asia some 10,000 years ago, millet is a staple grain in parts of Asia and Africa. Compared with wheat, maize and rice, millet is much more climate resilient; the crop needs little water and thrives in warmer, drier environments. Some more good news: Millet is one of many ancient grains — including teff, amaranth and sorghum — that are similarly sustainable and resilient (not to mention capable of being turned into beer).

Bambara groundnut

SOURCE OF: Protein, fiber, minerals (potassium, magnesium and iron)

USES: Roasted or boiled; gluten-free flour; dairy-free milk

You've heard of almond milk and soy milk. The next alternative at your coffee shop could be made from Bambara groundnuts, a drought-tolerant legume native to sub-Saharan Africa. Like other legumes, the Bambara groundnut is packed with protein. And bacteria on the plant convert atmospheric nitrogen into ammonia so the groundnut grows well in nutrient-poor soil without chemical fertilizers. A better understanding of the plant, says Festo Massawe of Future Food Beacon Malaysia, could pave the way for breeding programs to help the Bambara groundnut become as popular as the soybean, a legume that produces high yields but is less drought tolerant.

FROM TOP: SZJPHOTO/MOMENT/GETTY IMAGES; PONSULAK/ISTOCK/GETTY IMAGES PLUS

Mussels

SOURCE OF: Protein, omega-3, vitamin B12, minerals (iron, manganese and zinc)

USES: Steamed; added to pasta dishes, stews, soups

A delicious mussel linguine might someday become a weeknight regular on the family menu. Mussels and other bivalves, including oysters, clams and scallops, could make up about 40 percent of seafood by 2050, according to a 2020 report in *Nature*. With no need to be watered or fertilized, bivalve farms are prime for scaling up, which would lower prices for consumers. All bivalves have merit, but Halley Froehlich of UC Santa Barbara singles out mussels as "super hardy," "super nutritious" and underhyped. One downside: Shell-forming creatures are threatened as rising carbon levels boost ocean acidification. Kelp might be able to help.

Kelp

SOURCE OF: Vitamins, minerals (iodine, calcium and iron), antioxidants

USES: Salads, smoothies, salsa, pickles, noodles and chips; also found in toothpaste, shampoo and biofuels

Kelp has a few cool climate-friendly tricks. For one, by taking in carbon dioxide during photosynthesis, it can lower the acidity of its watery surroundings. Farmers in Maine and Alaska grow kelp and bivalves together so that the shelled critters can benefit from the less acidic water. Kelp also sequesters carbon, like underwater trees. That means growing and eating more kelp could be good for the environment. While kelp and other seaweeds have been widely consumed in Asia for thousands of years, they're still an acquired taste in many Western countries.

Enset

SOURCE OF: Carbohydrates, calcium, potassium and zinc

USES: Porridge or bread; also used to make rope, plates and building materials

The drought-tolerant enset, cultivated in Ethiopia, is nicknamed the "false banana" because the plant resembles a banana tree, though its fruit is inedible. It's also called "the tree against hunger" because its starchy stems can be harvested at any time of year, making it a reliable buffer food crop during dry periods. A 2021 report in *Environmental Research Letters* suggests that the enset's range could be expanded to other parts of Africa, and possibly beyond. The processing required to make enset edible is complex, says study author James Borrell of the Royal Botanic Gardens, Kew. So any expansion would have to be led by the communities who hold that Indigenous knowledge.

Cassava

SOURCE OF: Carbohydrates, potassium, vitamin C

USES: Whole cooked root; gluten-free flour; tapioca pearls in bubble tea

Cassava, a starchy root vegetable from South America, checks the boxes for climate resilience, sustainability and nutrition. Now grown in over 100 countries, cassava can withstand temperatures of up to 40° Celsius and is salt and drought tolerant. An added plus: Higher atmospheric CO_2 levels enhance the plant's tolerance to stress and can lead to higher yields. Raw cassava can contain toxic levels of cyanide, but the chemical can be removed by peeling, soaking and cooking the root. ■

Explore more

- Christopher Costello *et al*. "The future of food from the sea." *Nature*. August 19, 2020.

CLOCKWISE FROM TOP LEFT: MATT MACRO/EYEEM/GETTY IMAGES; MOAIMAGE/MOMENT/GETTY IMAGES; ILTONROGERIO/ISTOCK/GETTY IMAGES PLUS; MIKE GOLDWATER/ALAMY STOCK PHOTO

Climate-Friendly Farming in India

This aerial image shows solar panels installed among crops to power groundwater pumps and offer a new income source for farmers in western India's Dhundi village.

Planting trees and installing solar panels is making a dent in the country's carbon footprint

By Sibi Arasu

In 2007, 22-year-old P. Ramesh's groundnut farm was losing money. As was the norm in most of India (and still is), Ramesh was using a cocktail of pesticides and fertilizers across his 2.4 hectares in the Anantapur district of southern India. In this desert-like area, which gets less than 600 millimeters of rainfall most years, farming is a challenge.

"I lost a lot of money growing groundnuts through chemical farming methods," says Ramesh, who goes by the first letter of his father's name followed by his first name, as is common in many parts of southern India. The chemicals were expensive and his yields low.

Then in 2017, he dropped the chemicals. "Ever since I took up regenerative agricultural practices like agroforestry and natural farming, both my yield and income have increased," he says.

Agroforestry involves planting woody perennials (trees, shrubs, palms, bamboos, etc.) alongside agricultural crops (SN: 7/3/21 & 7/17/21, p. 30). One natural farming method calls for replacing all chemical fertilizers and pesticides with organic matter such as cow dung, cow urine and jaggery, a type of solid dark sugar made from sugarcane, to boost soil nutrient levels. Ramesh also expanded his crops, originally groundnuts and some tomatoes, by adding papaya, millets, okra, eggplant (called brinjal locally) and other crops.

With help from the nonprofit Accion Fraterna Ecology Centre in Anantapur, which works with farmers who want to try sustainable farming, Ramesh increased his profits enough to buy

IWMI-TATA PROGRAM, SHASHWAT CLEANTECH AND DHUNDI SAUR URJA UTPADAK SAHKARI MANDALI

more land, expanding his parcel to about four hectares. Like the thousands of other farmers practicing regenerative farming across India, Ramesh has managed to nourish his depleted soil, while his new trees help keep carbon out of the atmosphere, thus playing a small but important role in reducing India's carbon footprint. Recent studies have shown that the carbon sequestration potential of agroforestry is as much as 34 percent higher than standard forms of agriculture.

In western India, more than 1,000 kilometers from Anantapur, in Dhundi village in Gujarat, 36-year-old Pravinbhai Parmar is using his rice farm for climate change mitigation. By installing solar panels, he no longer uses diesel to power his groundwater pumps. And he has an incentive to pump only the water he needs because he can sell the electricity he doesn't use.

If all farmers like Parmar shifted to solar, India's carbon emissions, which are 2.88 billion metric tons per year, could drop by between 45 million and 62 million tons annually, according to a 2020 report in *Carbon Management*. So far, the country has about 250,000 solar irrigation pumps out of an estimated 20 million to 25 million total groundwater pumps.

For a nation that has to provide for what will soon be the world's largest population, growing food while trying to bring down already high greenhouse gas emissions from agricultural practices is difficult. Today, agriculture and livestock account for 14 percent of India's gross national greenhouse gas emissions. Adding in the electricity used by the agriculture sector brings this figure up to 22 percent.

Ramesh and Parmar are part of a small but growing group of farmers getting assistance from government and nongovernmental programs to change how they farm. There's still a ways to go to reach the estimated 146 million others who cultivate 160 million hectares of arable land in India. But these farmers' success stories are testimony that one of India's largest emitting sectors can change.

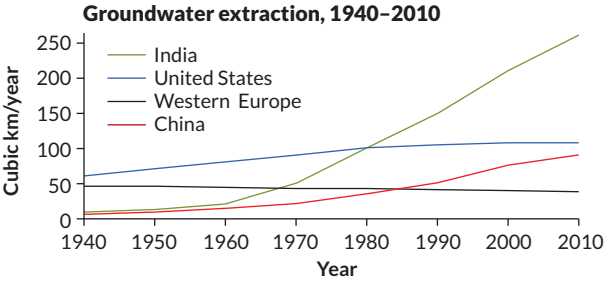
Feeding the soil, sustaining farmers

India's farmers are already deeply feeling the effects of climate change, coping with dry spells, erratic rainfall and increasingly frequent heat waves and tropical cyclones. "When we talk about climate-smart agriculture, we are largely talking about how it has reduced emissions," says Indu Murthy, sector head for climate, environment and sustainability at the Center for Study of Science, Technology and Policy, a think tank in Bengaluru. But such a system should also help farmers "cope with unexpected changes and weather patterns," she says.

This, in many ways, is the philosophy driving a variety of sustainable and regenerative agricultural practices under the agroecology umbrella. Natural farming and agroforestry are two components of this system that are finding more and more takers across India's varied landscapes, says Y.V. Malla Reddy, director of Accion Fraterna Ecology Centre.

"For me, the important change is the change in attitude of people towards trees and vegetation in the last few decades," Reddy says. "In the '70s and '80s, people were not really conscious

High groundwater use Starting in the 1960s, India's groundwater extraction began rising sharply, at a rate higher than in other places. This was primarily driven by the Green Revolution, a water-intensive agricultural policy to make the country food secure in the 1970s and '80s and continues in some form even today. SOURCE: T. SHAH/ GLOBAL WATER PARTNERSHIP TECHNICAL COMMITTEE BACKGROUND PAPER. NO. 19. 2014



of the value of the trees, but now they consider trees, especially fruit and utilitarian trees, as also a source of income." Reddy has advocated for sustainable farming in India for close to 50 years. Certain types of trees, such as pongamia, subabul and avisa, have economic benefits apart from their fruits; they provide fodder for livestock and biomass for fuel.

Reddy's organization has provided assistance to more than 60,000 Indian farming families to practice natural farming and agroforestry on almost 165,000 hectares. Calculation of the soil carbon sequestration potential of their work is ongoing. But a 2020 report by India's Ministry of Environment, Forest and Climate Change notes that these farming practices can help India reach its goal of having 33 percent forest and tree cover to meet its carbon sequestration commitments under the Paris climate agreement by 2030.

Regenerative agriculture is a relatively inexpensive way to reduce carbon dioxide in the atmosphere, as compared with other solutions. Regenerative farming costs $10 to $100 per ton of carbon dioxide removed from the atmosphere, compared with $100 to $1,000 per ton of carbon dioxide for technologies that mechanically remove carbon from the air, according to a 2020 analysis in *Nature Sustainability*. Such farming not only makes sense for the environment, but chances are the farmers' earnings will also increase as they shift to regenerative agriculture, Reddy says.

Growing solar

Establishing agroecology practices to see an effect on carbon sequestration can take years or decades. But using renewable energy in farming can quickly reduce emissions. For this reason, the nonprofit International Water Management Institute, IWMI, launched the program Solar Power as Remunerative Crop in Dhundi village in 2016.

"The biggest threat climate change presents, specifically to farmers, is the uncertainty that it brings," says Shilp Verma, an IWMI researcher of water, energy and food policies based in Anand. "Any agricultural practice that will help farmers cope with uncertainty will improve resilience to climate change." Farmers have more funds to deal with insecure conditions when

C. CHANG

Farmers in Anantapur, India, pose with the natural fertilizer they use on their crops. Called Ghanajeevamritam, it contains jaggery, cow dung, cow urine and sometimes flour from dried beans.

M. SHAIKSHAVALI

they can pump groundwater in a climate-friendly way that also provides incentives for keeping some water in the ground. "If you pump less, then you can sell the surplus energy to the grid," he says. Solar power becomes an income source.

Growing rice, especially lowland rice, which is grown on flooded land, requires a lot of water. On average it takes about 1,432 liters of water to produce one kilogram of rice, according to the International Rice Research Institute. The organization says that irrigated rice receives an estimated 34 to 43 percent of the world's total irrigation water. India is the largest extractor of groundwater in the world, accounting for 25 percent of global extraction. When diesel pumps do the extracting, carbon is emitted into the atmosphere. Parmar and his fellow farmers used to have to buy that fuel to keep their pumps going.

"We used to spend 25,000 rupees [about $330] a year for running our diesel-powered water pumps. This used to really cut into our profits," Parmar says. When IWMI asked him in 2015 to participate in a pilot solar-powered irrigation project with zero carbon emissions, Parmar was all ears.

Since then, Parmar and six fellow farmers in Dhundi have sold more than 240,000 kilowatt-hours to the state and earned more than 1.5 million rupees ($20,000). Parmar's annual income has doubled from 100,000–150,000 rupees on average to 200,000–250,000 rupees.

The boost is helping him educate his children, one of whom is pursuing a degree in agriculture—an encouraging sign in a country where farming is out of vogue with the younger generation. As Parmar says, "Solar power is timely, less polluting and also provides us an additional income. What is not to like about it?"

Parmar has learned to maintain and fix the panels and the pumps himself. Neighboring villages now ask for his help when they want to set up solar-powered pumps or need pump repairs. "I am happy that others are also following our lead. Honestly, I feel quite proud that they call me to help them with their solar pump systems."

IWMI's project in Dhundi has been so successful that the state of Gujarat started replicating the scheme in 2018 for all interested farmers under an initiative called Suryashakti Kisan Yojana, which translates to solar power project for farmers. And India's Ministry of New and Renewable Energy now subsidizes and provides low-interest loans for solar-powered irrigation among farmers.

"The main thing about climate-smart agriculture is that everything we do has to have less carbon footprint," says Aditi Mukherji, Verma's colleague and an author of February's report from the Intergovernmental Panel on Climate Change (SN: 3/26/22, p. 7). "That is the biggest challenge. How do you make something with a low carbon footprint, without having a negative impact on income and productivity?" Mukherji is the regional project leader for Solar Irrigation for Agricultural Resilience in South Asia, an IWMI project looking at various solar irrigation solutions in South Asia.

Back in Anantapur, "there is also a visible change in the vegetation in our district," Reddy says. "Earlier, there might not be any trees till the eye can see in many parts of the district. Now there is no place which doesn't have at least 20 trees in your line of sight. It's a small change, but extremely significant for our dry region." And Ramesh and other farmers now enjoy a stable, sustainable income from farming.

"When I was growing groundnuts, I used to sell it to the local markets," Ramesh says. He now sells directly to city dwellers through WhatsApp groups. And one of India's largest online grocery stores, bigbasket.com, and others have started purchasing directly from him to meet a growing demand for organic and "clean" fruits and vegetables.

"I'm confident now that my children too can take up farming and make a good living if they want to," Ramesh says. "I didn't feel the same way before discovering these nonchemical farming practices." ■

Explore more

- Solar Irrigation for Agricultural Resilience in South Asia: solar.iwmi.org

Sibi Arasu is an independent journalist based in Bengaluru, India. He tweets @sibi123.

Connect with the World's Largest Honor Society for Scientists and Engineers

IFoRE
POWERED BY SIGMA XI

High School, Undergraduate, and Graduate Students are invited to present their research during the IFoRE conference!
(In person and virtual)

November 3–6, 2022

www.sigmaxi.org/IFoRE

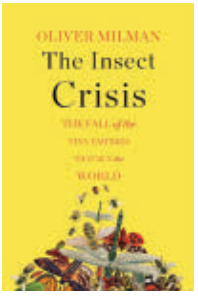
Become a Sigma Xi Member or Explorer Today

- Receive a subscription to *American Scientist* magazine
- Have access to grants for resarch
- Discounted IFoRE registration
- Connect with the best and brightest in science and engineering

www.sigmaxi.org

SIGMA XI
THE SCIENTIFIC RESEARCH HONOR SOCIETY

www.sigmaxi.org



The Insect Crisis
Oliver Milman
W.W. NORTON & CO., $27.95

BOOKSHELF

Why the 'insect apocalypse' is bad news for us all

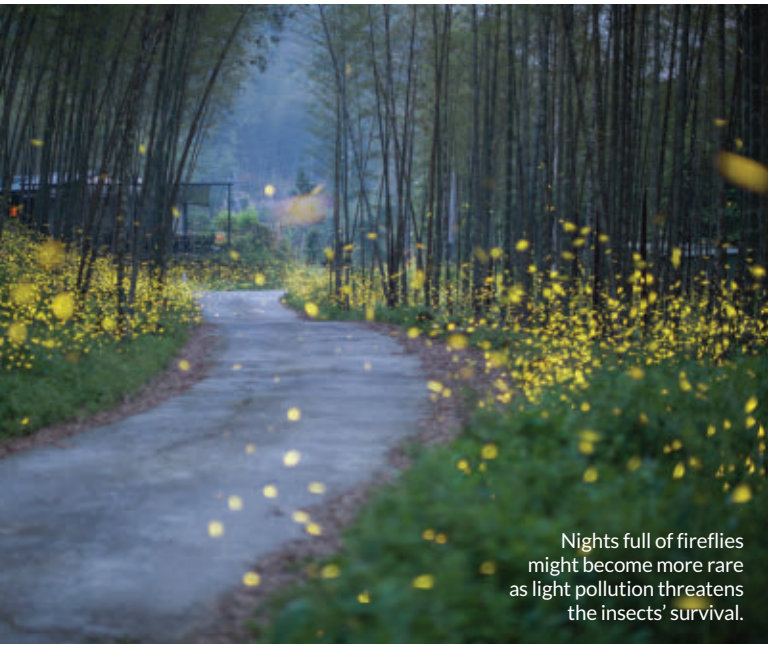
Imagine a world without insects. You might breathe a sigh of relief at the thought of mosquito-free summers, or you might worry about how agriculture will function without pollinators. What you probably won't picture is trudging through a landscape littered with feces and rotting corpses—what a world devoid of maggots and dung beetles would look like.

That's just a snippet of the horrifying picture of an insect-free future that journalist Oliver Milman paints in the beginning of *The Insect Crisis*. "The loss of insects would be an agonizing ordeal eclipsing any war and even rivaling the looming ravages of climate breakdown," he writes. And yet, the threat of an impending "insect apocalypse" doesn't get nearly the same level of attention as climate change.

Researchers have been observing declining insect populations for decades. For instance, a study of nearly 40 years of data from a protected rainforest in Puerto Rico found that insect biomass had decreased by 98 percent on the ground and 80 percent in the canopy since the mid-1970s.

The threats insects face are many: Light pollution, the increasing use of pesticides and climate change are just a few (SN: 8/8/15, *p.* 9). And it's not only rare species that are at risk—it's also species that were once common around the globe.

The reality of the crisis isn't as foreboding as Milman initially makes it seem. A world with no insects is unlikely, he acknowledges. Studies have found that while some species are in decline, others, such as freshwater insects, are doing fine (SN *Online*: 4/23/20). Rather than viewing the insect crisis as all insect populations on one downward-trending line on a graph, Milman suggests picturing lots of different lines—some holding steady, some sloping up or down, and some zigzagging. "Insects are being shifted to an unhappy state where there will be far more bedbugs and mosquitoes and far fewer bumblebees and monarch butterflies," he writes.



Nights full of fireflies might become more rare as light pollution threatens the insects' survival.

HIGRACE PHOTO/MOMENT/GETTY IMAGES

Those changes in biodiversity come with consequences. Farmers may have to fend off more pests that attack soybeans, for instance, and insect-pollinated fruits and vegetables will become hard to grow at scale. Some insect-eating animals will decline as their food disappears, which has already happened to some birds (SN: 8/9/14, *p.* 6), or even vanish. Water and soil quality could also be in jeopardy.

Milman investigates the crisis by sharing his own adventures with insects, along with those of researchers, taking readers from the United States to Mexico, across the Atlantic to Europe and all the way to Australia. By sharing scientists' stories, he makes the plight of insects personal. There's a researcher in Denmark who has spent 25 years surveying insect populations by driving his old Ford Anglia down the same country roads and counting the number of bugs squashed against the windshield. Back when he started, he'd regularly have to clean insect guts off his car. But in recent years, he has experienced a lot of "zero insect days." As I read that, I struggled to remember the last time I had to scrape any dead insects off my car. Another researcher recalls the joy of catching fireflies on his family ranch in Texas as a child. I felt a wave of sadness as I thought about how I don't see fireflies as much as I did when I was a kid. With more streetlights and the switch to LED bulbs, it's becoming harder for fireflies to spot potential mates.

Amid the doom and gloom, the book still manages to spark awe and delight with fun facts about insects. Bumblebee wings, for instance, vibrate so fast that they can produce gravitational forces of up to 50 g's—five times greater than what fighter jet pilots experience. Milman also offers hope, sharing how certain insects are adapting to the threats and how some people are fighting to protect the critters through political campaigns and changing farming habits.

By the book's end, readers may find that their attitude toward some insects has shifted from loathing to love, or at the very least, appreciation. (I, for one, never cared much for flies—until I learned we wouldn't have chocolate without them.) Milman makes clear how much we benefit from insects, and what we stand to lose without them. As one researcher puts it, our deeply woven reliance on insects is like the internet: When parts of the network are removed, the less internet there is, "until eventually it doesn't work anymore."

A world without the internet would be difficult but livable. The same can't be said for a world without insects.

—*Allie Wilkinson*

REAL-WORLD RESEARCH

At **Virginia Commonwealth University College of Engineering**, graduate students and fellows work alongside our diverse faculty on projects that will shape the future of medicine. From cellular mechanobiology to systems-level mechanics and imaging, our research is propelling ideas from the lab to the larger community.

#EngineersMakeItReal

egr.vcu.edu

VCU College of Engineering

CONVERSATIONS WITH MAYA

PAUL MODRICH
James B. Duke Professor of Biochemistry,
Duke University Medical Center

Maya Ajmera, President & CEO of the Society for Science and Publisher of *Science News*, chatted with Paul Modrich, James B. Duke Professor of Biochemistry at Duke University Medical Center, ahead of his retirement. Modrich won the Nobel Prize in chemistry in 2015 and participated in the 1964 Science Talent Search and the 1964 National Science Fair, today called the International Science and Engineering Fair.

Paul, you are an alum of both the 1964 Science Talent Search and the National Science Fair. How did those competitions impact your life?

As a teenager, I was interested in the possibility of a career in science, but I really had no idea how realistic that was. I think it's fair to say that the opportunity to attend the National Science Fair and compete in the Science Talent Search were truly great opportunities for me. Those competitions suggested that a career in science might actually be a real possibility for me. I also think the competitions had a lot to do with my getting into MIT as an undergraduate.

Your beginnings in science may seem atypical to some. You grew up in a small town in New Mexico where there was only one biology teacher, your dad. What inspired your interest in science?

I was always fascinated by science as a boy. When you grow up in a rural area, nature is right there. It's right in your face and for me, often quite moving. I still feel that same thing every time I return to New Mexico.

Who were some of your early mentors and how did they inspire or influence your career in science?

My parents, of course, consistently encouraged my curiosity about science. My father was a great biology teacher. He influenced not only me, but a number of others from my high school who went on to pursue careers in biology or medicine, which is unusual for a small town like mine.

Salvador Luria, one of the fathers of molecular biology, was my academic adviser at MIT. He was an excellent teacher who took great interest in his advisees. I'm convinced he had a lot to do with getting me into Stanford University's graduate school. I had the privilege of doing my graduate work in Bob Lehman's laboratory, where I studied an enzyme called DNA ligase that can seal a break in a DNA strand. Then I did my postdoc with Charles Richardson at Harvard Medical School, working on DNA replication. Bob and Charles are both among the world's greatest DNA biochemists, but they're also wonderful people. I learned how to do science working in their laboratories, where they allowed me a great deal of freedom in my choice of experimental pursuits. I regard working with them as highlights of my career.

You've described yourself as an experimentalist. What do you mean by this and how does it characterize your approach to research?

When I write a grant application, I frame the problem in terms of: This is what we know, these are the unanswered questions and this is how we'll address those questions experimentally. A well-designed experiment can give you the truth. The physicist Richard Feynman wrote, "The ultimate test of knowledge is experiment. Experiment is the sole judge of scientific 'truth.'"

You received the Nobel prize in chemistry in 2015 for your discoveries concerning the mechanisms of DNA repair. What was it like to get the call?

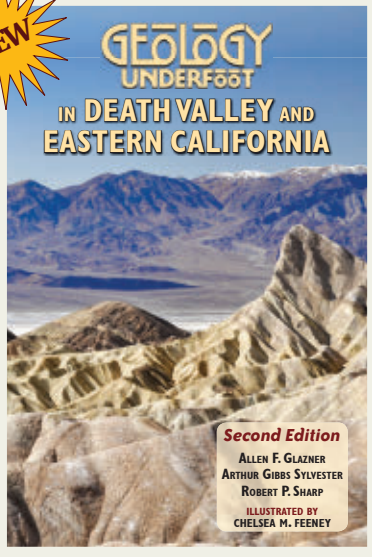
I never actually got the call. My wife and I were at our cabin in New Hampshire, and when we returned to North Carolina,

Get out of your car and take a closer look at the landforms around you!

GEOLOGY UNDERFOOT FROM

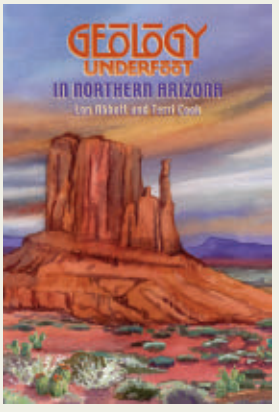
MOUNTAIN PRESS PUBLISHING COMPANY
P.O. BOX 2399 • MISSOULA, MONTANA 59806
406-728-1900 • WWW.MOUNTAIN-PRESS.COM

NEW

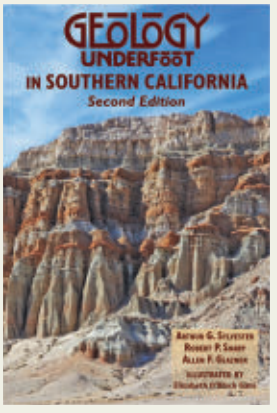


Eastern California—a geologically dramatic region with the ever-present risk of volcanic eruptions, earthquakes, flash floods, and sand storms—boasts spectacular and easily viewed rocks and landforms. Authors Allen Glazner and Art Sylvester build on coauthor Bob Sharp's insights to produce this full-color illustrated guide to 33 amazing geologic sites in Death Valley and the surrounding region.

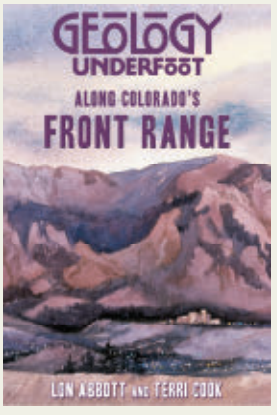
$24.00 paper, 328 pages, 6 x 9, full color, ISBN 978-0-87842-707-9



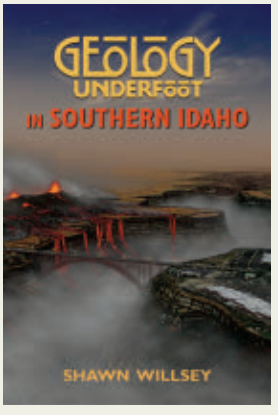
NORTHERN ARIZONA
$20.00 paper, 334 pages
ISBN 978-0-87842-528-0



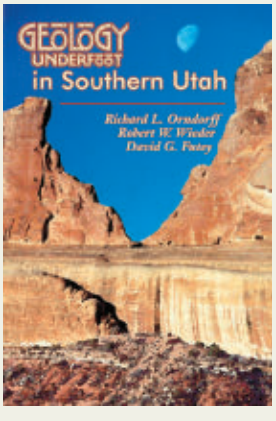
SOUTHERN CALIFORNIA
$24.00 paper, 308 pages
ISBN 978-0-87842-698-0



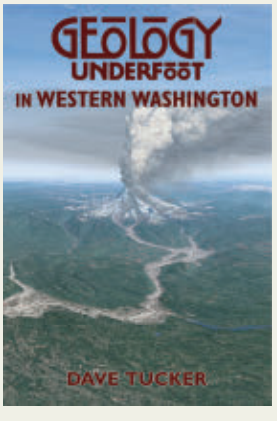
ALONG COLORADO'S FRONT RANGE
$24.00 paper, 348 pages
ISBN 978-0-87842-595-2



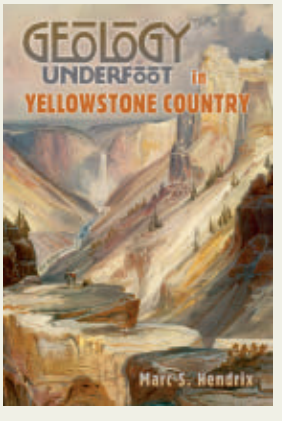
SOUTHERN IDAHO
$24.00 paper, 304 pages
ISBN 978-0-87842-678-2



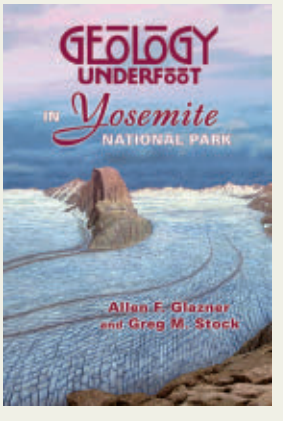
SOUTHERN UTAH
$20.00 paper, 320 pages
ISBN 978-0-87842-517-4



WESTERN WASHINGTON
$24.00 paper, 388 pages
ISBN 978-0-87842-640-9



YELLOWSTONE COUNTRY
$24.00 paper, 312 pages
ISBN 978-0-87842-576-1



YOSEMITE NATIONAL PARK
$24.00 paper, 304 pages
ISBN 978-0-87842-568-6

our answering machine was full of calls from Stockholm. I actually learned about the honor from a former postdoc, who left a voicemail on my cell phone. It was a shock but also a wonderful surprise.

How would you describe the impact of your work on human health as well as advancing your field?

There are multiple pathways of DNA repair. We worked in an area called mismatch repair, and what mismatch repair does is correct rare errors that occur when a chromosome is copied. During DNA replication, the two strands of the DNA helix separate, and two new strands are synthesized using the separated parental strands as templates. The enzymes responsible for synthesis of these new strands are extremely accurate, typically making about one mistake for every million to 10 million bases copied. But cells have a lot of DNA. A human cell contains 6 billion base pairs, so even with one error in a million or one error in 10 million, you still get a lot of mistakes. Those mistakes, which otherwise would become mutations, are corrected by mismatch repair.

We established basic features of how this pathway works, initially in the bacterium *E. coli* and then in human cells. During our work on the human pathway, we demonstrated that it is defective in cancer cells from patients with Lynch syndrome, one of the most common forms of hereditary cancer. We also showed that the pathway is defective in certain sporadic cancers where one of the mismatch repair genes turns out to be epigenetically silenced.

A few years ago, you met with then Vice President Joe Biden as part of the Cancer Moonshot initiative. Are there policies or institutional supports you think would be particularly impactful in supporting researchers addressing large interdisciplinary challenges?

That is something of great interest. The National Institutes of Health, as you know, is the primary funder of biomedical science in this country and has a history of promoting large interdisciplinary research, especially in areas that target certain diseases, like cancer. That is certainly appropriate given NIH's health-related focus, but I would like to speak to an alternate view: that the establishment of large, targeted programs must not occur at the expense of smaller basic science research projects initiated by individual investigators. Such research is important because much of what we know about the fundamental nature of cell and organ function have been derived from the pursuit of basic science questions in a small science format. Many of the most valuable technologies available to modern biomedical science—genome sequencing and the polymerase chain reaction for example—emerged from basic science discoveries made by individual investigators.

Paul Modrich conducts an experiment in 1977 while an assistant professor at Duke University.

What advice do you have for young people just starting college or their careers?

For college students who are considering the possibility of a research career, a good way to determine if this is the kind of life for you is to find a laboratory where you might work 10 to 15 hours a week, and maybe over the summer as well. For someone who is beginning their career as an academic scientist, I would suggest choosing a problem that they regard as important but highly undeveloped and then pursue that problem in great depth. Avoid the temptation to jump around in ways that contribute only incrementally to problem areas that have been largely developed by others.

What books inspired you when you were young?

When I was a teenager, I was very fond of science fiction. In college, I read every book that John Steinbeck wrote. He's still my favorite author.

There are so many challenges in the world today. What keeps you up at night?

The Russian invasion of Ukraine, of course, and the pandemic, although hopefully that's abating. I'm also troubled by the recent balkanization of politics in the United States and the apparent disappearance of compromise as a political tool in our Congress.

I also worry about the environmental, social and economic impacts of global warming and am particularly concerned that an underlying primary problem is not being publicly discussed at all. We talk about carbon emissions, but that's not the only problem. Another problem is the size of the global population.

Although there's not uniform agreement, people like former Harvard University sociobiologist Edward O. Wilson have estimated that Earth's carrying capacity is about 9 billion people. We're almost there. I personally regard this as a very serious problem, but it's one that appears to be on the mind of only a few scientists, when in fact it should be of concern to us all, especially policy makers.

MARCH 26, 2022

SOCIAL MEDIA

Happy 100th birthday to us!

Across a century of journalism, *Science News* has shined a light on all corners of science, from the Scopes trial to the atomic bomb, **Maria Temming** reported in "100 years of *Science News*" (*SN: 3/26/22, p. 16*). Readers joined the centennial celebration on social media. Twitter user **@ZhangZine** wrote: "Congratulations! I hope that *Science News* will provide us with more timely news about science and contribute to humans' science development."

Join the conversation

E-MAIL feedback@sciencenews.org

MAIL Attn: Feedback
1719 N St., NW
Washington, DC 20036

Connect with us

Reflecting on our past

During Science News*' early history, in the 1920s through '60s, we shared and endorsed ideas that were unscientific, racist, sexist and morally wrong. In "The darkness in our past"* (SN: 3/26/22, p. 26)*, the* **Science News** ***reckoning team*** *and* ***senior staff*** *apologized for these past prejudices and vowed to hold ourselves accountable moving forward.*

Many readers commended *Science News* for doing this work. "I can't thank you enough for [this] excellent and insightful article," reader **Kirsten Muir** wrote. "It is sobering to read, but enormously appreciated in light of your different attitude today and ongoing scientific rigor. It is important for you to have been open and transparent about your past, and I greatly respect and admire you for it."

The article made reader **Roberta Riggs**, who grew up in the 1950s and '60s, reflect on the social and cultural transformations she has experienced during her lifetime. "I really appreciate the fact that you showed honest grief for stepping over the line," **Riggs** wrote. "Change is a hard thing to do. But I have changed, hopefully for the better. I have changed my opinion on a great many things, and a lot of that, I believe, is because of the articles I have read in your magazine.... Since we cannot go backward, we must do what we can now, for today and every day that we have as we live out our lives."

Crater questions

A space rock probably about 4 to 5.4 kilometers wide crashed into Earth about 280 million years ago, and material blasted from that impact may have created a bevy of secondary craters, ***Sid Perkins*** *reported in "Impact caused a cascade of craters"* (SN: 3/26/22, p. 12)*.*

Reader **Anne Wolfe** wondered how the ancient space rock's size compares with others in space, and whether it traveled alone.

Much bigger asteroids exist in the asteroid belt. But of the more than 28,000 known asteroids near Earth, only about 900 are at least 1 kilometer wide, says planetary scientist **Thomas Kenkmann** of the University of Freiburg in Germany. On average, a space rock several kilometers in diameter hits Earth about once every several million years, making it a rare event, he says. Although some asteroids have satellites or companions, it's unclear whether the rock that struck Earth about 280 million years ago was traveling solo.

Wolfe also wondered in what other ways the primary impact affected the environment.

The blast wave generated by the impact would have devastated areas within a few hundred kilometers of the crash, **Kenkmann** says. In addition, heat from the impact most likely burned everything within that same radius.

Parched plants

South Africa's fynbos plants use their long, thin roots to commandeer soil nutrients and keep adjacent forest from encroaching on fynbos territory, ***Jake Buehler*** *reported in "African shrubs weaponize skinny roots"* (SN: 3/26/22, p. 10)*.*

Reader **Wendy** asked whether fynbos roots also take up water from soil faster than the nearby forest plants.

Thin roots are generally more efficient than thicker roots, such as those of forest trees, at absorbing water from soil within a small window of time, says ecologist **Mingzhen Lu** of the Santa Fe Institute in New Mexico. But thick roots live longer. In forests' more stable soil environment, where moisture fluctuates less dramatically compared with fynbos soils, thick roots would be able to provide forest species a steady flow of water, he says.

SUPPORT FUTURE STEM LEADERS

Become a Member of the Society

Concerned about the environment and the climate crisis, Regeneron Science Talent Search finalist Roberto Lopez (pictured above) studied how dead leaves from a globally invasive plant are harmful to the health of native salt marsh plants in a New York state park near his home, reducing the ability of the marsh to store carbon dioxide, key to mitigating climate change.

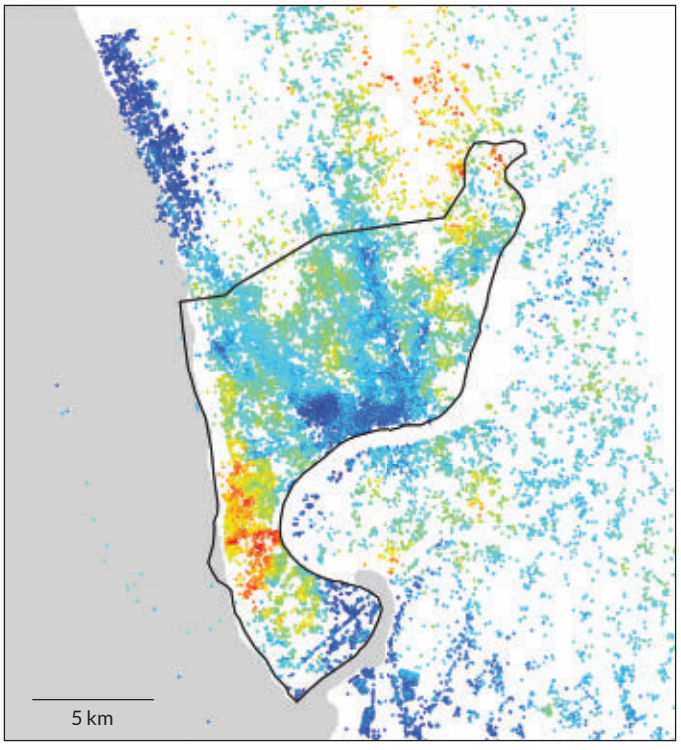
Today, we face global challenges, from the pandemic to the climate crisis. We need new generations of innovative scientists and engineers like Roberto, who have been inspired and supported by the Society's STEM programming and science journalism, to help us meet these and other challenges in the years ahead.

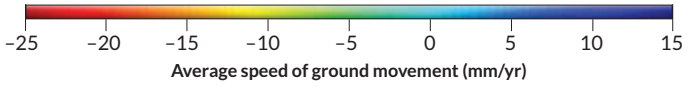
Society for Science inspires the next generation of scientists and engineers to address the world's most difficult problems through our world-class STEM research competitions and our trusted and comprehensive science journalism. But we can't do it without your help.

SOCIETY FOR SCIENCE

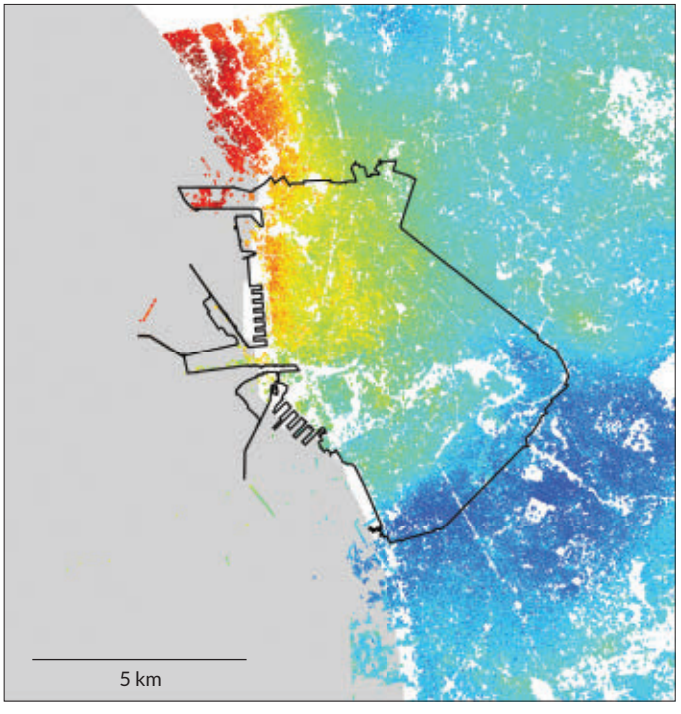
societyforscience.org/JoinMember

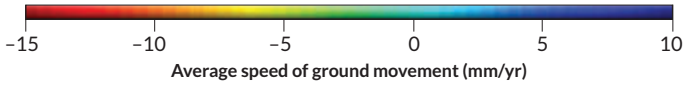
Chittagong, Bangladesh



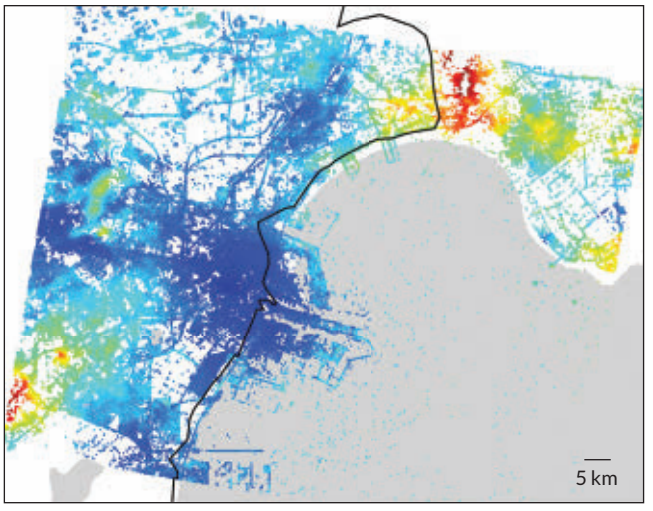


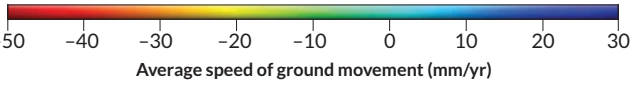
Manila, Philippines





Tianjin, China





That sinking feeling

Coastal cities around the world are sinking by up to several centimeters per year, on average, satellite observations reveal. The one-two punch of subsiding land and rising seas due to climate change means that these coastal regions are at greater risk for future flooding than previously thought, researchers report in the April 16 *Geophysical Research Letters*.

Satellite measurements of ground height in and around 99 coastal cities on six continents, obtained mostly from 2015 to 2020, reveal how fast the underlying terrain is subsiding. The maps shown here illustrate where and how fast the ground is dropping in three cities with pronounced subsidence. (Negative values correspond to the ground sinking; positive values correspond to the ground rising.)

Previous measurements of urban subsidence tended to focus on one city or region. But this investigation is "one of the first to really use data with global coverage," says Matt Wei, an earth scientist at the University of Rhode Island in Narragansett.

About one-third, or 34, of the analyzed cities are sinking in some places by more than 1 centimeter per year, Wei and his team found. The largest subsidence rates — up to 5 cm/yr — are mostly in Asian cities.

The team thinks that people are largely responsible for urban subsidence. Looking at Google Earth imagery of regions that were rapidly sinking, the researchers saw mostly residential or commercial areas. That's a tip-off that groundwater extraction is the culprit, the team concluded. Landscapes tend to settle as water is pumped out of aquifers (SN: 12/1/12, p. 13).

There is reason to be hopeful. In the past, Indonesia's Jakarta, for example, was sinking by nearly 30 cm/yr, on average. But now subsidence there and in some other places has slowed, possibly due to recent governmental regulations limiting groundwater extraction. — *Katherine Kornei*

ALL: P.-C. WU, M. WEI AND S. D'HONDT/*GEOPHYSICAL RESEARCH LETTERS* 2022


NATIONAL SECURITY AGENCY
UNITED STATES OF AMERICA
SOS
www.sos-vo.org/SN22MusicPuzzle

BRING THE WONDER OF THE WORLD TO YOUR CLASSROOM

National Geographic is where education meets exploration. Through immersive experiences, interactive lesson plans, maps, and other free classroom materials – there are endless ways to learn with National Geographic. Discover tools, resources, and support materials to feed your students' endless curiosity as they become the explorers of tomorrow.

PHOTO: LAURA JOHNSON

Explore free classroom resources at **NatGeoEd.org**

NATIONAL GEOGRAPHIC