How to Weigh a Black Hole | COVID-19 Testing for Back to School

ScienceNews

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PLANT POWER

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COVER Rows and rows of lettuce are about to become part of a project to see if physics can help farms flourish. *Les Serres Lefort*

What can science tell us about living a good life?

Given the state of the world, it seems apt to wonder how to find purpose and joy in dark times. How can one live a good life when it feels as if things just keep getting worse?

It's a question that many people have asked themselves in the last 18 months. Good news for us: A small group of scientists has put a great deal of thought into trying to answer that question. In this issue, social sciences writer Sujata Gupta explores how people can find fulfillment, even in disastrous times (Page 24).

Gupta argues that the pandemic is a prime example of a perspective-changing moment. Last December, as she was researching pandemic fatigue, she stumbled across a related line of work suggesting that novel or aesthetic experiences can help people lead rich lives. Gupta, who used to travel extensively, was intrigued. But before she could learn more, she, her husband and their young daughter got COVID-19. They recovered, but the episode left the family reeling. "I thought, 'Wow, I need to make some changes,'" Gupta told me. "I need to pay heed and listen to what this [crisis] is saying."

As she dug deeper into writings on how to live a good life, she saw herself reflected in the nascent rich life research. That feeling grew stronger as she spoke with philosopher Lorraine Besser of Vermont's Middlebury College and social psychologist Erin Westgate of the University of Florida in Gainesville. They both told her that richness could be cultivated, even without wild adventures. "I thought, 'Oh my god, it's me.' I had never connected with research quite like that."

New, creative experiences can feel hard to come by while isolated in a pandemic, but Gupta found a way: Learn to make pottery. "It's a creative outlet, and I put zero stress on it," she said. "You don't have to be good." The act of creating those lovely, often wobbly, pots has restored some of the richness she used to feel while exploring the world. —*Nancy Shute, Editor in Chief*

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6:1
student-to-faculty ratio

1,200+
science, math, and engineering labs on campus

24/7
hours the Center for Engineering Innovation and Design (CEID) is open for student use

200+
summer fellowships for undergraduate science and engineering students annually

2:1
student-to-faculty ratio in STEM majors

>40%
of Yale College students graduating with a STEM major are women

Yale

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Excerpt from the September 18, 1971 issue of *Science News*

50 YEARS AGO

Sea life's chemical senses

For fish and other underwater life, a sensitivity to chemicals plays the same role as the sense of smell does for land animals.... [Researchers] have been studying the subtle ways this delicate fish-communication system can be disrupted by pollutants.... One study examined the effects of kerosene pollution on the behavior of lobsters.... The experiments demonstrate that chemical communication interference takes place at extremely low dilutions.

UPDATE: Chemical pollution — from sewage and agricultural runoff to pharmaceutical waste — muddles aquatic animals' senses with potentially dire effects, decades of research has shown. A chemical used to treat sewage seems to limit some fish species' abilities to form schools, making the fish vulnerable to predators (*SN: 10/27/07, p. 262*). Drug-tainted waters can have a variety of effects on fish, including suppressing their appetites (*SN: 12/20/08, p. 15*). A plastic chemical also appears to confuse senses: Its scent can lure sea turtles into eating plastic debris (*SN: 3/28/20, p. 14*).

A researcher releases a baby great hammerhead shark into Florida's Biscayne Bay. At least nine baby hammerheads have been found in the area.

THE SCIENCE LIFE

An endangered-shark baby boom hints at a nursery

Finding the nursery of an endangered shark in a vast ocean is like finding a needle in a haystack. But that's just what scientists may have done near Miami. Biscayne Bay, a popular fishing and boating spot, hosts a nursery of great hammerhead sharks (*Sphyrna mokarran*), new research suggests. If confirmed, the nursery would be the first identified in U.S. Atlantic waters for this iconic shark species.

While scientists have used satellites to track migrations of adult hammerheads, where the sharks breed and give birth and where babies grow up is still "a bit of a mystery," says shark scientist Catherine Macdonald of the University of Miami.

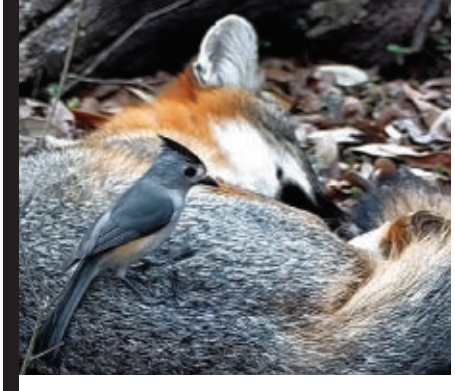
Macdonald investigates where and how sharks can thrive in areas, including Biscayne Bay, that are heavily impacted by humans. There, she and colleagues

SAY WHAT?

Kleptotrichy \KLEP-toh-TRIK-ee\ n.

A behavior in which birds steal hair from live mammals

Some birds take bold risks to gather a beakful of hair for their nests. Titmice have been spotted dive-bombing cats, alighting on dozing predators' backs and plucking strands of hair from people's heads. Now, there's a term for the unusual behavior: kleptotrichy. Derived from the Greek words for "to steal" and "hair," kleptotrichy has rarely been described by scientists, but dozens of YouTube videos capture the behavior, researchers report July 27 in *Ecology*. Titmice — and one chickadee — have been caught on video tugging hair from dogs, cats, humans, raccoons and even a porcupine.



This black-crested titmouse (*Baeolophus atricristatus*) in Texas was caught on video plucking hair from a sleeping fox. Such brazen behavior is called kleptotrichy.

Animal behaviorist Mark Hauber of the University of Illinois at Urbana-Champaign and colleagues searched the scientific literature and found only 11 anecdotes of birds stealing hair from live mammals. Most accounts involve titmice, but American crows, red-winged starlings and honeyeaters get in on the action too. Meanwhile, a YouTube search by the team turned up 99 videos of tufted titmice, a mountain chickadee and a black-crested titmouse plucking hair from mammals. The latter two bird species had not been identified by scientists as hair thieves.

"Popular observations precede science rather than the other way around, which is a valid way to do science," Hauber says.

— *Jaime Chambers*

FROM TOP: JULIA WESTER/FIELD SCHOOL; TEXAS BACKYARD WILDLIFE

Watch a bird steal fur from a raccoon at **bit.ly/SN_Kleptotrichy**

regularly survey shark abundance and diversity using a catch-and-release system: Sharks that get hooked on baited lines are reeled in, documented, tagged and put back into the water.

Discovering the potential hammerhead shark nursery was an accident. Macdonald's team got its first inkling of something special in June 2018, when researchers caught a baby great hammerhead — an interesting anomaly. In a decade of surveying, the team had never captured a hammerhead in these waters, says David Shiffman, a marine biologist at Arizona State University who is based in Washington, D.C. Several months later, the team caught another young hammerhead.

Over the next year and a half, "we kept catching them ... every few months," Macdonald says. So far, the team has documented nine baby great hammerheads, Macdonald, Shiffman and colleagues report in the August *Conservation Science and Practice*. Based on the sharks' sizes — all under 2 meters long — they were less than 5 years old. The area where the young sharks have been found is shallow and carpeted with seagrass, which probably provides protection and is rife with small fish to eat, the researchers suspect.

Though the Biscayne Bay site seems to be experiencing a hammerhead shark baby boom, designating the area as a nursery will require more monitoring. Baby hammerheads are more common at the site than at other areas surveyed. And the sharks come back to the site for multiple years, the team says. But it's unknown whether the sharks reside there for extended periods of weeks or months — the final criteria for the site to qualify as a nursery.

Great hammerheads breed about once every two years. And the rate at which people catch and kill the sharks, both accidentally and intentionally (*SN: 11/5/11, p. 26*), contributed to the species being classified as critically endangered in 2019. So when nurseries are discovered, "it's important they remain safe," says Jasmin Graham, a marine biologist at Mote Marine Laboratory & Aquarium in Sarasota, Fla., who was not involved in the work.

Scientists on a boat in Biscayne Bay off Miami measure a live baby great hammerhead shark.

The possibility of an endangered shark nursery in Biscayne Bay fills Macdonald with hope, and she is working to get legal protections for the site. "Even in such a heavily impacted place, it is possible for nature to be thriving," she says. — *Lesley Evans Ogden*

A newfound white dwarf (left, in this illustration) has a radius that is just slightly larger than that of the moon (right).

FROM TOP: FIELD SCHOOL; GIUSEPPE PARISI

THE –EST

Moon-sized dead star sets records

Only a smidge bigger than the moon, a newfound dead star is the smallest of its kind known. The white dwarf, a type of remnant left behind when certain stars peter out, has a radius of about 2,100 kilometers, researchers report in the July 1 *Nature*. That's close to the moon's approximately 1,700-kilometer radius. Most white dwarfs are closer in size to Earth, which has a radius of about 6,300 kilometers. The white dwarf's small girth means, counterintuitively, that it is also one of the most massive known objects of its kind, at about 1.3 times the sun's mass. That's because white dwarfs shrink as they gain mass. Dubbed ZTF J1901+1458 and located about 130 light-years from Earth, this stellar remnant is living on the edge, the team says. If it were much more massive, it would explode. — *Emily Conover*

SCIENCE STATS

Walls may give wind farms a boost

Walls that block wind may sound like just the wrong thing for increasing the performance of a wind turbine. But such windbreaks could actually help wind farms produce more power, physicists report.

Scientists already knew that a windbreak could boost a single wind turbine's power output. The barrier slows wind speed close to the ground while air rushing over the top of the barrier increases wind speed higher up. But for large wind farms, there's a drawback: The flow of air slows as it travels farther through rows of turbines.

But by balancing these competing effects, windbreaks placed in front of each turbine can increase a wind farm's power output, computer simulations suggest. Squat, wide barriers are best for optimizing performance, according to a simulated wind farm with six rows of turbines. Windbreaks that are a tenth the height of the turbine and at least five times the width of the blades could boost a farm's power output by 10 percent, physicists report July 30 in *Physical Review Fluids*. That's the equivalent of adding one turbine, on average, for every 10 in a wind farm. — *Emily Conover*

10 percent

The potential increase in the power generated by wind farms when low, wide walls are placed in front of turbines

COVID-19 tests, like the one this child received in Los Angeles in 2020, are one tool schools can use to monitor and prevent outbreaks.

MARIO TAMA/GETTY IMAGES

BODY & BRAIN

COVID-19 tests can keep kids in class

Schools are using multiple strategies to enable in-person learning

BY JONATHAN LAMBERT

Backpack? Check. Notebooks and pens? Check. Coronavirus test? Check.

With the start of fall, many parents and teachers hope to leave Zoom school behind as kids return to the classroom. But the exceptionally transmissible delta variant of the coronavirus threatens to dash these hopes. The U.S. Centers for Disease Control and Prevention advises that schools employ a suite of COVID-19 mitigation measures, including social distancing, masking, improved air filtration and testing students regularly.

Testing, in particular, "is a way we can spend money to reduce transmission while maintaining in-person schooltime," says Alyssa Bilinski, an infectious disease modeler at Brown University in Providence, R.I. "It's a flexible tool that can be scaled up or down depending on the on-the-ground situation, and it can both stop transmission and provide real-time, school-specific information that can inform decision making."

While some coronavirus outbreaks did occur in schools during the 2020–2021 school year, transmission was usually equal to or lower than community levels of the virus when schools had mitigation measures in place, the CDC says. But as pandemic fatigue has calcified, many school districts have faced pressure to remove measures like masking, social distancing or testing, even as the delta variant drives a nationwide surge in COVID-19 cases.

A layered approach that incorporates all mitigation measures is best, but with delta, "testing is going to be even more critical" in schools, says Gigi Gronvall, an immunologist at the Johns Hopkins Center for Health Security in Baltimore.

In a perfect world, all students would be tested daily with a free test that instantly provides results with 100 percent accuracy, Gronvall says. But such tests do not exist, and schools have limited budgets. So districts have to weigh trade-offs among different coronavirus tests, and balance frequency and scope of testing to fit schools' needs.

Here's a look at some of the testing strategies that schools are using and their inherent benefits and challenges.

When tests are pooled

Northborough-Southborough public schools in eastern Massachusetts started a new routine last February. Once a week, thousands of students (with parental consent) swabbed their noses at home, stuck the swab in a plastic baggie and brought it to school. There, swabs were pooled into groups of 16 and shipped to a nearby lab, where technicians combined material from the swabs in each group for PCR tests.

Lab tests using PCR, or polymerase chain reaction, detect bits of coronavirus genetic material. A PCR test will almost never say someone without the virus has it — what's called a false positive — but can miss infections, perhaps 10 to 20 percent or more of the time. Still, it's the most accurate test in use, though that performance comes at the price of time and money.

Combining individual samples into pools, as Northborough-Southborough schools did, is one cost-saving strategy. For example, in May, the school system conducted 10,104 tests, most of which were pooled, costing the district $141,052. Had the tests not been pooled, all of those individual PCR tests would have added up to $346,596, says Mary Ellen Duggan, the school system's director of health and wellness.

Theoretically, some pooled testing strategies can identify up to 20 times as many true positives as testing individual students, given a limited testing budget, researchers reported April 14 in *Science Translational Medicine*. With only so many dollars to spend, pooled testing can cover a larger population of people, catching infections that might otherwise be missed by using that same budget to only test individual swabs.

Northborough-Southborough schools had all individual swabs tested if a pool came back positive, but other schools have different protocols. "Some just send everyone home and say go get tested," Gronvall says. "There's a lot of flexibility."

For pooled testing to work, buy-in is crucial. In Northborough-Southborough schools, with a total of about 4,100 students, the highest average participation rate across schools was about 60 percent. When students tested positive, they were instructed to isolate. The students' contacts were also identified and called, a practice known as contact tracing.

"To get this program up and running was a full-time job," Duggan says. But it paid off. Overall, she says, the school system saw very few cases, a result of the full suite of mitigation strategies employed.

But pooled testing has downsides. Not all schools have easy access to labs that can run PCR tests. And it can take a couple of days to get PCR test results back and then even more time to do contact tracing, ample opportunity for infected students to spread the virus. This might especially be a problem with the delta variant, which may spread much sooner after infection.

For speedier information, some schools use rapid antigen tests, which don't quite match a PCR test's ability to identify only true cases but can reveal an infection in just 15 minutes.

Test to play, test to stay

Football players were the guinea pigs for Utah's rapid testing strategy.

Almost all of the state's schools tried to stay in person during the last school year. But a spike in cases that peaked in November prompted all extracurricular activities to be canceled, except for the football play-offs. "They were just about done, and we thought this would be a great place to test out testing," says Kendra Babitz, the COVID-19 testing director for the Utah Department of Health.

To compete, athletes had to present a negative test, usually a rapid antigen test provided by the state, within 72 hours before a game or practice. Players with positive tests were barred from participation and instructed to isolate for 10 days, with the option of testing out of isolation after seven days. Close contacts were told to quarantine too.

Anecdotally, this strategy incentivized adherence to other measures, like wearing masks, Babitz says. The play-offs themselves went off with few hitches, and the percentage of positive tests among players dropped from about 4 percent to about 2 percent over two weeks. Over the next several weeks, this testing strategy was extended to all extracurricular activities at 127 public high schools.

Thirteen Utah schools adopted a similar protocol for sustaining in-person learning. Instead of sending all students home for remote learning in the early stages of an outbreak, schools that used a "test-to-stay" program screened all consenting students with rapid antigen tests whenever COVID-19 cases spiked above 1 or 2 percent of the student body. (Some schools went further, testing students every two weeks regardless of cases.)

Students who tested negative could stay in school, while those who tested positive had to isolate at home for 10 days. Students who opted out of testing were recommended, but not required, to switch to remote learning for 10 days if testing participation rates were below 60 percent, or if more than 2.5 percent of participating students tested positive.

Allowing students to test out of remote learning after an outbreak saved more than 100,000 in-person student learning days, Babitz and others reported May 28 in *Morbidity and Mortality Weekly Report*. Reported COVID-19 cases also declined overall, though the study did not assess the impact of the testing intervention on transmission in schools. But a study in England found that schools where students could rapidly test out of quarantine had similar transmission rates as schools that kept students out of school during the full quarantine period, researchers reported July 25 at medRxiv.org.

The test-to-play and test-to-stay programs were "a big success," Babitz says. All told, nearly 60,000 students were tested through both programs, and only about 1,900, or 3.2 percent, got a positive result. Other states, including Delaware, are implementing similar rapid testing strategies for this school year.

Utah held the first high school football game in the United States during the 2020–2021 school year (shown). During the state's play-off season in November, football players tried out a rapid antigen testing strategy.

CHRIS GARDNER/GETTY IMAGES

Antigen tests work by detecting proteins from the coronavirus instead of analyzing genetic material as PCR tests do, which takes more time. That quick turnaround offers significant advantages over PCR testing. But some experts worry that the rapid tests' higher propensity for false positives among people without symptoms could isolate some students in unnecessary quarantines.

"If you're using a rapid test for screening, it's important to have a confirmatory test available, and available quickly, so that you can get confirmation of a positive result and know whether you really need to isolate that person and quarantine their contacts," says infectious disease physician Andrea Ciaranello of Massachusetts General Hospital in Boston.

Innovative ideas

Schools may soon have additional testing strategies to add to their repertoires. For instance, David Coil, a microbiologist at the University of California, Davis, is developing a form of surveillance that piggybacks off of the increased use of air filters in some schools.

"By testing air filters for viral RNA, we can see whether a virus is circulating in a classroom," he says. It's like the testing of pooled samples in that it covers many students in a single sample but doesn't require wrangling parental consent forms and actual swabs from kids, he says. That wrangling becomes necessary if a classroom tests positive, of course, but surveilling air filters instead of students could help schools get a coarse look at transmission without the challenges of testing lots of students.

Such creative measures may be necessary as a delta-driven COVID-19 surge collides with kids' return to school. With $10 billion in testing funding for K–12 schools through the American Rescue Plan, there's an opportunity to scale up promising approaches, says Bilinski, the infectious disease modeler at Brown University. "At this stage of the pandemic, we have both the technology and the funding to make exposures less costly and disruptive. We should use it." ■

— With reporting from Tina Hesman Saey

EARTH & ENVIRONMENT

Earth cannot avoid a warmer future

But just how hot it gets is up to us, a U.N. climate report says

BY CAROLYN GRAMLING

The science is unequivocal: Humans are dramatically overhauling Earth's climate. The effects of climate change are now found in every region around the globe and are intensifying rapidly, states a sweeping new analysis released August 9 by the United Nations' Intergovernmental Panel on Climate Change, or IPCC. And the window to reverse some of these effects is closing.

"There is no room for doubt any longer" about humans' responsibility for current climate change, says Kim Cobb, a climate scientist at Georgia Tech in Atlanta and an author of the report's first chapter. "We can say quite definitely" that a whole class of extreme events is linked to human-caused climate change.

Climate change is already affecting every region on Earth in multiple ways, from drought and fire conditions in the American West to heat waves in Europe and flooding in Asia, the report notes. Each of the last four decades has been the warmest on record since preindustrial times (*SN: 6/19/21, p. 32*).

The report also looks at several different scenarios of greenhouse gas warming, including perhaps the most hopeful scenarios in which the world achieves by about 2050 "net-zero" carbon emissions, where emitted gases are balanced by carbon removal from the atmosphere.

If the world gets down to net-zero emissions, the decades afterward hold "hints of light," says Baylor Fox-Kemper, an oceanographer at Brown University in Providence, R.I., and a coordinating lead author of a chapter of the report. "Temperatures come back down a little — not all the way back to preindustrial times, but there's a little recovery."

Other changes are irreversible on near-future timescales — that is, the next century or more — Fox-Kemper says. Even in those midcentury net-zero emissions scenarios, "it's still pretty bad," he says. Sea levels, for example, will continue to rise until about the year 2300, driven in part by Greenland's melting ice sheet. "We may have already crossed [the] threshold beyond which Greenland's melting could be stopped," he says. Still, swift and deep emissions reductions would significantly slow how much sea levels will rise by 2100, the report finds.

The new analysis is the sixth in a series of massive assessment reports undertaken by the IPCC since 1990. In each report, hundreds of scientists from around the world analyze the findings of thousands of studies to form a consensus of how Earth's climate is changing and what role people play in those changes.

Researchers understand climate change far better now than they did in 1990. In the last three decades, new findings have poured in from tens of thousands more observing stations, from a wealth of satellite instruments and from dramatically improved climate simulations (*SN: 2/29/20, p. 18*).

The IPCC's fifth report, released in 2013 and 2014, was a game changer. It was the first to state that greenhouse gas emissions from human activities are driving climate change — a conclusion that set the stage for 195 nations to agree in Paris in 2015 to curb those emissions (*SN: 1/9/16, p. 6*).

The Paris Agreement set a target of limiting the global average temperature to 2 degrees Celsius above preindustrial times. But many island nations and others most threatened by climate change feared that this target wasn't stringent enough. So the IPCC compared how a future Earth might look if warming were limited to just 1.5 degrees C instead.

That special report, released in 2018, revealed in fine detail how just half a degree of extra warming by 2100 could matter, from the increased likelihood of heat waves to higher sea levels (*SN: 12/22/18 & 1/5/19, p. 18*). Those concrete findings coupled with scorching temperatures in 2019 grabbed the attention of the public and policy makers alike.

IPCC scientists hope the new report, with its emphasis on the regional and local effects of climate change, will have a similar impact. And the timing of its release is significant. On October 31, heads of state from around the world are scheduled to meet in Glasgow, Scotland, to discuss updated plans to meet the targets of the Paris Agreement.

With previous reports, "the world listened, but it didn't act strongly enough," said Inger Andersen, executive director of the U.N. Environment Programme, at an August 9 event announcing the report's release. "We certainly urge them ... to live up to the facts on the table now." ■

Feeling the heat With more global warming, effects on weather patterns and extremes become more pronounced. A new report by the United Nations' Intergovernmental Panel on Climate Change estimates changes in extreme conditions due to global warming relative to preindustrial times. Changes are shown for today (1.1 degrees Celsius higher on average) and for 1.5 degrees C, 2 degrees C and 4 degrees C above preindustrial times. SOURCE: IPCC

Climate impacts under four different scenarios above preindustrial levels

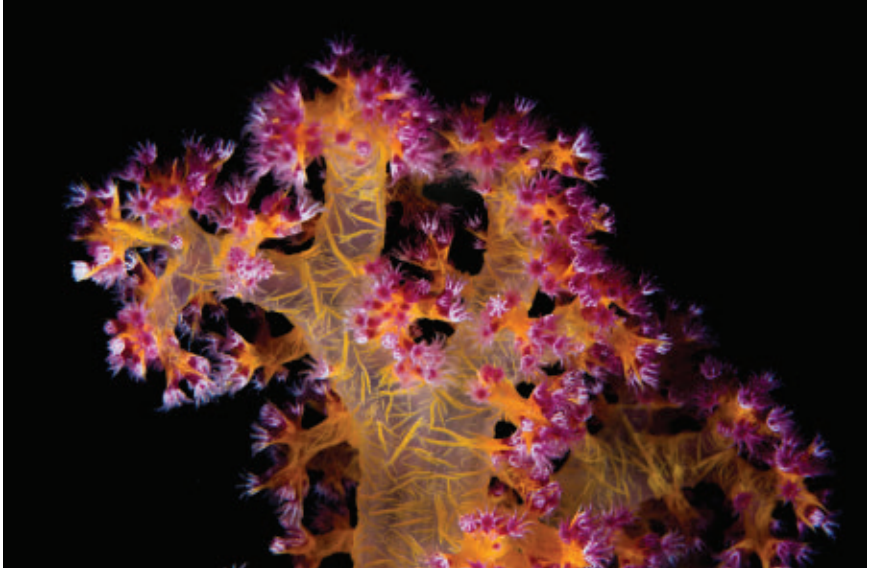
	Today's temperature (+1.1 degrees C)	+1.5 degrees C	+2 degrees C	+4 degrees C
Temperature: How much hotter is the hottest day in a decade	+1.2 degrees	+1.9 degrees	+2.6 degrees	+5.1 degrees
Drought: How many times as often a once-in-a-decade drought occurs	2 times	2.4 times	3.1 times	5.1 times
Precipitation: How many times as often a once-in-a-decade wettest day occurs	1.3 times	1.5 times	1.8 times	2.8 times
Snow: Change in extent of snow cover	–1%	–5%	–9%	–25%
Tropical cyclones: Change in proportion of cyclones rated intense	0	+10%	+13%	+30%

EARTH & ENVIRONMENT

Probiotics help corals in hot water

Select microbes boost the heat resilience of corals in lab tanks

BY JONATHAN LAMBERT



Probiotics prevented hard corals from dying due to heat stress in a lab experiment. In the future, researchers plan to test the method on soft corals similar to the one shown.

Warming seas threaten to turn coral reefs from kaleidoscopes of color into bleached fields of rubble. To stop this degradation, some scientists are exploring probiotics.

Dosing corals with a mix of beneficial bacteria staved off death in a heat wave simulated in aquariums, researchers report August 13 in *Science Advances*. Nearly half of corals given a benign saline solution instead did not survive those same conditions. The research offers a proof of concept that probiotics could help some corals survive heat stress.

"The results are incredibly promising," says Blake Ushijima, a microbiologist at the University of North Carolina Wilmington who wasn't involved in the research. The work lends legitimacy to using probiotics as coral medicine, he says, "but we're just scratching the surface. We don't understand how a lot of these beneficial microbes work."

Corals are not singular entities but coalitions of cooperative players. Center stage are photosynthetic algae that harness the power of the sun, providing energy to their animal host, the coral polyp. Scores of bacteria live in the coral too, many supporting their host by cycling nutrients or fighting pathogens. Collectively referred to as the coral "holobiont," corals and their microbial partners form the bedrock of one of the most biodiverse ecosystems on the planet.

Intensifying marine heat waves are testing the integrity of healthy holobionts. Under heat stress, corals' algae spew toxic chemicals, prompting polyps to kick the algae out. This process, known as bleaching, can kill corals (*SN: 10/29/16, p. 18*). Bacterial communities shift under heat stress too, disrupting the benefits some bacteria provide.

"Overall, we see a breakdown of symbiotic relationships, and all the microorganisms start to struggle," says marine ecologist Raquel Peixoto of King Abdullah University of Science and Technology in Thuwal, Saudi Arabia. Peixoto and her colleagues previously showed that treating corals with carefully concocted probiotic cocktails could mitigate coral bleaching in lab experiments. That's good, she says, "but we wanted to find out if we can protect them against mortality."

In the new study, the team simulated a marine heat wave across 10 aquariums, each with four fragments of *Mussismilia hispida* stony corals, turning up the temperature to 30° Celsius for 10 days before returning it to 26° C. Half the corals were squirted with six bacterial strains taken from *M. hispida* corals that were not part of the experiment every three days during the heat wave and every five days afterward. The other half got a saline treatment. Over the course of 75 days, the team measured coral health, changes in the holobiont's metabolic activity and which genes got turned on and off.

Corals in both groups bleached, but the probiotic treatment ultimately worked. While 40 percent of saline-treated corals succumbed to the heat, all corals bathed in bacteria survived. The probiotic seems to aid the recovery of corals by inducing genetic and metabolic changes in coral polyps that are associated with tamping down inflammation and repairing damaged cells, the researchers found.

"Climate change is affecting corals faster than they can adapt," but their microbial partners can respond to changes more quickly, says Kimberly Ritchie, a marine biologist at the University of South Carolina Beaufort who wasn't involved in the research. Such changes, which probiotic treatments could induce, might "buy corals more time," she says.

Peixoto and colleagues plan to test whether probiotics can help wild corals. But some scientists are skeptical of the added bacteria's utility, especially for large reefs with hundreds of coral species.

"Probiotics are sexy right now," says molecular ecologist Ty Roach of the Hawaii Institute of Marine Biology in Kaneohe. Roach can imagine scenarios where the approach might be useful, "but I don't think they're going to save the reefs," he says. Applying probiotics to large reefs that boast hundreds of coral species seems logistically challenging and there could be unintended consequences. "What's good for one coral may not be good for other corals or organisms," Roach says. "For ecosystems as complex as coral reefs, I can't see doing this on a large scale without having some unforeseen, potentially harmful effects."

The probiotics used in the study were carefully screened and are not known to be harmful to life, Peixoto says. Overall, probiotics "aren't going to be a silver bullet," she says. Reducing global warming is the only thing that will save the reefs. "But we still need restoration and rehabilitation to cope," she says, and probiotics show promise. ■

EARTH & ENVIRONMENT

Citizen seismologists help in Haiti

Residents assist in collecting data on earthquake hazards

BY CAROLYN GRAMLING

On August 14, a magnitude 7.2 earthquake struck Haiti, triggering landslides, toppling buildings and killing over 2,200 people, with over 12,000 people injured.

Scientists rushed to the area to learn what they can about the quake, in hopes of gaining a better understanding of the country's seismic hazards.

The earthquake's epicenter was near Petit-Trou-de-Nippes, a town on Haiti's southern peninsula about 125 kilometers west of Port-au-Prince. The Enriquillo-Plantain Garden fault zone passes straight through that peninsula, marking where the Caribbean tectonic plate to the south grinds against the small Gonâve tectonic plate to the north. Scientists often eye this fault zone when a deadly quake hits Haiti, such as the 2010 earthquake that killed at least 200,000 people.

But several months after that quake, scientists discovered that its origin was on a previously unknown fault, near but not part of the well-known Enriquillo zone. The fault was within a region of faults not mapped before, in part due to a dearth of seismometers in Haiti. Since then, researchers have worked to increase seismic measurements, including through the creation of a network of volunteer "citizen seismologists." Scientists aren't yet sure exactly what fault fractured for the most recent earthquake, but data collected by volunteers have already proved invaluable to tracking the quake and its aftershocks, says Dominique Boisson, a geologist at the State University of Haiti in Port-au-Prince.

Science News talked with Boisson and geophysicist Éric Calais of École Normale Supérieure in Paris about how citizen seismologists are helping. The interview has been edited for clarity and brevity.

How well are faults in this area mapped?

Boisson: The [Enriquillo] fault is well-known. But we are very far from having detailed maps of the active faults of the southern peninsula or other parts of the country. There's a lot of work to be done.

Data on microseisms [abundant, tiny earthquakes], including from citizen seismologists, will be helpful for imaging the structures in the subsurface. Even though the data [from the citizen seismologists] is not of the same quality as the professional networks, it's very important.

How important has the citizen seismology project been to tracking the recent earthquake and its aftershocks?

Calais: It has been essential. It's amazing how proactive the seismic station hosts have been. We call them hosts, because they host a tiny little box, about 10 centimeters by 5 centimeters by 5 centimeters. You just connect it to power and the internet, and it provides data in real time. We have built a system that analyzes the data in real time and provides aftershock locations. Within 30 seconds of an aftershock, we know exactly where it happened, the magnitude, the depth and so on.

Who are these volunteers?

Calais: Their backgrounds vary — we have a public notary, a hotel owner, a civil engineer. It's all over the map really. It's not easy to have internet and power all the time in Haiti. [Many people have] a power generator of some kind; you buy your internet plan by the day. At one station, closest to the epicenter ... the host was so sorry because he had not renewed his internet plan when the earthquake happened. Right away he contacted us and said, "Well, I just ran to the internet provider and I just bought a new plan!" His station came back online right away.

The data are very, very useful, and the interaction we're having with the hosts is teaching us a lot about how the risk is perceived and what kind of message [about seismic hazards] is useful.

In 2020, you (Calais and Boisson) and colleagues published a preliminary report on the citizen seismology project, calling it a socio-seismology experiment. How might this work improve earthquake awareness and reduce risks from these hazards?

Calais: It's an interesting endeavor because it's not only seismology that we're interested in. It's a project that we're conducting with sociologists and anthropologists. The project is too young to tell whether it has made any difference in preparedness.

After the 2010 earthquake, there was no baseline study that was done right after. So you come back 10 years after, and you can't tell a difference between how the risk is perceived. We're trying to change that. Right now we are trying to organize a team of sociologists to send into the field to interview people and make sure we start building this baseline. ■

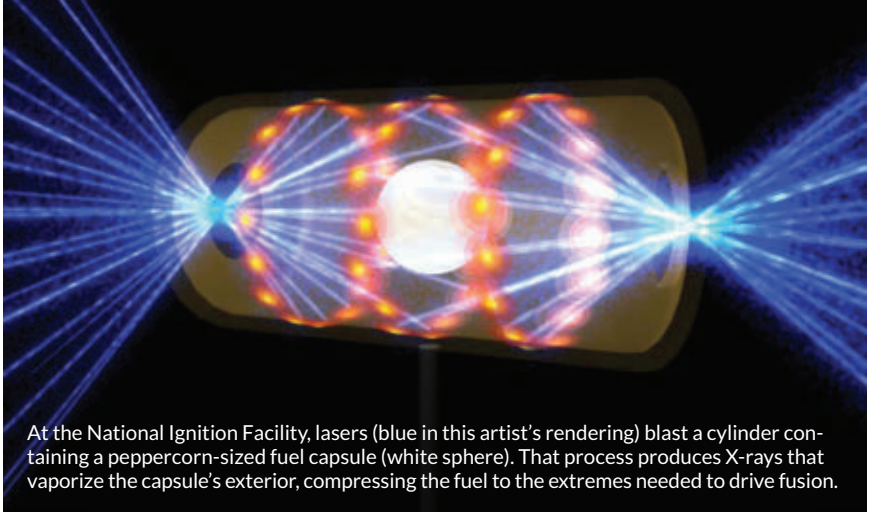
The magnitude 7.2 earthquake that struck Haiti on August 14 killed more than 2,200 people and caused widespread damage in the country's southern peninsula, including in Les Cayes (shown).

RICHARD PIERRIN/GETTY IMAGES

MATTER & ENERGY

Physicists near a nuclear fusion feat

Lasers set off reactions that come close to ignition



At the National Ignition Facility, lasers (blue in this artist's rendering) blast a cylinder containing a peppercorn-sized fuel capsule (white sphere). That process produces X-rays that vaporize the capsule's exterior, compressing the fuel to the extremes needed to drive fusion.

LAWRENCE LIVERMORE NATIONAL LABORATORY

BY EMILY CONOVER

With a powerful laser zap, scientists have blasted toward a milestone for nuclear fusion.

A fusion experiment at the world's biggest laser facility released 1.3 million joules of energy, coming close to a break-even point known as ignition, where fusion begins to release more energy than required to trigger it. Reaching ignition would strengthen hopes that fusion could one day serve as a clean, plentiful energy source, a goal that scientists have struggled to make progress toward (*SN: 2/17/18, p. 4*).

By pummeling a tiny capsule with lasers at the National Ignition Facility, or NIF, at Lawrence Livermore National Laboratory in California, scientists triggered fusion reactions that churned out more than 10 quadrillion watts of power over 100 trillionths of a second. In all, the experiment, performed August 8, released about 70 percent of the energy of the laser light used to set off the fusion reactions, putting the facility much closer to ignition than ever before.

Notably, because the capsule absorbs only a portion of the total laser energy focused on it, the reactions actually produced more energy than directly went into them. "That, just fundamentally, is a truly amazing feat," says plasma physicist Carolyn Kuranz of the University of Michigan in Ann Arbor, who was not involved with the research. By that metric, the fusion reactions produced about five times as much energy as was absorbed.

"It's a really exciting result, and it wasn't clear that NIF would be able to get to this result," Kuranz says. For years, NIF scientists have strived to reach ignition, but they have been plagued with setbacks (*SN: 4/20/13, p. 26*). While the new results have yet to be published in a scientific journal, NIF scientists went public when excitement about their discovery mounted.

"It makes me very hopeful ... for fusion in the future," Kuranz says.

Nuclear fusion, the same process that powers the sun, would be an appealing source of energy on Earth because it checks two important boxes for environmental friendliness: It wouldn't generate climate-warming greenhouse gases or dangerous, long-lived radioactive waste. In nuclear fusion, hydrogen nuclei meld together to form helium, releasing energy in the process. But fusion requires extreme temperatures and pressures, making it difficult to control.

NIF is not alone in the fusion quest. Other projects, such as ITER, an enormous facility under construction in southern France, are using different techniques to tackle the problem (*SN: 2/6/16, p. 18*). But those efforts have also met with difficulties. Perhaps unsurprisingly, controlling reactions akin to those in the sun is challenging no matter how you go about it.

In NIF's fusion experiments, 192 laser beams converge on a small cylinder containing a peppercorn-sized fuel capsule. When that powerful laser burst hits the cylinder, X-rays stream out, vaporizing the capsule's exterior and imploding the fuel within. That fuel is a mixture of deuterium and tritium, varieties of hydrogen that respectively contain one or two neutrons in their atomic nuclei. As the fuel implodes, it reaches the extreme densities, temperatures and pressures needed to fuse the hydrogen into helium. That helium can further heat the rest of the fuel, what's known as alpha heating, setting off a fusion chain reaction.

That last step is crucial to boosting the amount of energy that the reactions release. "What's new about this experiment is that we've created a system in which the alpha heating rate is far larger than we've ever achieved before," says NIF physicist Arthur Pak.

Scientists navigated a variety of quagmires to get to this stage. "There's a whole host of physics issues ... that we've faced off and mitigated," Pak says. For example, researchers took pains to make the capsule absorb more energy, to eliminate tiny defects in the capsule and to carefully tune the laser pulses to maximize fusion.

In 2018, researchers began seeing the payoff of those efforts. NIF achieved a then-record fusion energy of 55,000 joules. Then, in spring 2021, NIF reached 170,000 joules. Further tweaking the design of the experiment, scientists suspected, could increase the output even more. But the new experiment went beyond expectations, producing nearly eight times the energy of the previous effort.

Further studies will help NIF scientists determine exactly how their changes created such bountiful energy and how to enhance the output further. Still, even if NIF achieves full-fledged ignition, using fusion to generate power for practical purposes is still a long way off. "There will be a huge amount of work needed to turn the technology into a viable source of energy," says laser plasma physicist Stuart Mangles of Imperial College London, who was not involved with the research. "Nevertheless, this is a really important milestone on the way." ■

ATOM & COSMOS

How black holes eat hints at their mass

Flickering accretion disks provide a new way to weigh the giants

BY LISA GROSSMAN

An actively feeding black hole surrounds itself with a disk of hot gas and dust that flickers like a campfire. Astronomers have now found that monitoring changes in those flickers can reveal the behemoth's heft.

"It's a new way to weigh black holes," says astronomer Colin Burke of the University of Illinois at Urbana-Champaign. What's more, the method could be used on any astrophysical object with an accretion disk, and may even help find elusive midsize black holes, researchers report in the Aug. 13 *Science*.

It's not easy to measure a black hole's mass. For one thing, the dark giants are difficult to see. But black holes can reveal themselves when they eat. As gas and dust falls into a supermassive black hole, the material forms a disk that is heated to white-hot temperatures and can outshine all the stars in the galaxy combined.

Measuring the diameter of the hole in the center of a disk can reveal the black hole's mass using Einstein's general theory of relativity. But only the Event Horizon Telescope collaboration has made this sort of measurement, and for only one black hole so far (*SN: 12/21/19 & 1/4/20, p. 22*). Other black holes have been weighed via observations of their influence on the material around them, but that takes a lot of data and doesn't work for every supermassive black hole.

Looking for another way, Burke and colleagues turned to accretion disks. Astronomers aren't sure how black holes' disks flicker, but it seems like small changes in light combine to brighten or dim the entire disk over a given time span. Previous research had hinted that the time it takes for a disk to fade, brighten and fade again is related to the mass of its black hole. But those claims were controversial, and didn't cover the full range of black hole masses, Burke says.

So he and colleagues assembled observations of 67 actively feeding black holes with known masses. The behemoths spanned sizes from 10,000 to 10 billion solar masses. For the smallest of the black holes, the flickers changed on timescales of hours to weeks. Supermassive black holes with masses between 100 million and 10 billion solar masses flickered every few hundred days.

"That gives us a hint that, OK, if this relation holds for small supermassive black holes and big ones, maybe it's sort of a universal feature," Burke says.

Out of curiosity, the team also looked at the compact corpses of stars like the sun, which are some of the smallest objects to sport consistent accretion disks. Those dead stars followed the same relationship between flicker speed and mass.

The analyzed black holes didn't cover the entire possible range of masses. Known black holes that are from about 100 to 100,000 times the mass of the sun are rare. There are several potential candidates, but only one has been confirmed (*SN: 9/26/20, p. 7*). In the future, the rela-

ATOM & COSMOS

Auroras may heat up Jupiter's skies

Polar light shows could explain an unusually hot atmosphere

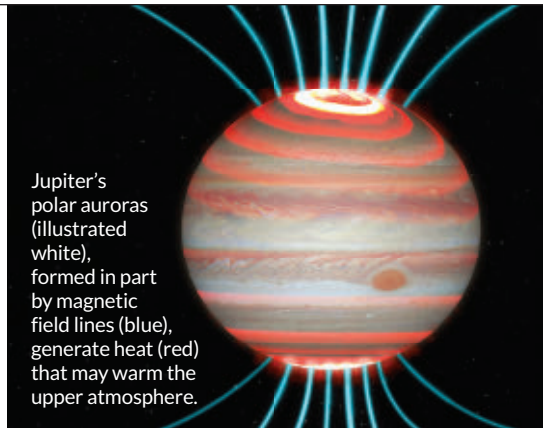
BY SID PERKINS

Jupiter's upper atmosphere is hundreds of degrees warmer than expected. After a decades-long search, scientists may have pinned down a likely source of that anomalous heat: the planet's intense auroras.

Given that Jupiter's average distance from the sun is 778 million kilometers, the planet's upper atmosphere should be about –73° Celsius, says planetary scientist James O'Donoghue of the JAXA Institute of Space and Astronautical Science in Sagamihara, Japan. That's largely due to the feeble illumination of the sun there, which amounts to less than 4 percent of the energy per square meter that hits Earth's atmosphere. Instead, the region several hundred kilometers above Jupiter's cloud tops has an average temperature of about 426° C.

Scientists first noticed this mismatch more than 40 years ago. Since then, researchers have come up with several ideas about where the thermal boost might originate, including pressure waves created by turbulence lower in the atmosphere. But observations by O'Donoghue and colleagues now provide evidence that auroras pump heat throughout the planet's upper atmosphere.

The researchers used the 10-meter Keck II telescope in Hawaii to observe Jupiter on one night each in 2016 and 2017. Specifically, the team looked for infrared emissions that betray the presence of positively charged hydrogen molecules. Those molecules are created when charged particles in the solar wind, among other sources, slam into the Jovian atmosphere, painting polar auroras.



Jupiter's polar auroras (illustrated white), formed in part by magnetic field lines (blue), generate heat (red) that may warm the upper atmosphere.

J. O'DONOGHUE/JAXA, HUBBLE/NASA, ESA, A. SIMON, J. SCHMIDT

Measuring the intensities of these molecules' infrared emissions let the team pin down how hot it gets high above the cloud tops. In those polar regions, temperatures in the upper atmosphere probably top out at about 725° C, the team reports in the Aug. 5 *Nature*. But at equatorial latitudes, the temperature falls to about 325° C. That pattern of a

tionship between disk flickers and black hole mass could tell astronomers exactly what kind of flickers to look for to bring midsize beasts out of hiding, Burke says.

Astrophysicist Vivienne Baldassare of Washington State University in Pullman studies black holes in dwarf galaxies, which may be remnants of ancient black holes that formed in the early universe. One of the biggest challenges in her work is measuring black hole masses. The study's "super exciting results ... will have a large impact for my research, and I expect many others' as well," she says.

The method offers a simpler way to weigh black holes than any previous technique, Burke says, but perhaps not a faster one. More-massive black holes would need hundreds of days, or possibly years, of observations to reveal their masses.

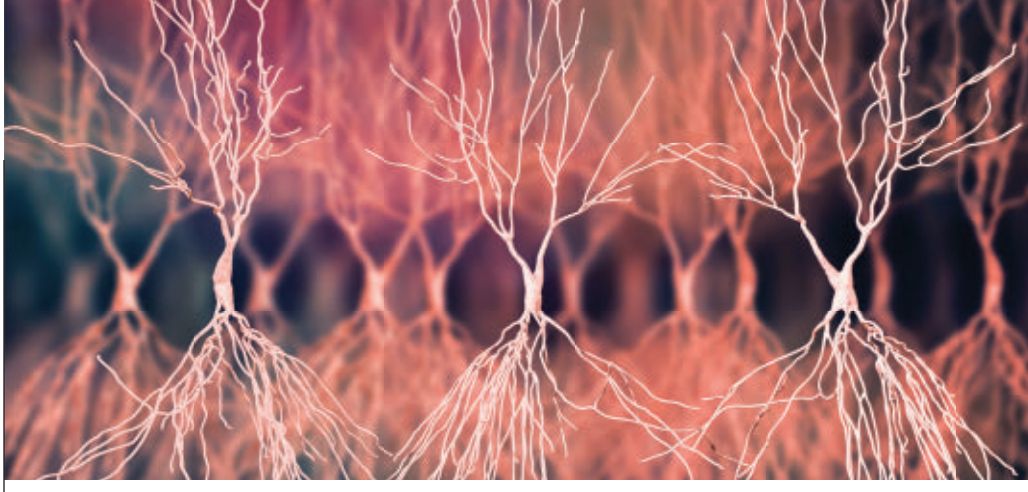
The Vera C. Rubin Observatory in Chile, expected to start operations in 2023, plans to take that kind of data. Once the telescope has run for long enough, the observations needed to weigh black holes "will fall out" from the data, Burke says. "We're already building it. We may as well do this." ■

gradual drop-off in temperature toward lower latitudes bolsters the notion that Jupiter's auroras are the source of anomalous heat in the upper atmosphere and that winds disperse that warmth from the polar regions.

The night in January 2017 that the team observed Jupiter was particularly well-timed because the planet was experiencing a strong solar flare. Besides an intense northern aurora, data revealed a broad swath of warmer-than-normal gases at midlatitudes, which the researchers interpret as a wave of warmth rolling southward.

The team's observations "are close to a smoking gun for the redistribution of auroral energy," says planetary scientist Tommi Koskinen of the University of Arizona in Tucson. The next challenges, he says, are to understand the underlying mechanisms of heat production and transfer and to incorporate them into simulations of Jupiter's atmosphere. ■

KATERYNA KON/SCIENCE PHOTO LIBRARY/GETTY IMAGES



Bursts of activity created by nerve cells (illustrated) in the hippocampus, called sharp-wave ripples, are thought to solidify memories. These ripples may also lower blood sugar levels in the body, a study in rats suggests.

BODY & BRAIN

Brain ripples drop sugar levels in rats

Nerve cell activity involved in memory may sway metabolism

BY LAURA SANDERS

Ripples of nerve cell activity that lock in memories may have an unexpected job outside of the brain: dropping blood sugar levels in the body.

Soon after a burst of ripples in a rat's hippocampus, a brain structure that plays a key role in memory, sugar levels elsewhere in the body dipped, new experiments show. The curve ball results, reported August 11 in *Nature*, suggest that certain types of brain activity and blood sugar control — a key part of metabolism — are entwined in surprising and mysterious ways.

"This paper represents a significant advance in our understanding of how the hippocampus modulates metabolism," says Elizabeth Gould, a neuroscientist at Princeton University who wasn't involved in the study.

Neural shudders called sharp-wave ripples zig and zag in the brains of people as they learn new things and draw memories back up (*SN: 9/14/19, p. 14*). Ripples also feature prominently during deep sleep and are thought to accompany the neural work of transforming short-term knowledge into long-term memories.

Neuroscientist David Tingley, now at Harvard University, wondered whether these signals might also change something outside of the brain. Tingley and colleagues fitted continuous glucose monitors onto the backs of eight rats. The researchers simultaneously measured the rats' brain waves with electrodes implanted in the hippocampus.

About 10 minutes after a bout of ripples, blood sugar levels in the body fell, the monitors showed. "We saw these dips in the second rat, and the third rat, and the fourth rat," says coauthor György Buzsáki, a neuroscientist at New York University Grossman School of Medicine. "It was super consistent. The magnitude is small, but [the dips] are always there."

Rats' blood sugar levels also dropped after the team induced bouts of brain ripples using light. When the researchers jammed the ripples' signals with a drug that quiets nerve cells, blood sugar levels did not drop. That suggests these ripples send signals that ping-pong through the brain and ultimately tell the body to reduce its sugar.

"All of this was very surprising," says neuroscientist Jan Born of the University of Tübingen in Germany. You might expect a busy brain at work to call for more energy, in the form of sugar, not less, says Born, who cowrote a commentary on the study in *Nature*.

Buzsáki speculates that these ripples might have evolved to aid in metabolism. As time passed, the ripples may have been pulled in on memory storage.

If this newfound link between brain waves and metabolism exists in people, it might hint at a way to influence sugar levels by tweaking ripples, Buzsáki says, an idea that could be useful for people with diabetes and other metabolic problems. ■

Factory workers in India, such as these tailors in Mumbai, often work without air conditioning. On hot days, worker productivity drops.

HUMANS & SOCIETY

Extreme heat distorts human behavior

In a warming world, aggression may rise while productivity falls

BY SUJATA GUPTA

On a sweltering summer afternoon almost a decade ago, Meenu Tewari was visiting a weaving company in Surat in western India. Tewari, an urban planner, frequently makes such visits to understand how manufacturing companies operate. On that day, though, her tour of the factory floor left her puzzled.

"There were no workers there ... only machines," says Tewari, of the University of North Carolina at Chapel Hill.

The missing employees were resting in the shade under a nearby awning. Scorching temperatures had been causing workers to make mistakes or even faint near the dangerous machinery, Tewari's guide told her. So the company had mandated that workers come in earlier and leave later so that they could rest during the midday heat.

People's bodies aren't built to handle heat beyond wet bulb temperatures — a combined measure of heat and humidity — of around 35° Celsius, or about 95° Fahrenheit (*SN: 6/6/20, p. 6*). Mounting evidence shows that when heat taxes people's bodies, their performance on various tasks, as well as overall coping mechanisms, also suffer. Researchers have linked extreme heat to increased aggression, lower cognitive ability and lost productivity. With rising global temperatures, and record-breaking heat waves baking parts of the world, the effects of extreme heat on human behavior could pose a growing problem.

Lower-income people and countries, with limited resources for staying cool as climate change warms the world, will probably suffer the most, researchers say. "The physiological effects of heat may be universal, but the way it manifests ... is highly unequal," says economist R. Jisung Park of UCLA.

Heat and aggression

Scientists have been documenting humans' difficulties coping with extreme heat for over a century. Much of that work, however, has taken place in highly controlled lab settings.

For instance, a few decades ago, social psychologist Craig Anderson and colleagues showed undergraduates four video clips of couples engaged in dialog. One clip was neutral in tone, while the remaining three showed escalating tension between the duo. The undergraduate students watching the clips were each sitting in a room with the thermostat set to one of five different temperatures, ranging from a cool 14° C (57° F) to a hot 36° C (97° F). The researchers then asked the students to score the couples' hostility level. Anderson, now at Iowa State University in Ames, found that students in uncomfortably warm rooms scored all the couples, even the neutral one, as more hostile than students in rooms with comfortable temperatures did.

Heat tends to make people more irritable, says Anderson, whose findings appeared in *Advances in Experimental Social Psychology* in 2000. As a result, "they tend to just perceive things as being more nasty when they're hot than when they're comfortable."

Such perceptions can give way to actual violence when people lack an escape hatch, research suggests. But this "heat-aggression hypothesis" has been hard to demonstrate outside the lab. Teasing out the effect of heat from other environmental or biological variables linked to aggression is tricky in the messy real world. Studies in the last few years, however, have started confirming the idea.

A July working paper by the National Bureau of Economic Research came close to re-creating the level of control found in a lab by focusing on inmates in Mississippi prisons and jails that lack air conditioning. Economists Anita Mukherjee of the University of Wisconsin–Madison and Nicholas Sanders of Cornell University looked at rates of violence across 36 correctional facilities from 2004 to 2010. Overall, each facility averaged about 65 violent acts per year. But on days when outdoor temperatures reached above around 27° C (81° F) — which occur about 60 days per year — the probability of violence among inmates rose 18 percent.

Most of those days had an average maximum temperature of roughly 34° C (93° F). But the readings did not account for Mississippi's high humidity, Mukherjee says. Moreover, many of the United States' aging correctional facilities lack air conditioning and proper ventilation, so temperatures inside the facilities often exceed temperatures outside.

DANIEL BEREHULAK/GETTY IMAGES

Politicians often frame providing inmates with air conditioning as a matter of comfort, Mukherjee says. "When we're talking 120-plus degrees [Fahrenheit] inside a prison for many days a year, it becomes a moral issue."

Extrapolating from the Mississippi data, Mukherjee and Sanders estimate that heat generates an additional 4,000 violent acts in U.S. correctional facilities each year.

Violence also spikes alongside heat outside of prisons, studies suggest. For instance, during May to September from 2010 to 2017, violent crime in Los Angeles was about 5.5 percent higher on days with temperatures from about 24° to 32° C (75° to 89° F), compared with days below those temperatures, researchers report in the May *Journal of Public Economics*. Violent crime was almost 10 percent higher on even hotter days.

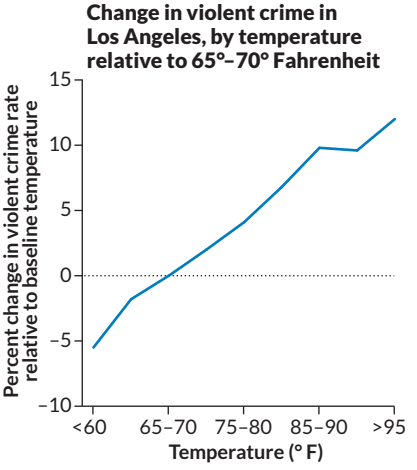
Heat and performance

The relationship between heat and human behavior extends well beyond violence. Consider students taking exams in hot school buildings.

Park, the UCLA economist, and colleagues looked at how high temperatures might affect student performance across the United States. They zoomed in on the PSAT, a standardized exam administered to high schoolers that provides a pathway to scholarships. The team evaluated 21 million scores from nearly 10 million students who took the exam at least twice from 1998 to 2012. That way, the team could compare how students performed relative to themselves. The researchers correlated exam scores with daily temperature data from around 3,000 weather stations across the country, as well as information about each student's access to air conditioning.

Student scores typically increase between the first time they take the exam and the second. But even when the team factored in that rise, students in schools without air conditioning scored lower than would have been expected, the researchers reported in 2020 in the *American Economic Journal: Economic Policy*. What's more, Black and Hispanic students were more likely to attend school and test in hotter buildings than their white counterparts. The resulting temperature differences could account for 3 to 7 percent of the PSAT's racial achievement gap, the team says.

Fueling crime A new study looking at crime data for Los Angeles from 2010 to 2017 shows that violent crime rises when temperatures exceed 65° to 70° Fahrenheit. SOURCE: K. HEILMANN, M.E. KHAN AND C.K. TANG/*JOURNAL OF PUBLIC ECONOMICS* 2021



Heat also affects performance in the workplace. Following Tewari's visit to the weaving factory in Surat, she began combing through nearly a decade's worth of data on worker output in India — where industrial air conditioning can be rare — at several weaving and garment sewing factories.

When temperatures climbed beyond 35° C (95° F), average daily production in weaving dropped by about 2 percent and garment sewing by as much as 8 percent, compared with days under 30° C (86° F), Tewari and colleagues estimate in the June *Journal of Political Economy*.

The researchers then looked at industries across India using national survey data. Productivity started dropping when average daily maximum temperatures rose above 20° C (68° F). The team's calculations suggest that average annual output will drop by 2.1 percent if average daily temperatures warm by 1 degree C (1.8 degrees F) over current conditions. Annual gross domestic product, or the value of goods and services produced in a single year, would drop by 3 percent.

The takeaway: Extreme heat hurts some countries' bottom line, Tewari says.

Beating the heat

The burdens of high heat are often borne by a country's poorest residents. For instance, in the United States, a legacy of discriminatory housing policies means poor people often live in the hottest parts of a city, a July 14 report from Climate Central, an independent climate science research and communications organization, notes. In these concentrated pockets of heat, called urban heat islands, midafternoon temperatures can rise by 8 to 11 degrees C (14 to 20 degrees F) above outlying areas. The effects tend to be worse in poor neighborhoods due to high density, limited green space and shade, and an abundance of paved roads and surfaces that absorb rather than reflect heat.

Given these inequities, the simplest choice is to provide everyone with air conditioning, says environmental economist Matthew Kahn of the University of Southern California in Los Angeles.

But cooling buildings is far from free. Cooling equipment accounted for about 17 percent of the world's total electricity demand in 2018, according to a 2020 United Nations report. Air conditioning use in emerging economies alone will lead to 33 times as much energy consumption by the year 2100, estimates suggest. At the moment, most of that energy comes from oil, coal and gas, so meeting that demand would contribute to global warming.

Even with soaring temperatures, Tewari says, air-conditioning entire factories remains more expensive than giving workers midday siestas or selectively air-conditioning rooms. And better cooling options exist, she says, including increasing tree cover in cities and using building materials that reflect sunlight. "Air conditioning is not sustainable."

But poor people deserve access to air conditioning, Kahn says. The long-term solution is to expedite efforts to green the energy grid, he says. "The poor have the least capacity to adapt. In a fair society, I hope we don't just shrug at that fact." ■

E. OTWELL

HUMANS & SOCIETY

More Denisovan ancestry tracked

Mysterious hominid group left a big legacy in the Philippines

The Ayta people (some shown) in the Philippines include the Ayta Magbukon, an ethnic community with the highest known level of Denisovan ancestry.

GERHARD JOREN/LIGHTROCKET VIA GETTY IMAGES

BY BRUCE BOWER

Denisovans are an elusive bunch, known mainly from ancient DNA samples as well as DNA that these ancient hominids shared with *Homo sapiens* through interbreeding. They left their biggest genetic imprint on people who now live in Southeast Asian islands, nearby Papua New Guinea and Australia. Genetic evidence now shows that a Philippine Negrito ethnic group has inherited the most Denisovan ancestry of all. Indigenous people known as the Ayta Magbukon get about 5 percent of their DNA from Denisovans, a new study finds.

This finding fits a scenario in which two or more Stone Age Denisovan populations independently reached various Southeast Asian islands, including the Philippines and a landmass that consisted of what's now Papua New Guinea, Australia and Tasmania. Exact arrival dates are unknown, but Denisovans may have made nearly 200,000-year-old stone tools found on the Indonesian island of Sulawesi (*SN: 2/6/16, p. 7*). *H. sapiens* groups that started arriving about 50,000 years ago or earlier then interbred with resident Denisovans.

Evolutionary geneticists Maximilian Larena and Mattias Jakobsson, both at Uppsala University in Sweden, and their team describe the new genetic evidence August 12 in *Current Biology*.

Even as the complexities of ancient interbreeding in Southeast Asia become clearer, Denisovans remain a mysterious crowd. "It's unclear how the different Denisovan groups on the mainland and on Southeast Asian islands were related and how genetically diverse they were," Jakobsson says.

Papua New Guinea highlanders — estimated in the new study to carry close to 4 percent Denisovan DNA — were previously thought to be the modern record holders for Denisovan ancestry. But the Ayta Magbukon display roughly 30 to 40 percent more Denisovan ancestry than Papua New Guinea highlanders and Indigenous Australians, Jakobsson says. That calculation accounts for recent mating of East Asians with Philippine Negrito groups, including the Ayta Magbukon, that diluted Denisovan inheritance to varying degrees.

Genetic analyses suggest that Ayta Magbukon people retain slightly more Denisovan ancestry than other Philippine Negrito groups due to having mated less often with East Asian migrants to the island around 2,281 years ago, the scientists say. The genetic analyses compared ancient DNA from Denisovans and Neandertals with that of 1,107 individuals from 118 ethnic groups in the Philippines, including 25 Negrito populations. Comparisons were then made with previously collected DNA from present-day Papua New Guinea highlanders and Indigenous Australians.

The new report underscores that "still today there are populations that have not been fully genetically described and that Denisovans were geographically widespread," says Cosimo Posth, a paleogeneticist at the University of Tübingen in Germany who was not involved with the research.

But it's too early to say whether Stone Age *Homo* fossils found on Southeast Asian islands come from Denisovans, populations that interbred with Denisovans or other *Homo* lineages, Posth says. Only DNA extracted from those fossils can resolve that issue, he says. Unfortunately, ancient DNA preserves poorly in fossils from tropical climates.

Only a handful of confirmed Denisovan fossils exist. Those consist of a few fragmentary specimens from a Siberian cave where Denisovans lived from about 300,000 to 50,000 years ago and a roughly 160,000-year-old partial jaw found on the Tibetan Plateau (*SN: 6/8/19, p. 6*).

Fossils from the Philippines classified as *H. luzonensis*, dating to 50,000 years ago or more (*SN: 5/11/19 & 5/25/19, p. 7*), might actually represent Denisovans. But a lack of consensus on what Denisovans looked like leaves the evolutionary identity of those fossils uncertain.

Larena and Jakobsson's findings "further increase my suspicions that Denisovan fossils are hiding in plain sight" among previously excavated discoveries on Southeast Asian islands, says population geneticist João Teixeira of the University of Adelaide in Australia, who did not participate in the new study.

Denisovans may have genetically encompassed *H. luzonensis* and two other fossil hominids found on different Southeast Asian islands, *H. floresiensis* on Flores and *H. erectus* on Java, Teixeira suspects. *H. floresiensis*, also known as the hobbits, survived from at least 100,000 years ago to around 60,000 years ago. *H. erectus* arrived on Java about 1.6 million years ago and died out between 117,000 and 108,000 years ago.

Geographic ancestry patterns suggest there were two genetically distinct Denisovan populations in mainland Asia, Teixeira and colleagues reported in the May *Nature Ecology & Evolution*. A southern population traveled through Indonesian islands and then to the landmass that became Papua New Guinea and Australia, while a northern population reached the Philippines and possibly nearby islands. ■

Ancient grave tied to nonbinary person

The medieval individual was first thought to be a woman warrior

BY BRUCE BOWER

For decades, archaeologists have thought that a nearly 1,000-year-old grave in southern Finland belonged to a powerful woman who might have been a warrior. But an individual who was biologically male may actually have been interred there, researchers now say. And there are signs that this person was perhaps a respected individual with a nonbinary gender identity.

Discovered in 1968 at a site known as Suontaka, the grave held a largely decomposed human skeleton. Only two leg-bone fragments were excavated. The grave also included jewelry traditionally associated with women and two swords typically linked to men. The grave's items date to the latter part of Finland's early medieval period, between 1050 and 1300.

Now, an analysis of DNA extracted from one of the bone fragments suggests that the individual buried in the grave was a male born with an extra X chromosome, say archaeologist Ulla Moilanen of the University of Turku in Finland and colleagues. Symptoms of this condition, known as Klinefelter syndrome, include low testosterone, reduced facial and body hair, enlarged breasts and learning and language-related problems. Effects of this rare condition on growth and appearance range from mild to noticeable.

That genetic evidence, combined with the unusual mix of male- and female-related items in the grave, suggests that the individual buried there was nonbinary, Moilanen's group says. Gender identity refers to a person's concept of self as male, female, a blend of both or neither. It often, but not always, coincides with a person's biological sex. Nonbinary individuals have gender identities that are not strictly male or female.

Even in early medieval societies that emphasized masculinity and warfare, some individuals who didn't fit community expectations about how males and females should behave may have been interred in ways that commemorated their gender identities, the scientists conclude July 15 in the *European Journal of Archaeology*.

"This burial [at Suontaka] has an unusual and strong mixture of feminine and masculine symbolism, and this might indicate that the individual was not strictly associated with either [a male or female] gender," Moilanen says. The nature of that gender identity is a mystery. Further complicating matters, early medieval gender identities may have been shaped by poorly understood social and community forces, Moilanen says.

People today vary greatly in their responses to Klinefelter syndrome, says psychologist Chris Kraft, codirector of clinical services at the Johns Hopkins School of Medicine's Sex and Gender Clinic. Some develop nonmasculine gender identities, while others express confusion about their gender. But many people with Klinefelter syndrome adopt a masculine gender identity that matches their assigned sex at birth. Reasons for these differences are poorly understood.

"It's hard to know how someone in early medieval Finland would have reacted to having Klinefelter syndrome," Kraft says.

Moilanen's group also studied 23 animal hairs and three bird feathers retrieved from soil that had been excavated with the leg-bone fragments. Based on that evidence, the Suontaka individual was probably dressed in traditionally feminine clothes made of sheep's wool and furs from animals that included rabbits or hares, the researchers say. Bird feathers came from a pillow or bedding, which along with brooches placed in the grave were associated with females, the researchers suspect.

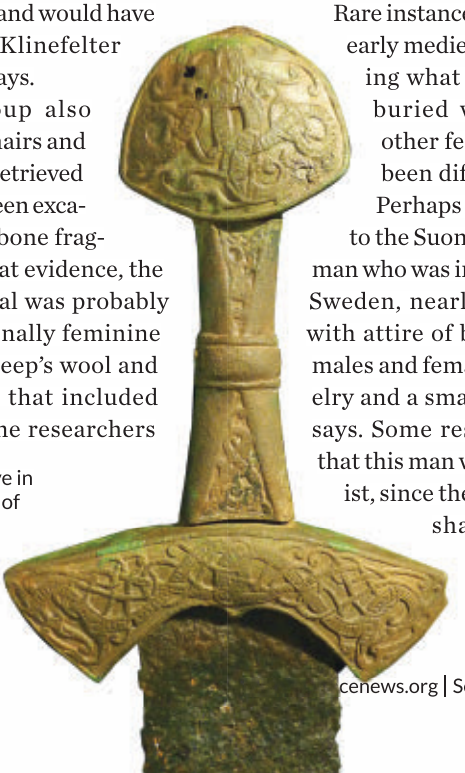
But in a move tied to early medieval ideas about masculinity, a hiltless sword was apparently placed on top of the person's body at the time of burial. A fancier sword with a carved bronze hilt was probably placed near the body later, perhaps to show continuing respect for the Suontaka individual, the investigators say.

The study plausibly suggests that the grave held a respected person who had neither a typical male nor female sense of their social gender identity, says archaeologist Marianne Moen of the University of Oslo.

But even if a woman had been placed in the grave with swords and jewelry, the evidence would indicate that some individuals with nontraditional identities — such as a woman who viewed herself as biologically female but socially male according to conventions about warriors at the time — were respected in early medieval Finland and perhaps elsewhere in Scandinavia, Moen adds.

Other researchers have controversially proposed that a roughly 1,000-year-old grave in Sweden held the remains either of a female Viking warrior or a woman buried with the apparel and weapons of a warrior (*SN: 10/14/17, p. 6*).

Rare instances in Scandinavia of early medieval graves containing what appear to be men buried with jewelry and other feminine items have been difficult to interpret. Perhaps the closest parallel to the Suontaka individual is a man who was interred at Vivallen, Sweden, nearly 1,000 years ago with attire of both high-ranking males and females, as well as jewelry and a small knife, Moilanen says. Some researchers suspect that this man was a ritual specialist, since there is evidence that shamans dressed in women's clothes in early medieval Scandinavia. ■



An early medieval grave in Finland included a mix of traditionally female- and male-related items, including this sword with a bronze hilt.

FINNISH HERITAGE AGENCY (CC BY 4.0)

The Seed of an Idea

At a greenhouse in Mirabel, near Montreal, the agriculture company Hydroserre is launching a pilot project to scale up plasma agriculture. Because the facility gets most of its electricity through hydropower, the project will run on renewable energy.

LES SERRES LEFORT

Can plasma, the fourth state of matter, boost plant growth?

By Stephen Ornes

Physicist Stephan Reuter of Polytechnique Montréal spends most days using his expertise in energy and matter to improve medical technologies. Recently though, he stood in a sea of green to consider how a shower of charged particles might affect lettuce.

He had been invited to one of the largest commercial greenhouses in Quebec to help the growers rethink the energy of agriculture. Inside the building, encased by glass walls and covering more ground than four soccer fields, thousands upon thousands of lettuce plants floated on polystyrene mats in a hydroponic, or no-soil, growing system. The crop was nearly ready to be picked, packaged and shipped. Reuter's task was to use physics to help the company, Hydroserre Inc. in Mirabel, reduce its carbon footprint.

To that end, the company is interested in finding new ways to fight pathogens and to deliver fertilizer to the growing plants. Many fertilizers contain ammonia, which is produced from nitrogen (necessary for plant growth) and hydrogen using a chemical reaction called the Haber-Bosch process. This process revolutionized agriculture in the early 20th century by making mass production of fertilizer possible. However, the process yields hundreds of millions of metric tons of carbon dioxide each year.

"Ideally, we want a fertilizer that's renewable," Reuter says. And to make it truly green, it should be created at the farm, making transport, another carbon emitter, unnecessary. Reuter and a growing number of chemists, physicists and engineers think they can see how to make that happen. These researchers are working toward future farms that are truly sustainable, where the energy from renewable sources like wind or solar is harnessed to make an efficient fertilizer on-site. They hope to realize this vision by exploiting plasma.

Plasma everywhere

Reuter might seem an unlikely consultant for an agricultural challenge. After all, his expertise is in the physics of plasma, one of the four fundamental states of matter, along with solids, liquids and gases.

Plasma is remarkably common. In fact, most matter seen in the known universe — more than 99.9 percent, according to astrophysicists — is in a plasma state. Lightning produces plasma. So do those inexpensive novelty lamps in museum gift shops. Switch on the power, and an electrode at the sphere's center produces a high voltage that interacts with the gas sealed inside the glass to form tendrils of colored plasma that radiate outward. Touch the glass, and the plasma tendrils seem to reach toward your fingers.

The sun is a ball of plasma and gas. The solar wind is a stream of plasma that peels off the sun (*SN: 12/21/19 & 1/4/20, p. 6*). When that wind collides with the protective, plasma-rich magnetic cushion that envelopes Earth, the interactions produce rivers of light seen in the aurora borealis and aurora australis.

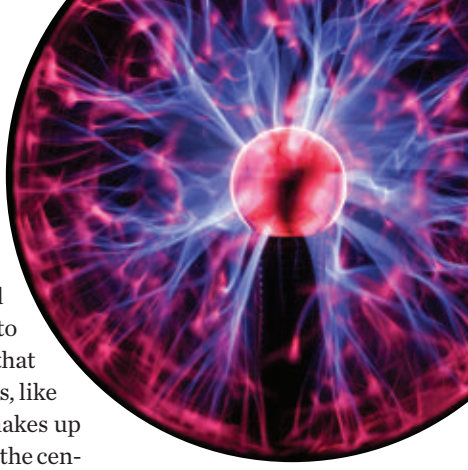
Plasma is also a workhorse of modern technology. Engineers use it to etch the millions of tiny transistors found on the chips in today's computers, cars and musical birthday cards. The pixels in plasma televisions contain gas that forms a plasma, sealed inside tiny cells sandwiched between two glass plates, and neon signs and fluorescent lights glow because of plasma. Some former astronauts even predict that plasma engines will someday propel us to Mars.

But what exactly is plasma? It's a soup of electrons with their negative charges, positive ions and neutral atoms that also produces electromagnetic fields and ultraviolet and infrared radiation. Plasma comes about when gas gets super energized — by heat or an electric current, for example — and electrons are freed from atoms.

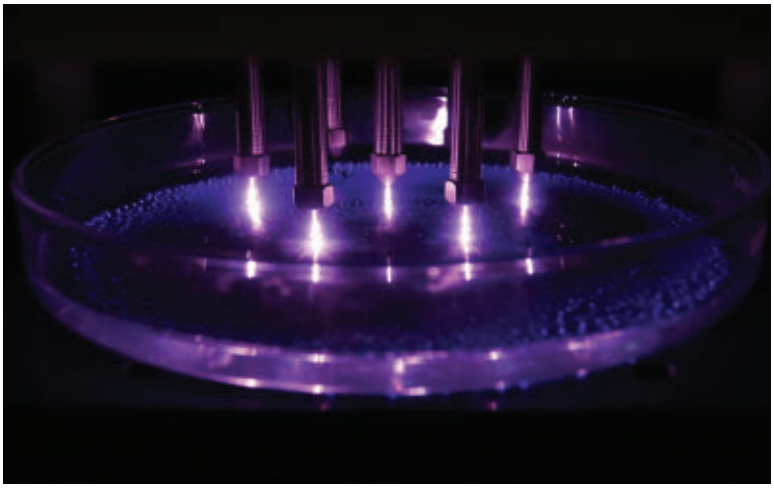
Plasmas occur naturally or can be human-made. When produced by high temperatures, such as in the sun, it's called "hot plasma," while the plasma created in a plasma ball and other room-temperature, low-pressure environments is called "cold plasma." Plasma balls make it easy to see: They're filled with a gaseous mixture that includes one of the very stable, noble gases, like argon, xenon, neon or krypton. Plasma makes up those glowing tendrils that reach out from the center. The high-frequency current excites electrons that then separate from the atoms of gas. Many agricultural experiments include a mix of noble gases and air to yield ions of nitrogen and oxygen.

Scientists have long been interested in plasma's biological implications. In the late 19th century, the Finnish physicist Karl Selim Lemström observed that the width of growth rings in fir trees near the Arctic Circle followed the cycle of the aurora borealis, widening when the northern lights were strongest. He hypothesized that the light show somehow encouraged plant growth. To artificially emulate the northern lights, he placed a metal wire net over growing plants and ran a current through it. Under the right conditions, he reported, the treatment produced larger vegetable yields.

For decades, scientists have known that exposure to plasma can safely kill pathogenic bacteria, fungi and viruses. Small studies in animals also suggest that plasma can prompt the growth of blood vessels in skin. In his research, Reuter studies ways to harness these properties to inhibit new infections in wounds and expedite healing or treat other skin conditions. But more recently, he and other physicists have been working on ways to use the power of plasma to improve food production.



Remember those mesmerizing plasma balls? The tiny lightning inside is plasma, which forms when high voltage at the center of the ball causes electrons to separate from atoms in the surrounding gas, yielding a mix of charged and neutral particles.



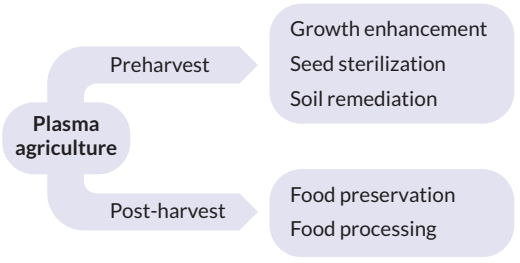
For small-scale tests, physicist Stephan Reuter and colleagues use a setup like the one below. An electric discharge creates plasma, which adds reactive species of nitrogen and oxygen to the water in the dish. This plasma-treated water might be able to fertilize growing plants.

FROM TOP: CHOCOLATEOAK/WIKIMEDIA COMMONS (CC BY-SA 3.0); SEAN WATSON, BERNARD NISOL, MIKE WERTHEIMER, S. REUTER

Two paths

Researchers are investigating a range of potential agricultural benefits from plasma. Some studies suggest plasma boosts plant growth and yield. Others show that plasma also might have a role in preserving food by eliminating pathogenic bacteria and fungi from plant surfaces. SOURCE: P. ATTRI *ET AL*/*PROCESSES* 2020

How plasma may help plants



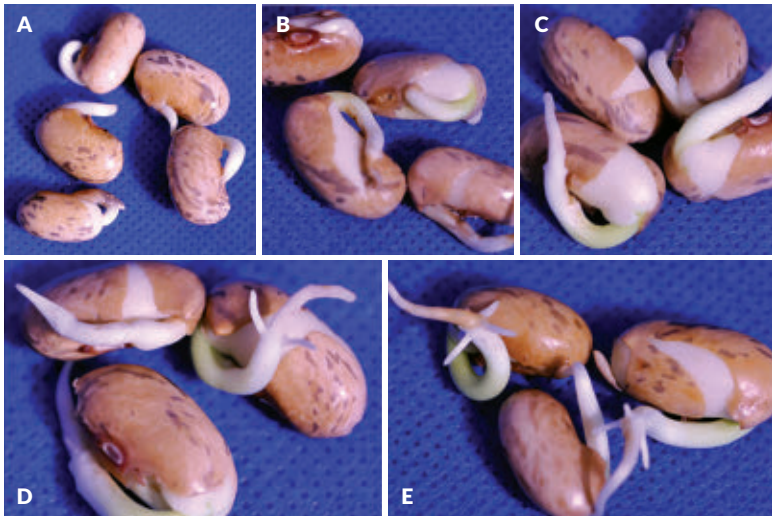
Experiments conducted in the last decade or so have tested a mix of ways to apply plasma to seeds, seedlings, crops and fields. These include plasma generated using noble gases, as well as plasma generated from air. In some cases, plasma is directly applied through plasma "jets" that stream over the seeds or plants. Another approach uses plasma-treated water that can do double duty: irrigation and fertilization. Some studies have reported a range of benefits, from helping plants grow faster and bigger to resisting pests.

"Even in this very, very early stage of research that we're at with plasma, which has really only come into its own in the last 10 to 15 years, we're seeing very promising data," says plant pathologist Brendan Niemira at the Food Safety and Intervention Technologies Research unit at the U.S. Department of Agriculture's Eastern Regional Research Center in Wyndmoor, Pa. He's a fan of the approach: On Zoom, Niemira's avatar shows an almond basking in an eerie, purple plasma glow.

The challenge now, he says, is to figure out whether plasma can deliver at the level of hectares of crops. "Can we make it work in a field environment [to] deliver an advantage that can be integrated into grow systems in the future?"

Roots emerge

Biochemist Alexander Volkov and colleagues exposed bush bean seeds to plasma jets, then immersed the seeds in water for a day. Two days later, plasma-treated seeds showed larger radicles, or starter roots. The least growth occurred in untreated seeds (A). The others received plasma for 30 seconds (B), one minute (C), five minutes (D) and 15 minutes (E). Using a plasma globe, he got less striking results.



Nested within that challenge are many others, including finding a way to deliver plasma to plants on a large scale, confirming benefits reported in lab studies and showing that plasma is better than current methods. And, finally, figuring out what the charged soup of plasma is actually doing to plants.

Recent advances became possible, Niemira says, largely because in the 1990s and early 2000s, scientists developed efficient and cost-effective ways to generate cold plasmas by streaming high-energy electrons into a gas. Those electrons would collide with gas molecules, knocking off electrons and producing charged particles. Since then, he says, there's been something of a rush to test plasma on plants at all stages of growth and with a range of strategies.

Surface changes

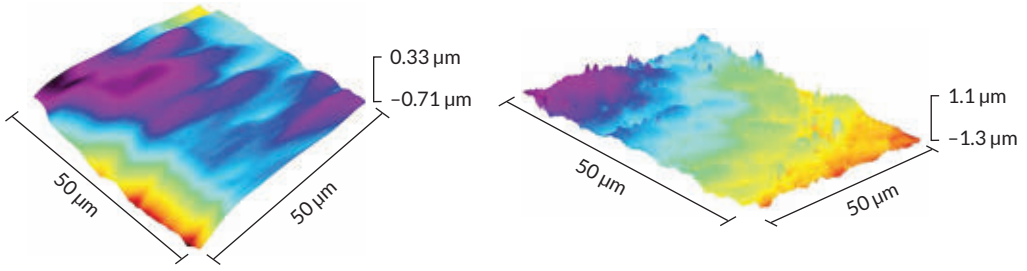
One of the most appealing uses of plasma, according to Reuter, is as a fertilizer alternative to ammonia. His plan for the Mirabel greenhouse project, which he helped launch in spring 2021 with scientists from the Quebec-based nonprofit IRDA, or Research and Development Institute for the Agri-Environment, goes something like this: The plasma is generated by sending an electric current through a gas that, ideally, is just air. That process creates a mix of charged and neutral particles, including electrons and ions, that can produce reactive species of nitrogen and oxygen. In tabletop experiments and then in the greenhouse, Reuter and his colleagues will enrich water with plasma, then study whether it can reduce pathogens and affect the growing plants.

Reactive species, as the name implies, are ready to react with atoms and molecules, including in living things, and are biologically available to plants. When the plasma is added to the water, those reactive species dissolve. The resulting plasma-infused water, with its biologically available nitrogen, will then be used to irrigate the plants. It will do the same job as ammonia: Nitrogen, which plants require for growth, is delivered as ions, excited molecules and compounds in the water. While heavy doses of reactive species can harm plant cells or DNA, the amount in plasma-treated water has been shown to be safe for the plant, Reuter says.

Experiments led by biochemist Alexander Volkov of Oakwood University in Huntsville, Ala., offer another example of the kind of research going on in plasma agriculture. Volkov studies the ways in which plants and electromagnetism

FROM TOP: C. CHANG; A.G. VOLKOV *ET AL*/*PLASMA MEDICINE* 2020

Changes in seed surface with plasma treatment



Rocky road
The surface of an untreated bush bean seed, as seen in an atomic force microscope image, is relatively smooth (left). After a one-minute plasma treatment (right), the surface becomes rough and corrugated, which may enable water to better penetrate the seed's exterior.

interact. For example, he's shown how an electric stimulus can trigger the closing mechanism on a Venus flytrap.

Recently, Volkov set out to study how plasma would affect 20 seeds of dragon's-tongue, a cultivar of the bush bean *Phaseolus vulgaris*. The experiment was low-tech. He and colleagues balanced the seeds on a plasma ball for one minute each, then incubated the seeds in water for seven hours. Two days later, the scientists found that in plasma-treated seeds, the radicle — the little protrusion of root that makes a seed a seedling — measured 2.7 centimeters, compared with 1.8 centimeters in untreated seeds, a gain of 50 percent. The team reported the results in *Functional Plant Biology* in February 2021.

Less than a centimeter of extra growth may seem modest, but Volkov was encouraged. The benefit couldn't have come from the reactive species of nitrogen and oxygen because they can't exit the glass sphere, but somehow, the treated seeds seemed to take up more water to grow faster.

To investigate that idea, he and colleagues studied the seeds using an atomic force microscope and magnetic resonance imaging, which reveals how tissues take up water. At the micrometer-level view of the atomic force microscope, Volkov saw that exposure had roughed up the surface of the seeds. The images looked like carved mountain ranges. Those ridges gave the water more surface area to glom on to, and more openings through which to soak the inside of the seeds, he hypothesized. MRI images of treated beans showed larger swaths of white — indicating more water inside — than untreated beans.

"When we use the plasma balls or lamps, the water can penetrate easily through the pores and accelerate germination," he says.

Growing evidence

Physicist Nevena Puač of the Institute of Physics Belgrade in Serbia has performed dozens of studies testing plasma on plants and has been working in the field for decades. She says most studies — successful or not — have tested two ideas: plasma as a disinfectant or as a growth instigator.

On the disinfecting front, plasma jet treatments of less than a minute on foods including apples, cherry tomatoes and lettuce can reduce disease-causing bacteria, such as *Escherichia coli*, *Salmonella* and *Listeria*. Some studies have looked at higher exposure times as well: In a 2008 study, five minutes of plasma treatment inactivated 90 percent of pathogenic *Aspergillus parasiticus* fungi on hazelnuts, peanuts and pistachios.

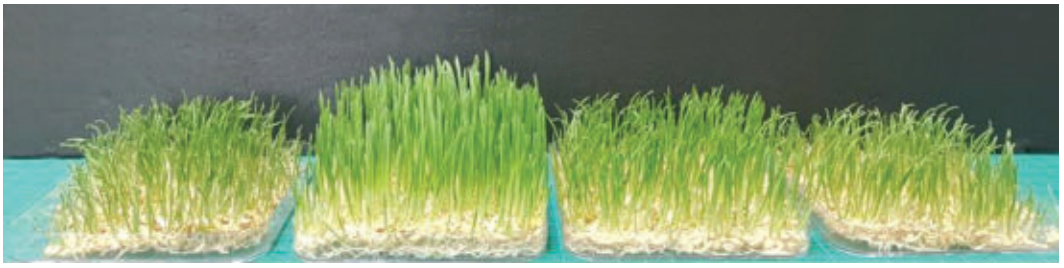
This is the research branch that Niemira works on as well. In May 2019 in *LWT–Food Science and Technology*, he and colleagues showed that plasma treatment combined with an existing sanitizer killed 99.9 percent of *Listeria* on apples in under four minutes. Working alone, the sanitizer achieved comparable results after an hour. The combination works much better than either one could possibly work alone, he says.

Investigations on seed germination and plant growth are similarly promising. Researchers at the Chinese Academy of Sciences in Nanjing exposed soybean seeds to plasma. Seven days after exposure, the roots were up to 27 percent heavier than roots from untreated seeds, the team reported in 2014. The same year, researchers in Romania reported similar gains for radish roots and sprouts.

At last year's Gaseous Electronics Conference, hosted online by the American Physical Society, researchers from Japan presented results from a study of young seedlings treated directly with plasma and with plasma-treated water in a rice paddy in the Aichi prefecture. Plants treated directly with plasma early in the growth process had up to a 15 percent higher yield than untreated plants. But treating plants late in the growth process lowered the yield. Timing matters, Puač says. So does the application method: In some cases in the experiments in Japan, plasma-treated water actually lowered the yield.

"To my knowledge this was the first study where plants were treated directly," rather than as seeds

A.G. VOLKOV *ET AL*/*PLASMA MEDICINE* 2020



Nine days after sowing barley, researchers in South Korea found that untreated sprouts (far left) did not grow as well as sprouts that received one six-minute plasma exposure (second from left). Sprouts treated for six minutes on two consecutive days (second from right) and sprouts treated three days in a row (far right) didn't grow particularly well, suggesting that too much plasma may slow growth.

J.-S. SONG ET AL/J. OF PHYSICS D: APPLIED PHYSICS 2020

or after harvest for disinfection, says engineer Katharina Stapelmann of North Carolina State University in Raleigh, who organized the session.

Studies have connected plasma treatment to a range of benefits, Puač says, from growth rate to yield. But other studies suggest that plasma won't ever be a one-size-fits-all technology.

Researchers in South Korea reported in the *Journal of Physics D: Applied Physics* in 2020, for example, that while a six-minute plasma exposure boosted germination rates of barley sprouts, an 18-minute exposure, over three days, produced no benefit in growth and lowered total plant weight. Experimental results published in 2000 looked at the effects of direct plasma jets on peas, corn and radishes and found detrimental effects that varied by the gas used in the plasma. The seeds were exposed for two to 20 minutes, and seeds with prolonged exposure were slower to germinate than untreated seeds.

What the research shows, Reuter says, is that before plasma becomes a staple on farms around the world, scientists need to better understand the myriad ways that the fourth state of matter could affect plants.

For instance, successful outcomes for plants might be due in part to the UV radiation produced by plasma; UV radiation has long been used as a disinfectant. The reactive nitrogen and oxygen species, which can be helpful or harmful to living cells depending on how they're used, probably help as nutrients and disinfectants, as well. Plasma also produces electric and magnetic fields and infrared and visible light. Their impact on plants also hasn't been fully explored. Even though researchers know what's in the plasma, and can see how the plants respond, they don't have the details mapped out, Volkov says.

Gardens big and small

Projects are under way around the world to test plasma on large scales and in different settings. Dutch scientists working in Uganda have developed portable "reactors" that use plasma to generate fertilizers from the air. They hope this invention can meet the need for fertilizers in places where farmers often can't get ammonia. Early in 2022, Reuter hopes to report his first results from desktop experiments. The hydroponic growing system at Hydroserre will provide him with the opportunity to refine his method.

With any luck, he says, the project will show a way for future farms to replace ammonia and reduce carbon emissions.

While researchers and growers await those results, citizen scientists, amateur physicists and experimental gardeners have been known to make space in the shed for a plasma ball next to their rakes and shovels, to run their own experiments at home.

Volkov has jumped in. When the pandemic shut down his lab last year, he took his work — and his plasma balls — home. He bathed the vegetable seeds for his garden for a minute in the lamp's rich, purplish glow, and then planted them.

"It was cucumber, tomatoes, eggplants, cabbage," he says. A backyard test run isn't proof of anything, Volkov readily acknowledges, and any gardener can attest that a finicky combination of variables can make or break a garden.

But he did see an astounding harvest last fall. By late October, he was still picking big, ripe tomatoes from the vines grown from plasma-treated seeds, at a time when the plants from untreated seeds have often withered. The cucumbers were bigger and juicier. The cabbages, planted in a friend's nursery, were heavier and more delicious, he says. "I got a fantastic amount of everything." ■

Explore more

- Pankaj Attri *et al*. "Plasma agriculture from laboratory to farm: a review." *Processes*. August 17, 2020.
- Pietro Ranieri *et al*. "Plasma agriculture: review from the perspective of the plant and its ecosystem." *Plasma Processes and Polymers*. January 2021.

Stephen Ornes is a freelance science writer based in Nashville.

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Pangilinan | Angad Singh Pannu | Kinnoree Rabeya Pasha | Aasha Patel | Avi Patel | Arian Phillips | Samhita Pokkunuri | Maddie Nicole Queen | Nipun Rajan | Aishwarya Ramasamy | Achyut Reddy | Elizabeth Reilly | Maddie Rejab | Rowan Rice | Ella Roberts | Mason Roberts | Nick Rodino | Sam Rohrbach | Srija Roy | Diego Alejandro Ruiz | Alexis Grace Rust | Maria Vittoria Elena Rutherford | Sahishnu Saha | Shreemoyee Saha | Makana Salim-Uesi | Arjun Samavedam | Akilan Sankaran | Moitri Santra | Nivedha Sathishkumar | Josephine E. Schultz | Mikolas Alexander Schwickert | Chloe Sebek | Ansh Sehgal | Aastha Shah | Anand Shah | Ananya Shah | Praneel Anil Shah | Rhea Denish Shah | Sahil Rajiv Shah | Sana Revati Shah | Tariq Shahid | Nanar Shahinian | Maryam Shahkhan | Lillian Shamamian | Zain Mehbob Shariff | Camellia Sharma | Dhruva Sharma | Addison Josephine Shell | Kevin Shen | Cloris Shi | Trevyn K. Shields | Prisha Shroff | Aryaman Dixit Shukla | Niharika Shukla | Joseph Simak | Raunak Singh | Varun Singh | Coolsjes B. Singhvi | Ram Sivaraman | Miguel Worren Smiley | Sophia Smith | Gaia Sperone | Shreya Srinath | Uma Sthanu | Elias Adamu Stienecker | Henry Stievater | Raeleigh Elaine Stolle | Madelyn Belle Streyle | Clara Strom | Sierra Anne Sun | Ilesh Sundar | Sowmya Sundar | Sriram Sureshkumar | Maya Sushkin | Zaaina Sabeel Syeda | Cora Tallman | Aadrit Talukdar | Maya Tang | Anaiah Skye Tareyama | Lucy Angel Teng | Suhaansai Thatikonda | Hima Thota | Aarushi Tiwari | Lara Tseng | Emily Tsiros | Becky Turner | Radhika Ambika Unnikrishnan | Kai Unwin-Wisnosky | Arvid Charles Larsson Vaidyanathan | Christopher Valeri | Ekaterini Kalliope Vallas | Hailey Miya Van | Paloma Vargas | Leya Varricatt | Aditi Venkataraman | Elisa Noel Virkler | Anna Virsik | Oliva Wagner | Charlotte Annie White | Harper Wilson | Zoe H. 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ROADS TO THE GOOD LIFE

Happiness and meaning are not the only ways to get there

By Sujata Gupta

In December, my husband, our 5-year-old daughter and I tested positive for COVID-19. Life, already off-kilter, lurched. Smell, taste, breath — were they normal? The air smelled only of cold; everything tasted vaguely of cardboard.

The state mailed us a pulse oximeter to read oxygen levels from our fingers. The device beeped when those levels dipped too low — a seemingly objective measure during a subjective time. We used the device with abandon, only my husband regularly triggering the alarm. He went to bed, where he stayed for days, or maybe it was weeks. Time distilled into moments: remote school, meals, Christmas, pulse-ox, beep.

We exited quarantine on January 1, the day of fresh starts. Except my once energetic 8-year-old son, who somehow never tested positive, now loafed in front of the heater for hours. My husband, his breathing still abnormal and his fatigue lingering, raged. Ever the extrovert, I absorbed their emotions as my own. My risk calculation shifted, as despair overshadowed the fear of disease. The sickness we had hid from for so long had found us anyway. Were we now immune? Should we proceed just as before?

Prior to the sickness, I'd been researching pandemic fatigue, a term used to describe the boredom that can arise during a protracted crisis like the one we're in now (*SN Online: 2/15/21*). "People prefer action to inaction," social psychologist Erin Westgate of the University of Florida in Gainesville told me. For some, that compulsion toward the experiential runs deep, she and colleagues reported in 2014 in *Science*. When the researchers gave college students a choice between sitting idly in a quiet room or pushing a button to receive an electric shock, a startling number went for the shock.

I have been seeking, and pushing, that button all my life. I've taught English in Japan, worked as a national park ranger and, following an unfortunate series of events, sold pineapples along a tourist highway in Hawaii in exchange for a tent over my head. Westgate's recent work suggests that button pushing sorts often flourish in rich and aesthetic environs. I took heed. Against the dreary backdrop of being homebound in a global health crisis, I signed up for private pottery lessons, drawn viscerally to the idea of creating something from mud.

A third path

Psychologists who study well-being or human flourishing have long posited that the "good life" can be pursued via two paths: happiness or meaning.

"So far, psychologists worked with this dichotomy — a dichotomous model of well-being about life," says psychologist Shigehiro Oishi. He describes the happy life as one of joy, comfort and security, and the meaningful life as one of significance, purpose and coherence, or order. Happiness and meaning can run parallel or intersect, Oishi says. Both concepts are largely rooted in personal and societal stability.

What happens, though, when the ground beneath one's feet buckles? Or what if one was never quite stable to begin with? What hope is there for finding a path to the good life?

For the last six years, Oishi and his team at the University of Virginia in Charlottesville have been hammering out their response: a third path to the good life coined "psychological richness." Their research suggests that the ingredients of a rich life come not from stability in life circumstances or in

CLOCKWISE FROM TOP LEFT: THE PUBLIC DOMAIN REVIEW/RAWPIXEL (CC0 1.0); TONY DUFFY/GETTY IMAGES PLUS; INTERNET ARCHIVE BOOK IMAGES/FLICKR; MICHAEL KUBY/EYEEM/GETTY IMAGES PLUS; _TA'_/GETTY IMAGES PLUS; AVNPHOTOLAB/GETTY IMAGES PLUS; KRISTEN CHADWICK/USDA FOREST SERVICE; ADAPTED BY T. TIBBITTS

temperament. Rather, the path to a rich life arises from novelty seeking, curiosity and moments that shift one's view of the world. Rich experiences are neither inherently good nor bad; they may be intentional or accidental, joyous or traumatic.

The pandemic, in this light, embodies a novel, perspective-changing, psychologically rich moment. It has shattered our routines and livelihoods, robbed us of our loved ones and plunged many into despondency. But it has also steered some of us to the mud. We have captured wild yeast for sourdough breads, planted gardens and knitted sweaters; we have stared at a wet mound of clay on a wheel and wondered, what next?

This third good life path can provide a balm in difficult times, says Westgate, Oishi's former graduate student. "Psychological richness opens up an avenue to the good life for people for whom circumstances may seem to have cut off paths to happiness and meaning."

Aristotle's legacy

If you want to understand psychological richness, read about Oliver Sacks, advises Lorraine Besser, a philosopher at Middlebury College in Vermont and Oishi's collaborator. She is thinking of an adieu to the world that Sacks wrote in the *New York Times* in February 2015, shortly after learning he was dying of cancer.

The renowned author and neurologist drew his inspiration from philosopher David Hume, who had written a similar adieu in 1776. Hume described himself as possessing a "mild disposition," Sacks wrote. "Here I depart from Hume. While I have enjoyed loving relationships and friendships and have no real enmities, I cannot say (nor would anyone who knows me say) that I am a man of mild dispositions. On the contrary, I am a man of vehement disposition, with violent enthusiasms, and extreme immoderation in all my passions."

Ancient discussions of the good life do not appear to consider Sacks' model. Instead, fourth century B.C. Greek philosopher Aristotle looms large in this esoteric space. He opens his treatise, *Nicomachean Ethics*, by reviewing the various contenders for the good life — pleasure, honor, wealth, health or eminence — eventually arriving at "eudaimonia," essentially human flourishing. The eudaimonic person, Aristotle wrote, "is active in accordance with complete virtue ... not for some unspecified period but throughout a complete life."

Of those contenders, only pleasure and eudaimonia, the "feeling good and being good" sides of that dichotomous coin, have withstood the long test of time, Westgate says.

Aristotle, an unequivocal be-gooder, considered the good life an objective ideal. So does Susan Wolf. "Some philosophers, including me, say a good life isn't just good from the inside," says Wolf, a moral philosopher at the University of North Carolina at Chapel Hill. Instead, a life must also be good from the outside, or from the perspective of one's community.

But the emergence of positive psychology several decades ago shifted attention from the collective to the individual. Now, Westgate says, "whether or not it's a good life is really in the eyes of the person who led that life."

Sacks' vision

Sacks' early years were marked by heartache, according to a documentary of his life that aired on PBS in April. Born in 1933 in London, Sacks was sent to a boarding school during World War II, where the other children bullied him and his older brother, Michael. In that environment, Michael became psychotic and was diagnosed with schizophrenia. The family was devastated. Then, when Sacks was 18, his parents discovered he was gay. His mother, with whom he shared a close bond, called him an "abomination."

"Her words haunted me for much of my life and played a major part in inhibiting and injecting with guilt my sense of my own sexuality," Sacks said.

Sacks fled to San Francisco on his 27th birthday and interned at a medical center. Off hours, Sacks muscled up, eventually lifting a 600-pound bar from a squat to set a California weight lifting record. He also got hooked on amphetamines, thereby sleeping and eating little, while roaring high and fast on his motorcycle. Sacks, the documentary suggests, was running from his own overwhelming loneliness.

"That kind of sensitivity is dangerous. It requires a degree of appetite, vitality, a responsiveness, which means that you could go off the rails at any moment," the documentary's director Ric Burns tells me. "The question becomes: What is the relationship you're going to have to your own appetites?"

On New Year's Eve 1965, Sacks stared into the abyss of his drug addiction. "I looked at my emaciated face and I said, 'Oliver, you will not see another New Year's Day unless you get help,'" Sacks recalled in the documentary.

Six months later, Sacks began seeing migraine patients at a clinic in New York City. During what would turn out to be his last amphetamine high, Sacks read a 500-page book on the theory behind migraines, with detailed case studies, written by physician Edward Liveing in the 1870s. "I read through the whole book in a state of ecstasy," Sacks said. "With the amphetamines in me, sometimes it seemed to me that the neurological heavens opened and that the migraine was shining like a constellation in the sky."

After that vision, Sacks began writing detailed accounts of his patients' experiences, a process that merged his intellectual and creative passions. Embarking on this psychologically rich literary journey would sustain Sacks throughout his life.

Writer Sujata Gupta has been taking pottery lessons for a new aesthetic experience.

SARAH CAMILLE WILSON

Beyond the dichotomy

In fall 2015, Westgate was a graduate student in Oishi's lab. With lab members squeezed into his tiny office for a meeting, Westgate recalls, Oishi walked in and asked: "Is happiness and meaning all there is?"

That meeting and the ensuing discussion marked a turning point for Oishi. He had, like most well-being researchers, been publishing papers that worked within the happiness-meaning dichotomy. Yet he had grown disillusioned by those paths' shortcomings. For instance, why, as research has consistently shown, did happiness hinge on having considerably more money than is strictly necessary? And why did homogenous friend circles give people more happiness and satisfaction in their lives than diverse circles?

After that meeting, Westgate recalls, the team homed in on one question: If you lack money and stability, can you still have a good life?

The team looked for a third path, one filled with rich, aesthetic experiences. First the group developed a scale to measure psychological richness. The scale mirrored those used to measure happiness and meaning. Respondents rank 17 statements from 1 for strongly disagree to 7 for strongly agree. Statements include: "On my deathbed, I am likely to say 'I had an interesting life'" and "My life would make a good novel or movie." The results, appearing June 2019 in the *Journal of Research in Personality*, showed that scoring high in a personality trait known as "openness to experience" predicted high richness scores but not necessarily happiness or meaning.

Later research revealed that people high in richness are also emotionally intense, prone to experiencing strong positive and negative emotions. People high in meaning and happiness, meanwhile, experience positive emotions more strongly than negative emotions.

To see how the three paths — happiness, meaning and richness — play out across life, the team evaluated obituaries appearing in the summer of 2016 in the *New York Times*, the Singapore-based *Strait Times* and a local Charlottesville newspaper. Research assistants were tasked with describing obituaries using just 12 adjectives, such as "secure" and "comfortable" for happiness, "fulfilling" and "sense of purpose" for meaning and "dramatic" and "eventful" for psychological richness. Obituaries that scored high in psychological richness also scored high in meaning, but not happiness.

The research, appearing online August 12 in *Psychological Science*, found that major life events, such as divorce, career changes and personal tragedies, linked to higher richness, but not meaning or happiness.

Still, Oishi and his team needed to answer the obvious: Could such an intense, unpredictable and frequently unhappy life really be a path people desired? The researchers asked more than 3,100 people across nine countries — the United States, Japan, South Korea, India, Singapore, Norway, Portugal, Germany and Angola — to score 15 terms similar to those used in the obituary studies on how closely the terms described their ideal lives on a scale from 1 (not at all) to 7 (very much). A nine-term subset of the 15 terms showed that for most countries, people's ideal life was most characterized by happiness and least characterized by richness, the researchers reported June 2020 in *Affective Science*. Nonetheless, average richness ratings ranged from 3.7 to 5.62, suggesting that people desired some richness in their lives.

When neurologist Oliver Sacks was in his late 20s, as shown here in 1961 in Greenwich Village, N.Y., he was living a wild, yet solitary life.

THE OLIVER SACKS FOUNDATION

Given that ambiguity, the researchers then forced participants to choose which life they desired most: happy, meaningful or rich. Fifty to 70 percent of respondents chose terms reflecting happiness and 14 to 36 percent chose meaning as their ideal life. Percentages varied by country, but a sizable minority — 7 to 17 percent — chose a psychologically rich life.

When the researchers asked 1,611 people in the United States and 680 people in South Korea if their lives would have been happier, more meaningful or psychologically richer if they could undo their greatest regret in life, roughly 28 percent of Americans and 35 percent of South Koreans reported that their lives would have been psychologically richer with a do-over.

"That suggests to me that maybe implicit in a lot of people's desires is psychological richness: 'I wish I had taken on that opportunity,'" Oishi says.

Puzzle assembly not necessary

Not everyone, however, accepts the shift from a good life dichotomy to a good life triad. "There's a bundle of conversations to be had about these conceptually tethered concepts," says developmental psychologist Anthony Burrow of Cornell University. "Because for some people, isn't it possible that a psychologically rich life is a life of purpose, is a life of meaning?"

The critique is valid. As the obituary studies showed, richness and its link to major, often negative, life events appears distinct from happiness. But those negative life experiences can foster meaning. A large body of literature shows, for instance, that natural disasters and other traumatic events can trigger a phenomenon known as post-traumatic growth: a transformation that gives people a newfound appreciation for life and a desire to help others (*SN Online: 4/3/19*).

An experiment from several years ago illustrates how this

transformation plays out. Before richness was in consideration, behavioral economist Kathleen Vohs of the University of Minnesota in Minneapolis sought to understand meaning and happiness in isolation, which was tricky because happy people also tend to lead lives high in meaning and vice versa. The researchers identified only those variables linked to happiness, such as satisfying one's needs and wants, or only meaning, such as spending time with one's children. Their findings, appearing in 2013 in the *Journal of Positive Psychology*, revealed that happiness in isolation is linked to a focus on the present while meaning in isolation connects the past, present and future, often through self-reflection.

The distinction between meaning and richness, as such, hinges on whether stitching together the strands of one's life, or coherence, is essential to building a good life. People who study meaning say yes; Oishi says no, turning to fiction to make his point. In Muriel Barbery's 2006 novel *The Elegance of the Hedgehog* and Rabih Alameddine's 2014 *An Unnecessary Woman*, the main characters are poor and lonely women who are neither interested in making the world a better place nor feel that their experiences add up to some greater whole. Instead, the two women, Renée and Aaliya, pursue lives filled with consuming literature, art and music, Oishi says.

"Both women appreciate moments of ineffable beauty, Proustian moments of elongated time and aesthetics, and lead a life full of inner richness," he and colleagues wrote in 2019.

Oishi's proposition is simple, yet radical: Experiences, whether mostly vicarious as with Renée and Aaliya, or firsthand, can offer a good life without summing up to anything greater than their parts.

"Ideally, we want to have all three: happiness, meaning and psychological richness," Oishi told me in an e-mail. "But having just one is sufficient to lead a good life."

The creative impulse

After the neurological heavens opened, Sacks published his own book on migraines in 1970. He followed it with *Awakenings* in 1973, documenting the miraculous recovery and relapse of catatonic patients who began to clap, walk and talk after treatment with a medication for Parkinson's disease, before fading back into unresponsiveness.

Despite his lifelong intellectual and creative frenzy, Sacks remained ever alone. After a brief fling at age 40, he was celibate for the next 35 years.

T. TIBBITTS

Rich dimensions

Shigehiro Oishi and colleagues zeroed in on the core dimensions of a psychologically rich life.

What rings true? Below is a sampling of statements Oishi's team uses to measure a person's level of psychological richness, or propensity toward novel, perspective-changing experiences. Participants answer on a scale from 1 (strongly disagree) to 7 (strongly agree).

I have had a lot of novel experiences.

My life has been full of unique, unusual experiences.

My life consists of rich, intense moments.

My life has been dramatic.

I experience a full range of emotions via first-hand experiences such as travel and attending concerts.

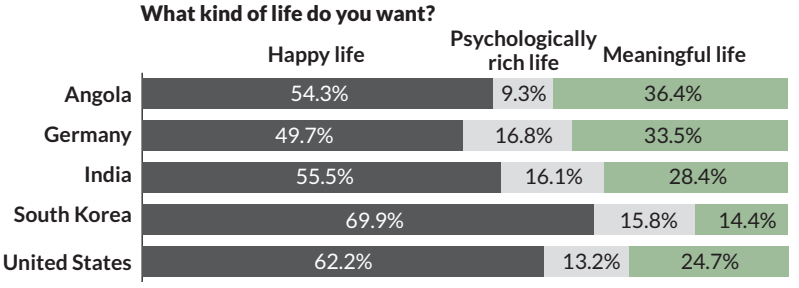
I have a lot of personal stories to tell others.

On my deathbed, I am likely to say "I had an interesting life."

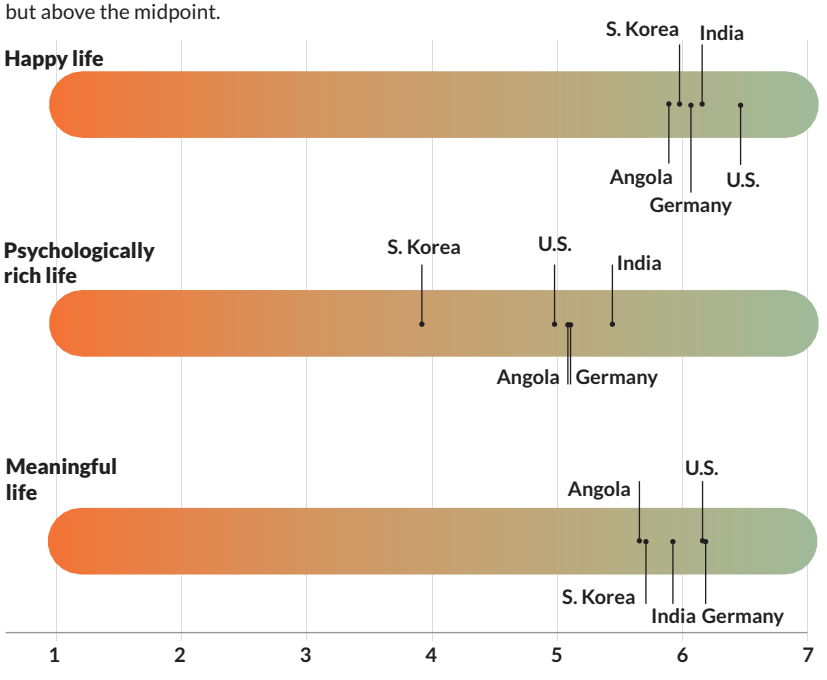
On my deathbed, I am likely to say "I have seen and learned a lot."

My life would make a good novel or movie.

Choose one When forced to choose just one path to a good life, most people, with some variability by country, opt for a life high in happiness, with meaning coming in second. Yet a sizable minority choose psychological richness.



An ideal life When asked to describe how well nine terms that are linked to happiness, meaning or richness described their ideal lives, from 1 (not at all) to 7 (very much), average scores among respondents for "rich" words, such as "eventful" and "interesting," were lower than scores for words describing happiness or meaning, but above the midpoint.



SOURCES: S. OISHI *ET AL/AFFECTIVE SCIENCE* 2020; S. OISHI *ET AL/J. RESEARCH IN PERSONALITY* 2019

"He was not happy. He was creative. He was productive. And he was moving forward," Burns says. "And I think if one is creative, productive and moving forward, one is moving toward happiness."

Though Burns uses the term "creative" casually, the pursuit of art seems uniquely suited to those seeking, or forced into, a rich life. "People who score high in openness to experience tend to lead more creative lives," says Oshin Vartanian, a cognitive neuroscientist at the University of Toronto.

And Oishi's work has shown that aesthetic experiences increase richness. For instance, in a 2020 study in the *European Journal of Personality*, Oishi and colleagues compared richness levels between students studying abroad and students who remained on campus. Though both groups started at the same richness levels, richness scores among the students studying abroad went up after 12 weeks.

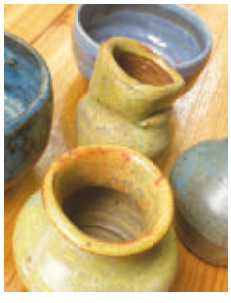
Student diaries revealed that the study abroad students participated in considerably more artistic activities, such as going to museums and concerts, than students who remained on campus. Engagement with art, Oishi says, "explained partially why the study abroad group had higher psychological richness."

As COVID-19 variants ricochet around the globe, a great many people are now like those students studying abroad — not traveling, but dosed in a different kind of richness. Here, in this foreign terrain, we too seek beauty.

Scientists have largely focused on the artistic genius, the prototypic creative, Vartanian says. But the pandemic suggests that we should also study, and encourage, the everyday creative.

Vartanian counts himself among this everyday lot. During the pandemic shutdown, someone gave him a broken play structure for his children. Vartanian couldn't access the parts he needed to fix it, so he learned how to chisel and do woodwork to get the apparatus in working order. "Doing things I'd never done before," Vartanian says, "was so greatly satisfying for me."

I recognize the feeling. When I entered the pottery studio, I knew nothing of the craft. Simply centering the clay on the wheel took me seven lessons. While I can now center small lumps of clay with relative ease, beautiful forms elude me. A half year on, I have thrown misshapen bowls, a smattering of wobbly cups and precarious vases that fold at the neck. I am, at my own life's midpoint, awash in imperfect vessels.



Gupta has created an assortment of wobbly vases, bowls and cups.

Three pursuits Though there can be overlap, the paths to the good life have different features. Happiness tends to be marked by security, meaning by a sense of purpose and richness by perspective-changing experiences. SOURCE: S. OISHI AND E. WESTGATE/*PSYCHOLOGICAL REVIEW* 2021

	Happy	Meaningful	Psychologically rich
Key features	Comfort Joy Security	Significance Purpose Coherence	Variety Interest Perspective change
Facilitators	Money Time Relationships Positive mind-set	Moral principles Consistency Relationships Religiosity	Curiosity Time Energy Spontaneity

Oliver Sacks (left) found psychological richness and meaning, thanks to his writings and interactions with patients. Finding happiness took him until near the end of his life. When Sacks was in his late 70s, he met the love of his life, author and photographer Bill Hayes (right).

Completing the triad

In the Venn diagram of the good life, Sacks spent much of his time outside all three circles. By midlife, though, psychological richness had become his beacon.

Yet, in crafting his patients' stories, Sacks made his life about something larger than himself, Burns says. "He turned the mirror around [and said,] 'I'm going to look outward in order to also look inward.' " Sacks had landed at the overlap between richness and meaning.

Then, in his late 70s, Sacks fell deeply, madly in love. After a lifetime of struggle, he finally felt he belonged, not just in literary or academic circles but within himself. In that adieu, Sacks remarked: "My predominant feeling is one of gratitude. I have loved and been loved; I have been given much and I have given something in return; I have read and traveled and thought and written."

Gratitude, research shows, is the language of happiness. At the sunset of his life, then, Sacks had arrived at the junction of those three paths.

He nailed the ending, Burns says. "That's given to very, very few of us." ■

Explore more

■ S. Oishi *et al.* "Happiness, meaning and psychological richness." *Affective Science.* June 23, 2020.

FROM TOP: THE OLIVER SACKS FOUNDATION; ADAM GOODENOUGH

Science News for Students

Science News for Students is an award-winning, free online magazine that reports daily on research and new developments across scientific disciplines for inquiring minds of every age — from middle school on up.

Warning: Wildfires might make you itch

Smoke emitted by California's 2018 Camp Fire, like that coloring this San Francisco vista, has just been linked to eczema. This skin condition's "itch can be very life-altering," notes dermatologist Maria Wei of the University of California, San Francisco. It affects mood and leads to sleep loss. Her team reviewed doctor visits and prescriptions for eczema drugs in the weeks before, during and after the wildfire. One surprise, she reports: A very short-term exposure to wildfire pollution caused an immediate uptick in eczema, especially in kids, whose doctor visits for the condition climbed by nearly 50 percent after the fire. — *Kathiann Kowalski*

Read more: **www.sciencenewsforstudents.org/wildfires-itch**

A bubble of air lets some lizards breathe underwater

Some small lizards have a newfound superpower: Like scuba divers, they can stay underwater a long time. Evolutionary biologist Chris Boccia of Queen's University in Canada followed up on a strange story. His mentor had seen an underwater *Anolis* lizard repeatedly suck air in and out of an exhaled bubble for several minutes. Later, in Costa Rica, Boccia chased after these lizards to see how common that behavior was. He confirmed *Anolis* lizards regularly evade predators by diving underwater and then rebreathing air exhaled as bubbles. One champion bubble rebreather hid out this way for 18 minutes. — *Sharon Oosthoek*

Read more: **www.sciencenewsforstudents.org/lizards-breathe-underwater**

Warming cities may see more rain — and frequent flooding

Scientists are finding that as already warm cities get even hotter, that heat is fueling rainstorms — sometimes prolonged intense ones. Cities can modify Earth's water cycle through what's becoming known as the urban rain effect. Pavement, concrete buildings and dark-roofed houses absorb more heat than forests or rural sites. Urban pollutants can serve as seeds for the formation of cloud droplets. Tall buildings channel pollutants and the solar-heated air upward. And here's another contributor: Cities can split storms, rerouting their paths. The good news: Science is also identifying clever strategies to blunt the growth of these flood-threatening urban downpours. — *Bethany Brookshire*

Read more: **www.sciencenewsforstudents.org/rain-cities**

Fuzz
Mary Roach
W.W. NORTON & CO., $26.95

BOOKSHELF

Step into the criminal lives of animals

Around the world, criminals run free in the forest. These villains can't be arrested — because they're not human. In her latest book, *Fuzz: When Nature Breaks the Law*, Mary Roach puts the spotlight on these miscreants. On the Midway Islands, albatrosses carry out suicide missions against the U.S. Navy's planes. In Colorado, bears break and enter, raiding the refrigerators of mountain homes. And deer do so much jaywalking.

Nature's perp list also includes camels, mountain lions, crows and many more. Through such examples, Roach tackles this question: What should we do when animals break laws intended for people?

The book brims with Roach's irreverent humor, which particularly shines when she experiences human-animal conflict firsthand. She tastes rat bait to better understand its allure and gets training on how to tell if a human body was mauled by a bear or by a human pretending to be a bear. She even engineers a robbery: "I had bananas. I was asking for it. I wanted to know what it was like to be mugged by monkeys."

But it's not all fun and reindeer games. Roach highlights how much real pain comes from human-animal interactions. Elephants routinely destroy people's crops and homes. They, along with leopards, bears, deer and others, can also kill people. She also tackles the ethics of eradicating pests by mass poisoning or altering their genetics.

The stories might seem disparate, but they serve a wider point. Many wildlife strategies seek to save people from wild animals' unwelcome behavior, or to increase the numbers of animals that people want to shoot, eat or admire. What would happen, Roach wonders, if we thought more about coexistence instead of conflict or exploitation?

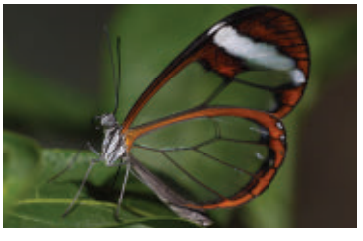
Most chapters offer a blend of modern science and history, with Roach's flair for spotting hidden absurdities. Not all the stories of nature's criminal intent quite land, however. She highlights, for instance, how falling trees kill people, and how uncooked beans cause significant gastrointestinal distress. But it's a stretch: Widow-makers and musical fruits are inanimate objects, lacking motive, means or opportunity. It's hard to feel threatened by a tree or bean that can't come running after you.

Nonetheless, as another entry in Roach's canon of books, *Fuzz* stands tall (and hairy), educating as much as it entertains. But please: Just learn from her. Do not taste the rat bait. — *Bethany Brookshire*

JULY 31, 2021

Wondrous wings

Spindly scales and a waxy coating are the secret to glasswing butterflies' transparent wings (shown below), **Maria Temming** reported in "What's behind this butterfly's see-through wings" (*SN: 7/31/21, p. 32*). Reader **Connie Jagodzinski** found the research fascinating: "It made me think of *Star Trek*'s cloaking devices and how this … amazing little insect could galvanize big old human technology."



AARON POMERANTZ

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Corny fuel

*Genetically modified baker's yeast can turn corn stover — cornstalks, leaves and other harvest debris that farmers often leave to rot in fields — into ethanol, **Nikk Ogasa** reported in "Yeast turns corn leftovers into fuel" (*SN: 7/31/21, p. 12*).* Reader **Doug Brown** wanted to know how removing the corn leftovers would affect soil systems, considering that the materials contribute to soil structure, health and maintenance.

Leaving corn stover behind to promote healthy soils is important, **Ogasa** says. "The vision isn't to strip the fields bare, but to extract a minor portion — around 20 to 25 percent — of the corn stover for ethanol production."

Reader **Diana Lutz** wondered if ethanol production would help curb the climate crisis, considering that burning the fuel produces carbon dioxide.

While burning ethanol does release CO_2, growing corn can capture the greenhouse gas, **Ogasa** says. This cycling of carbon is different from burning fossil fuels, which only adds more CO_2 to the atmosphere. Long-term climate solutions certainly need to include alternatives to burning fuels, says metabolic engineer **Felix Lam** of MIT. Substituting some fossil fuel use with ethanol or other biofuels could help reduce CO_2 emissions now while scientists develop emission-free energy sources, **Lam** says.

Cosmic mysteries

*The last century of astronomy has revealed the complexity of the cosmos, including the existence of exoplanets and colliding galaxies, **Lisa Grossman** reported in "A century of new worlds" (*SN: 7/31/21, p. 18*).* Reader **Raleigh Truitt** asked whether the presence of colliding galaxies means there are exceptions to the idea that galaxies are moving away from each other.

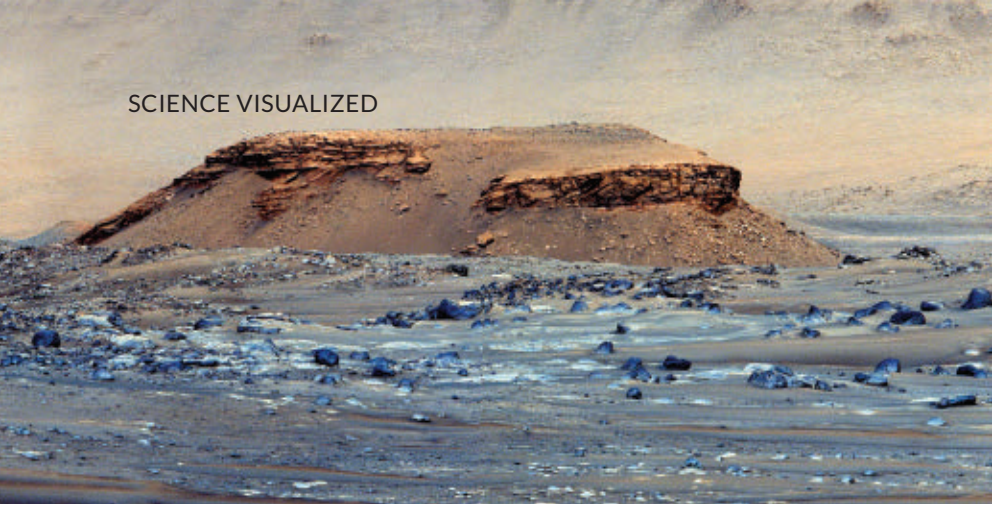
It's a question of scale, **Grossman** says. "On large enough scales, yes, the universe is expanding at an accelerating rate, and galaxies are flying away from each other. But that doesn't mean they can never meet," she says. "Gravity is still very good at bringing matter together, and galaxies run into each other all the time."

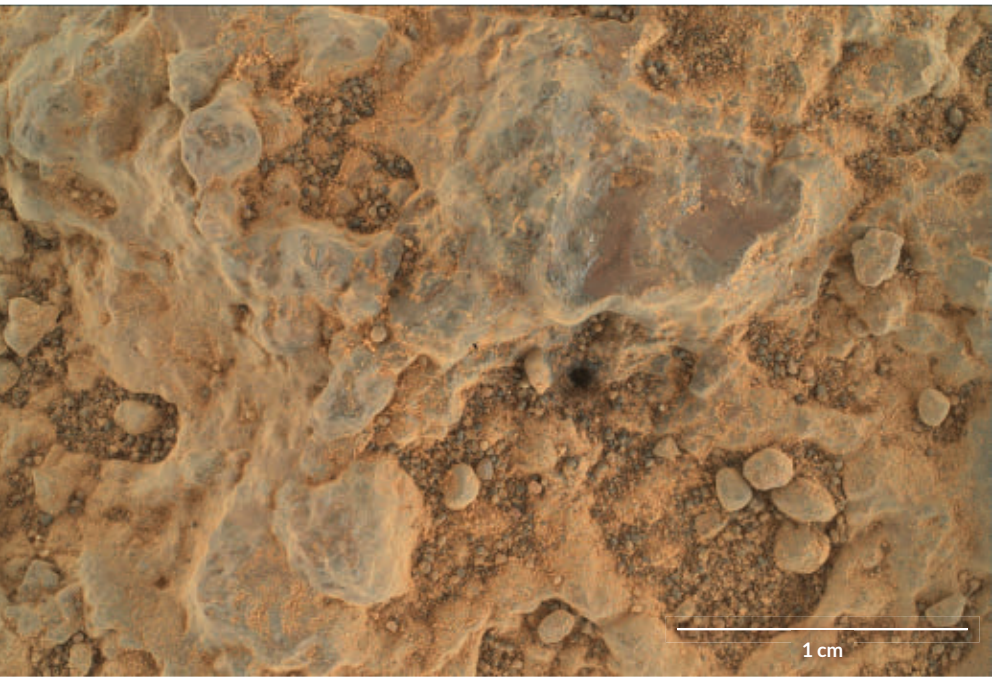
Grossman reported that Mars' sky, initially thought to be blue, is actually pinkish-yellow thanks to dust particles in the air. Given that Earth's oceans are blue like its sky, reader **Emily Rader** wondered what color Mars' surface water would have been long ago.

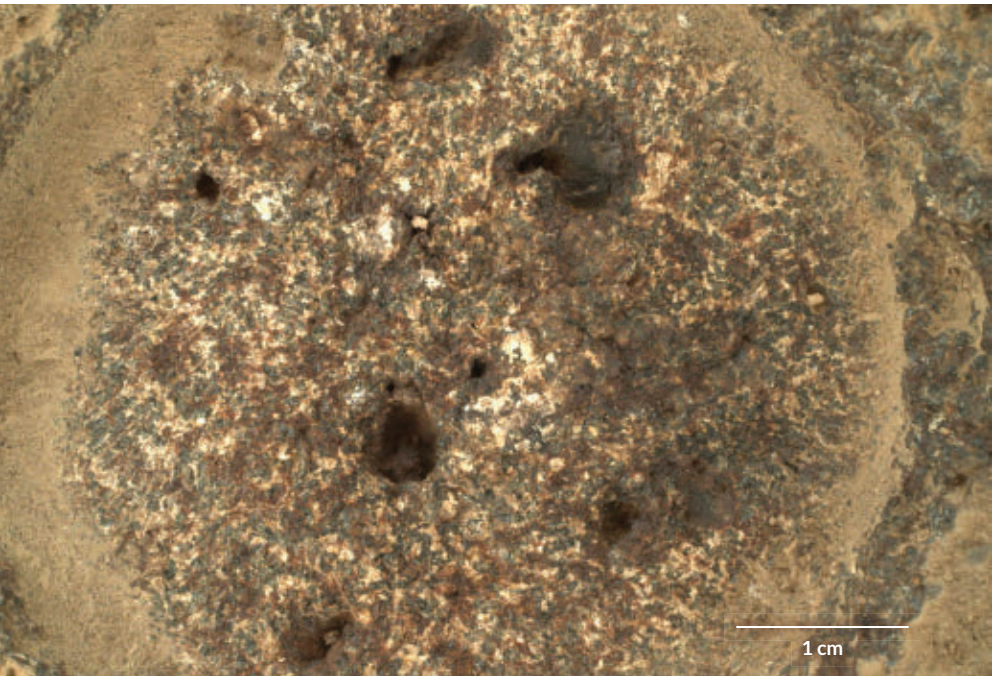
Martian oceans would probably have appeared blue, says planetary scientist **Germán Martínez** of the Lunar and Planetary Institute in Houston. Mars' atmospheric composition, which helps determine the color of its sky, does not affect most of the sunlight that reaches the planet's surface, **Martínez** says. Sunlight at the surface contains all colors in the visible light spectrum. Water molecules absorb red, orange, green and yellow wavelengths from sunlight and scatter blue wavelengths. That is why we perceive Earth's oceans as blue, he says. So just as on Earth, water on ancient Mars would have looked blue.

Correction

"Mind games" (*SN: 8/14/21, p. 18*) failed to note that psychologist Stephen Reicher of the University of St. Andrews in Scotland collaborated with psychologist S. Alexander Haslam of the University of Queensland in Australia to conduct a prison experiment in which guards developed their own rules. The experiment took place in 2001, not 2002.







See Mars through Perseverance's eyes

In February, the Perseverance rover touched down on Mars and went to work. NASA's rover has seen the first flight of a Martian robot, gotten its drill bit dirty and begun traversing the floor of Jezero crater, thought to be the dry basin of an ancient lake.

Eroded outcrops close to the rover's landing site (one shown in false color, top) could be remnants from that lake.

"Many of us expected these outcrops to be quite uninteresting, based on orbital data," says Perseverance deputy project scientist Katie Stack Morgan of NASA's Jet Propulsion Lab in Pasadena, Calif. But images from the ground showed beautiful layers, just like what you would find in a deep-lake deposit, she says.

Perseverance is taking a closer look at individual rocks too. One rock (close-up shown, middle) has fascinating textures and "crazy red coatings" that are more purple than typical Mars dust, says planetary scientist Briony Horgan of Purdue University in West Lafayette, Ind., one of the mission's long-term science planners. The coatings probably imply alteration by water, and the purple color suggests that they contain some iron, she says.

The rover is also on the hunt for igneous, or volcanic, rocks because those rocks tend to be old and preserve a record of their age well. "If you want to figure out when things happened on Mars, you want an igneous rock," Stack Morgan says.

Light- and dark-colored spots in one rock (close-up shown, bottom) could be crystals, which would suggest long-ago volcanic activity. But these crystals are bigger than expected for lava that would have cooled at the surface. Similar crystals form deep in Earth, where magma solidifies slowly. When lava cools at Earth's surface, the crystals "don't have time to grow big," Stack Morgan says. The next step, she says, is thinking through how rocks like this could have formed. — *Lisa Grossman*

FROM TOP: JIM BELL/ASU, JPL-CALTECH/NASA, MSSS; JPL-CALTECH/NASA, MSSS; JPL-CALTECH/NASA

See more images from Perseverance at **bit.ly/SN_MarsUpClose**

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Jon Graff was a lifelong *Science News* reader who greatly admired the communications skills of its writers and editors. During his life, Jon helped devise the secure methods we use every day to make online credit card transactions. He also loved taking long trips in the Southwest on his beloved green bike.

When Jon looked back over his life as he grew older, he thought about the things that mattered to him most—his biking friends, his seminal work as a cryptographic architect and decades of reading *Science News*.

Sadly, Jon died in January 2021 at the age of 77. Before he died, Jon made a bequest intention to create an endowment—The Jon C. Graff Fund for *Science News*—whose income will benefit both the Society for Science and *Science News* journalism in perpetuity.

Bequest gifts are the right kind of gift for many of us, enabling us to support the organizations we most admire after our lifetimes.

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