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ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ AUGUST 29, 2020

COVID 19 in Class

What we know about how children spread coronavirus

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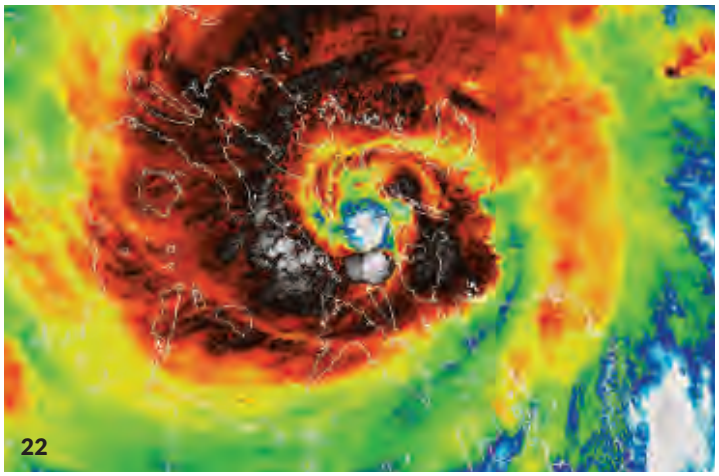
22

Features

22 Closing a Gap in Weather Forecasting
By improving models to predict three weeks into the future between short term and seasonal forecasts researchers hope to help communities plan for extreme weather. *By Alexandra Witze*

30 Erasing the Shadow of Early Trauma
Puberty may offer a crucial window for children who had a difficult start. Their brains may be able to reset impaired responses to stress. *By Esther Landhuis*

News

6 As schools reopen, new hints emerge on kids and coronavirus transmission

7 The most polluted U.S. neighborhoods 40 years ago still tend to have the worst air quality

8 Immune system misfires suggest a potential way to treat COVID 19 early in the disease

10 Missing immune genes may enable parasitic mating in some anglerfish

Deciphered genome helps explain a rare reptile s oddities

11 White dwarfs shrink as they gain mass

12 The physics of solar flares could be key to predicting the sun s big outbursts

Gravitational waves could help verify that wormholes are real

13 Antarctica may offer astronomers the clearest views of the night sky

14 COVID 19 lockdowns hushed humans seismic noise

16 Vikings likely suffered from smallpox

Submerged Inca offering provides clues to lake s sacred role

18 Some spider webs appear to be laced with neurotoxins

A swallowed beetle makes a great escape from a frog s digestive system

20 **News in Brief**
Even after millions of years, dormant microbes can be revived

New penguin colonies are discovered in satellite images

A new kind of lightning is seen on Jupiter

The universe may be smoother than physicists thought


10


4

Departments

2 **EDITOR S NOTE**

4 **NOTEBOOK**
Scientists cosplayed a Mars rover; a new look at sperm reveals how they actually swim

38 **REVIEWS & PREVIEWS**
The game Endangered shows how difficult conservation can be

42 **FEEDBACK**

44 **SCIENCE VISUALIZED**
Some deep sea fish are ultradark

COVER As the COVID 19 pandemic rages on, scien tists struggle to answer how to keep students and teachers safe. *Julie Sebadelha/Abaca/Sipa USA (Sipa via AP Images)*

When science doesn t yet have the answers

Back-to-school time is usually greeted with delight by children and parents. This year, school has become a hellscape of uncertainty due to the United States' failure to subdue the coronavirus. We all want children to be back at school, learning and playing with their peers. How to get them there with at least a modicum of safety is the latest challenge in a year of extraordinary challenges.

On the face of it, making schools safe enough in a pandemic seems like a straightforward public health question. But though scientists have learned a great deal in the last seven months about how the coronavirus is transmitted and how to reduce risk, there's still so much we don't know, especially when it comes to kids. And as with too many other issues involving this pandemic, misinformation is rampant.

To find out what the science really says about children and COVID-19, five of our reporters set to work evaluating current research and interviewing a wide range of scientists across disciplines. Our reporters then distilled that information into a concise report addressing key questions about COVID-19, children and schools. One of those important questions — How easily do kids spread COVID-19? — is explored on Page 6. Others — including whether there is a "safe" threshold for community spread that could be used for reopening schools, what physical changes schools can make to reduce risk and whether grouping students in bubbles or pods is actually helpful — can be found on our website (bit.ly/SN_COVID-19Kids).

What we found out is that because the science is still uncertain on how the coronavirus affects children and how readily they infect others, there's no clear path to keeping kids safe, or even reducing risk. Though children appear less likely to become seriously ill or die than adults, youngsters do get infected. They also can transmit the virus to others, including educators, school staff and family members who are at higher risk of serious illness merely by being adults. Countries that have successfully reopened schools have done so first by achieving much lower rates of community spread than in the United States. Then those schools paid strict attention to social distancing, wearing masks and hygiene, including handwashing and frequent cleaning of classrooms.

So education this fall, from pre-K all the way up through college, will be a "massive collection of experiments," our reporters write, whether the students are in classrooms or online. Many of us at *Science News*, including me, find our own families in the midst of that experiment. We're right there with the many millions of families struggling to figure out how to keep family members as safe as possible while getting children the education they need.

It didn't have to be this way. Solutions will emerge, though not as quickly as we need them. New data will provide more clarity; lessons can be learned from the countries that are successfully managing school during a global pandemic. Many of those lessons will be painful reminders of how we have failed America's children. But we are learning through experience.

— Nancy Shute, Editor in Chief

Tears From a Volcano

Uniquely American stone ignites romance

On May 18, 1980, the once-slumbering Mount St. Helens erupted in the Pacific Northwest. It was the most impressive display of nature's power in North America's recorded history. But even more impressive is what emerged from the chaos... a spectacular new creation born of ancient minerals named Helenite. Its lush, vivid color and amazing story instantly captured the attention of jewelry connoisseurs worldwide. You can now have four carats of the world's newest stone for an absolutely unbelievable price.

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Excerpt from the September 12, 1970 issue of *Science News*

50 YEARS AGO

Another auto entry

The recent week-long clean air car race from Massachusetts to California provided a shotgun approach to development of low-emission or nonpolluting vehicle engines. Yet despite more than 40 entries employing five engine classes, the winner was a modified standard internal-combustion engine.... There is a consensus among some engineers that the answer will lie with some form of electrically powered vehicle.

UPDATE: Most vehicles today house internal combustion engines, but cars with electric motors are gaining ground. In 2010, there were about 17,000 electric cars globally, including all electric cars and plug in hybrids. By 2019, that number had soared to 7.2 million, the International Energy Agency reported in June. Although air pollution and oil shortages sparked interest in electric cars, the vehicles also curb greenhouse gas emissions. In 2019, generating energy for electric cars emitted about half as much carbon dioxide equivalent as that emitted from the same number of gas fueled vehicles, the agency noted.

Scientists set up equipment in the Nevada desert in February. Similar equipment on NASA s Perseverance rover is on the way to Mars.

THE SCIENCE LIFE

To rehearse Perseverance s mission, scientists pretended to be a Mars rover

Megan Barrington watched the sun rise over the rocky outcrop. When light struck the outcrop at exactly the right angle, she mounted what looked like eye-exam equipment on a tripod and aimed it at the spot. The goal: Gather evidence that this windswept wilderness once teemed with life, and then beam the information to her colleagues back home.

Soon, a version of that setup will be deployed on Mars. The state-of-the-art, zoomable, multispectral camera is part of the toolkit on NASA's Perseverance rover, which launched to Mars on July 30. "That instrument is going to allow me to look at the mineralogy of Mars at Jezero crater," the rover's landing spot, which is thought to be the remnants of an ancient lake bed and river delta, says Barrington, a planetary scientist at Cornell University.

A yellow rumped leaf eared mouse, similar to this one, was found at a record high altitude. The mouse was scurrying among the rocks at the summit of a dormant volcano in South America.

THE EST

South American mouse caught living the high life

A yellow-rumped leaf-eared mouse has shattered the world record for the highest-dwelling mammal.

The mouse (*Phyllotis xanthopygus rupestris*) was found 6,739 meters above sea level on the summit of Volcán Llullaillaco, a dormant volcano on the border of Chile and Argentina. The record was previously held by the large-eared pika (*Ochotona macrotis*), reported at an altitude of 6,130 meters during a 1921 Mount Everest expedition.

That mammals can live at these heights is astonishing, considering there's only about 44 percent of the oxygen available at sea level. "It's very difficult to sustain any kind of physical activity," says Jay Storz, an evolutionary biologist at the University of Nebraska–Lincoln. The temperature is also rarely above freezing and can drop as low as –60° Celsius.

Storz and colleagues captured several yellow-rumped leaf-eared mice, plus mice from three other species from a range of high altitudes, the team reports in the Aug. 4 *Proceedings of the National Academy of Sciences*. The team plans to look for genetic changes that might have equipped these animals to survive at high elevations. Surprisingly, another yellow-rumped leaf-eared mouse was found at sea level, indicating that this species also has the broadest altitude distribution of any mammal. — *Jack J. Lee*

FROM TOP: JPL CALTECH/NASA; MARCIAL QUIROGA CARMONA

Watch a team nab the highest dwelling mammal at **bit.ly/SN_HighestMammal**

The February role-playing exercise in the Nevada desert by Barrington and six colleagues was a kind of dress rehearsal for the rover's various instruments. Another 150 team members around the world played the "Earth" team, sending commands from mission control and receiving data as it would appear coming from the real rover.

Perseverance has the most ambitious to-do list of any rover yet: Seek signs of past Martian life, prepare the way for future human missions and collect at least 20 samples of Martian rock for eventual return to Earth (*SN: 7/4/20 & 7/18/20, p. 30*). The dress rehearsal in the desert helped ensure that when the rover lands on Mars in February 2021, Perseverance's handlers on Earth can get straight to the science.

Previous exercises were run in the Mojave Desert in California in 2017 and 2019. For 2020, the rover team headed to Walker Lake in western Nevada. The lake's water has been receding for thousands of years, so there are areas of ancient shoreline with no visible water.

Engineer Raymond Francis photographs rocks during a Mars mission test run in Nevada.

Walker Lake's rocks preserved a cornucopia of biological signals for the team to discover: fossilized fish bones and shells of shrimplike crustaceans, which are not expected on Mars, as well as microbial fossils called stromatolites, which could plausibly be found in Jezero crater.

Trip leader Raymond Francis, an engineer at NASA's Jet Propulsion Laboratory in Pasadena, Calif., and colleagues brought handheld versions of almost all the rover's instruments to gather whatever data the Earth team requested. There was a drill, spectrometers, ground-penetrating radar, lasers, plus several elaborate camera setups to represent the rover's navigation, hazard avoidance and zoomable 3-D science cameras.

Almost everything went smoothly. By the end of the two-week exercise, the team reviewing the data remotely had started exploring the stromatolites. "They were doing a good job of finding the biomarkers," says Francis, who now has hope that "if Mars is hiding stromatolites, maybe we'll see them."

The field trip concluded in late February, just as awareness of the novel coronavirus was rising in the United States. By March 15, Jet Propulsion Lab employees were working from home. If the pandemic is ongoing when the rover lands, Francis doesn't know what the team will do. "The good news," he says, "is the mission is designed for remote operations." —*Lisa Grossman*

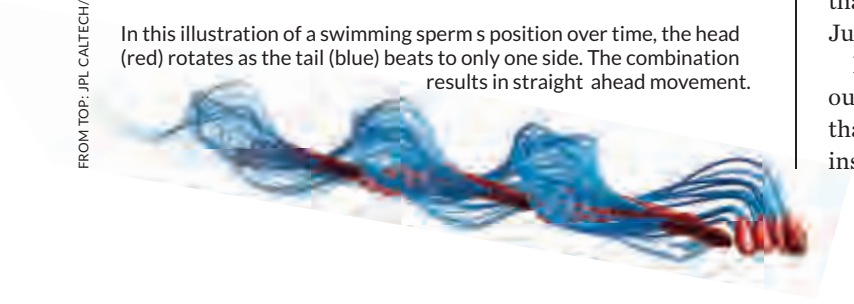
RETHINK

Science upends centuries old wisdom about swimming sperm

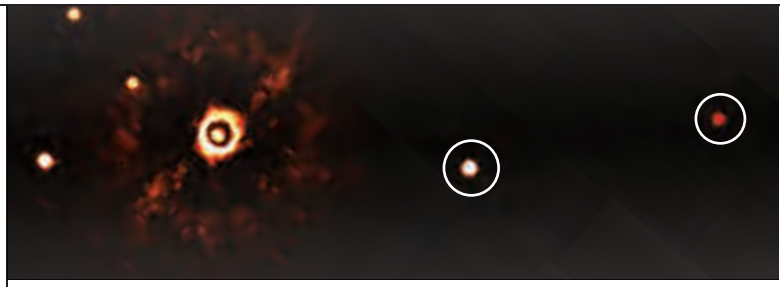
Sperm have long fooled scientists. Instead of swimming by twirling their tails like propellers, human sperm lopsidedly flick their tails and roll to balance out the off-center strokes.

More than 300 years ago, microscopy pioneer Antonie van Leeuwenhoek described sperm tails swaying like that of a snake or an eel. But the prevailing view that sperm tails move in a balanced way doesn't capture what actually happens in 3-D, researchers report in the July 29 *Science Advances*.

Mathematician Hermes Gadêlha and colleagues tracked sperm swimming freely in the lab using high-speed 3-D microscopy and analyzed the cells' position data. The team found sperm tails wiggle to only one side. Such a lopsided stroke would lead sperm to swim in circles, says Gadêlha, of the University of Bristol in England. But sperm also rotate, balancing out the strokes to swim straight ahead. Additional investigation is needed to know if sperm move the same way in the female reproductive tract. —*Jack J. Lee*



In this illustration of a swimming sperm s position over time, the head (red) rotates as the tail (blue) beats to only one side. The combination results in straight ahead movement.



PICTURE THIS

A weird solar system cousin makes its photographic debut

For the first time, an exoplanet family around a sunlike star has had its portrait taken. Astronomers used the Very Large Telescope in Chile to snap a photo of two giant planets orbiting a star with about the sun's mass, scientists report in the July *Astrophysical Journal Letters*.

The star, TYC 8998-760-1, is about 300 light-years from Earth. And its planets (circled above) are unlike anything seen in our solar system. The inner planet weighs 14 times the mass of Jupiter and is 160 times farther from its star than Earth is from the sun. The outer one weighs six times Jupiter's mass and orbits at twice its sibling's distance.

Photographs of exoplanets are rare, and just two previously taken pics feature a star, neither sunlike, with more than one planet. The newly imaged family could provide insight into how solar systems can form. —*Lisa Grossman*

FROM TOP: JPL CALTECH/NASA; BOHN *ET AL*, ESO; POLYMATHS LAB.COM

BODY & BRAIN

How easily do kids spread COVID 19?

As schools reopen, scientists are still studying transmission risks

BY ERIN GARCIA DE JESUS

It's back-to-school time in the United States, but for the world's leader in coronavirus infections and deaths, what "back to school" means is hardly clear.

No other country has attempted to send children to school with coronavirus infection levels as high as they are in some parts of the country. Many large school districts, including those in Los Angeles and Atlanta, have returned to school with all students learning from home. Other districts have opted for models that mix in-person learning with remote classwork. And in some places, such as Connecticut, students will be back in the classroom full time.

School districts have been struggling to make the call on how to reopen, given a lack of data on how to reduce risk. One big open question has been: Can children transmit the coronavirus?

A growing body of research suggests the answer is yes. "But it seems fairly clear that, at least for young children, they probably transmit less" than other age groups, says epidemiologist Aubree Gordon of the University of Michigan in Ann Arbor. The details of how or why, however, are a moving target.

Some of the latest studies emerging from other countries tell conflicting stories. A study tracing nearly 60,000 contacts of 5,706 COVID-19 patients in South Korea, for instance, revealed that 10- to 19-year-olds may transmit the virus more like adults do, researchers from the Korea Centers for Disease Control and Prevention report online July 16 in *Emerging Infectious Diseases*. Transmission rates in households for older kids and adults in the study ranged from 7 to 18.6 percent. Kids younger than 10, however, appeared less likely to pass the virus on — infecting only 5.3 percent of contacts living in the same home. But a small, preliminary study from Italy, posted online July 29 at medRxiv.org, found that children younger than 15 were more likely to transmit the virus than older age groups. Among the 49 contacts of 14 children in that age group, 22.4 percent got infected.

Because they are more likely to have mild cases of COVID-19 or be asymptomatic, children can easily be overlooked as transmitters, Gordon says. To determine how often children really pass the virus on to others, researchers would need to monitor large groups of people before they get sick. That would help experts identify a potentially asymptomatic child that went on to infect family members. As infected adults are much more likely to develop symptoms, such cases are typically identified first, perhaps after a child has already recovered.

But when children do get sick, they appear to carry plenty of virus. A preliminary study of symptomatic people, posted July 19 at medRxiv.org, found that children have the same amount of virus in their bodies as adults do during an infection. Another small study found that children younger than 5 have even higher amounts of the coronavirus's genetic material in the upper respiratory tract than older kids or adults do, researchers report online July 30 in *JAMA Pediatrics*.

One possible reason children may transmit the virus less than adults do is because kids most often have mild symptoms or are asymptomatic and therefore may not cough as much, releasing less virus into the surrounding air.

Why kids don't often get as sick is also still unclear, though younger children may have lower amounts of a protein called ACE2 in the nose than older kids or adults, researchers report in the June 16 *JAMA*. The virus hijacks ACE2 to break into host cells, so less ACE2 protein could mean children younger than 10 have fewer susceptible cells for the virus to infect.

Despite all of the uncertainty, one thing is clear: The number of COVID-19 cases in children has been going up across the United States. As of August 6, state-level data compiled by the American Academy of Pediatrics and Children's Hospital Association show that children represented 9.1 percent of all

Teacher Chablis Torres reads to children in a preschool class this summer in Monterey Park, Calif. Preschoolers and other young kids may be less likely than older kids to transmit COVID 19.

FREDERIC J. BROWN/AFP/GETTY IMAGES

Read more about school openings and COVID 19 at **bit.ly/SN_COVID 19Kids**

U.S. COVID-19 cases, up from 3.7 percent in mid-May. That increase could be in part because more kids are now getting exposed as stay-at-home orders have been lifted. At an overnight summer camp in Georgia in June, for instance, more than 200 people — most of whom were children — got infected with the coronavirus.

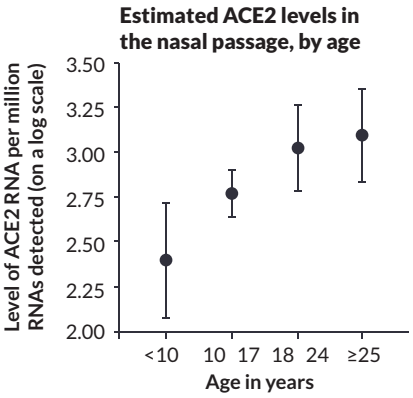
Given that children are susceptible to the virus — and, at least to some degree, able to pass it on to others — schools that have opted for in-person learning will need to know when the virus is spreading within the student body. One solution is to test all kids at regular intervals, with those students testing positive quickly notified and kept home. But schools largely lack the infrastructure for that much testing, and in some places, getting results back can take over a week.

"It's just not going to be feasible in most areas of the country," says Tina Tan, a pediatric infectious disease specialist at Northwestern University Feinberg School of Medicine in Chicago. In its latest testing in schools guidelines, the U.S. Centers for Disease Control and Prevention does not recommend universal testing of all students. Instead, the agency suggests testing only students with COVID-19 symptoms and those who have been in contact with a confirmed or suspected case.

"The onus is going to be on families to keep kids at home if they have symptoms of any kind," says Sandra Albrecht, a social epidemiologist at Columbia University.

With a lack of testing, schools will have to keep an eye on case levels in the larger community, says Jennifer Nuzzo, an epidemiologist at the Johns Hopkins Center for Health Security. If cases spike, schools may have to close. ■

With additional reporting by Jonathan Lambert



Fewer inroads Young children appear to have lower levels of ACE2 protein in the nose than do older children and adults. The corona virus uses that protein to enter cells. Low ACE2 levels may explain why young kids are less likely to get infected. SOURCE: S. BUNYAVANICH, A. DO AND A. VICENCIO/*JAMA* 2020

HUMANS & SOCIETY

U.S. air pollution disparities linger

Air quality is improving overall, but poor areas still fare worst

BY JONATHAN LAMBERT

While air quality has improved across the United States in recent decades, disparities persist in terms of who breathes the worst air. Communities exposed to the most air pollution in the 1980s — often poor and with high proportions of Black and Hispanic residents — are largely in the same relative position today, researchers report in the July 31 *Science*.

Many kinds of pollutants clog the air, but scientists are especially interested in particulate matter less than 2.5 micrometers wide. Called PM2.5, the particles are associated with myriad health problems, including cardiovascular disease, respiratory illness and neurological problems.

Marginalized communities, often closer to factories or major roadways than whiter, wealthier communities, bear the brunt of PM2.5 pollution. That exposure contributes to racial health inequities. "There hasn't been clear documentation of how these disparities have evolved over time," says economist Jonathan Colmer of the University of Virginia in Charlottesville. The U.S. Environmental Protection Agency began measuring PM2.5 only in 1999.

Colmer and colleagues estimated annual average PM2.5 levels for each square kilometer in the contiguous United States from 1981 to 2016 using data derived from ground measurements, satellites and simulations of pollutant movement through space. The team mapped the estimates onto about 65,000 census tracts to rank neighborhoods from most to least polluted annually and noted how rankings changed over time.

Whereas average PM2.5 concentrations decreased by about 70 percent across the entire study area, the relative ranking of neighborhoods hardly budged.

On average, whiter, more affluent neighborhoods were less polluted throughout the 36-year time frame. Disadvantaged neighborhoods with more Black or Hispanic people remained more polluted, despite experiencing a larger absolute drop in PM2.5 levels.

"It's really good news that air pollution is dropping for everyone," says Anjum Hajat, an epidemiologist at the University of Washington in Seattle. But even relatively low levels of pollution pose serious health risks, and the reductions might not translate to improved health for the hardest-hit communities. "To me, the take-home message is that inequity is very stubborn," she says.

The study wasn't designed to address why inequities persist, though a move away from manufacturing or coal production was associated with improved air quality in certain neighborhoods.

More important, Hajat says, is power structure. "The communities that were the most marginalized and had the least political power in the 1980s are likely the same communities that continue to have the least power today."

White, wealthy communities have been able to prevent polluting facilities from being placed in their neighborhoods, she says, while marginalized communities often haven't had this power. To see real change, "marginalized communities need to be included in discussions about their future," she says, for instance through community members holding decision-making roles. ■

C. CHANG

BODY & BRAIN

Interferons tested as COVID-19 drug

Treatment early in the disease may stem immune overreactions

BY TINA HESMAN SAEY

In severe cases of COVID-19, the immune system throws everything it has at the coronavirus, but some weapons end up hurting the patient instead of the virus.

Now researchers have new clues for getting the immune system back on target before the disease becomes severe. One of the most comprehensive looks to date at the immune system of COVID-19 patients pinpoints where things go awry. Bolstering the body's first line of defense against the virus using drugs called interferons may help prevent severe illness.

In a study of 113 patients admitted to Yale New Haven Hospital from March 18 to May 27, researchers monitored immune system chemicals and cells in two groups: severely ill COVID-19 patients who needed intensive care versus moderately ill patients who didn't end up in the ICU. For comparison, the team looked at healthy health care workers.

Moderately ill patients had an initial spurt of immune chemicals that fight viruses, then those levels gradually returned to normal, Akiko Iwasaki, a Yale immunologist, and colleagues report online July 27 in *Nature*. But in severely ill patients, levels of those chemicals remained high. In addition, parts of the immune system involved with allergies and usually dedicated to expelling parasitic worms got enlisted against the virus. Severely ill patients also had low levels of T cells, involved in recognizing and killing viruses.

That catalog of ways the immune system misfires is striking, says Michal Tal, an immunologist at Stanford University. "The immune system is just throwing the whole kitchen sink at this [virus]." That desperation may hurt patients by causing tissue-damaging inflammation.

One of those misfiring immune system weapons is interferon-alpha, normally one of the body's first defenses against viruses. The chemical is usually produced in the first couple of days of an infection, then wanes as other parts of the immune system kick in. But in people with severe disease, levels of interferon either don't dip as they should, or interferon becomes part of the kitchen sink of immune chemicals that can end up being harmful, the researchers found.

If a patient comes into the hospital after 10 days of being sick, Iwasaki says, "and their blood levels of interferon-alpha are sky-high, that's probably an indication that that person needs more attention and [will] potentially need mechanical ventilators." People in the study with high interferon-alpha levels had 4.5 times as high a risk of being admitted to the ICU or dying during the study as people with normal levels.

> The immune system is just throwing the whole kitchen sink at this [virus].
>
> MICHAL TAL

Interferon-alpha itself may not make the illness worse, says Eleanor Fish, an immunologist at the University of Toronto. Instead, it may be an issue of timing. In severely ill patients, elevated levels of interferon may be a consequence of extreme inflammation. These interferons come "too little, too late, but whether it's exacerbating disease needs to be teased out," she says. "What we know is that absence of interferon early on in disease is not a good thing."

Normally, interferons are produced when cells' virus alarms are tripped. Interferons flood the infected area, signal other cells to raise their defenses and help kill infected cells. With most viruses, "if you generate a robust interferon response within a few minutes of exposure to the virus, you're likely going to be fine," Iwasaki says.

But, she says, "in the case of COVID, this well-orchestrated line of events isn't happening." Early on, the virus shuts down the interferon response. That allows the virus to invade the lungs and do damage without setting off early alarms. Other immune chemicals, called cytokines and chemokines, flood the damaged area attempting to expel invaders and heal the tissue, but can set off a "cytokine storm" that further batters tissues. The high levels of interferon-alpha seen in severely ill patients may be produced by cells that don't normally make that chemical in a last-ditch effort to combat the virus, Iwasaki says.

"The earlier you can control the virus, the less damage you're going to get," she says. One promising way of potentially controlling the virus early on is by giving people interferons. For example, in a study of 77 people with COVID-19, interferon-alpha helped clear infections almost seven days sooner on average than arbidol hydrochloride, a drug thought to block viral entry into cells, Fish and colleagues found.

Ramping up interferons didn't lead to an overzealous immune response, as feared. In fact, people taking interferon had lower levels of an inflammatory protein called IL-6 in the blood than people taking the other drug, Fish's group reported online May 15 in *Frontiers in Immunology*. A study of interferon-beta, given along with anti-HIV drugs, also suggests that interferon speeds recovery. The U.K.-based drug company Synairgen reported July 20 in a news release that inhaled interferon-beta reduced the risk of developing severe disease among patients in a small trial compared with people taking a placebo.

More interferon trials are in the works. The U.S. National Institute of Allergy and Infectious Diseases announced August 5 the launch of a clinical trial of about 1,000 hospitalized people with COVID-19 that will test interferon-beta 1a in combination with the antiviral drug remdesivir. But the new study in *Nature* hints that it may be too late to give interferon once a person is sick enough to be hospitalized.

Giving interferon as soon as possible after detecting infection may prevent severe illness and speed recovery, Fish and other scientists say. Interferons may also work as a preventive for people at high risk of contracting the coronavirus. ■

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GENES & CELLS

How anglerfish survive parasitic sex

Some deep sea species lack crucial immune system genes

BY ERIN GARCIA DE JESUS

For deep-sea anglerfish, sex resembles an organ transplant. A male fuses its tissues to a larger female during mating, allowing the two to share not only sperm but also blood and skin. The fish are the only animals known to mate in this parasitic way.

How males and females join and avoid being rejected by each other's immune systems — like a mismatched organ transplant — has been a mystery. Now, a study finds that some species lack key genes involved in the body's immune response, which may make fusion without deadly consequences possible, researchers report online July 30 in *Science*.

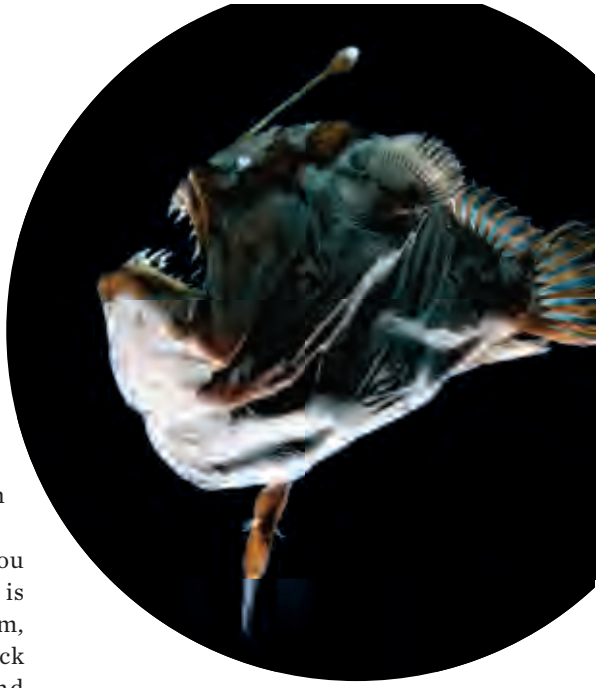
In vertebrates, immune protection typically involves a response called adaptive immunity, which identifies and eliminates foreign threats like viruses. Immune cells, such as T cells, recognize fragments of invaders and present those pieces to other cells that then mount an attack. In another line of defense, proteins called antibodies bind to trespassers to mark them for removal by the immune system.

The genes missing from some deep-sea anglerfish are involved in making those systems work.

"When you look at [these fish], you scratch your head and think, 'How is that possible?' " says Thomas Boehm, an immunologist at the Max Planck Institute of Immunobiology and Epigenetics in Freiburg, Germany. In humans, finding the right match for organ transplants is often difficult because of the adaptive immune system, "but these creatures seem to be doing it without knowing what's going on."

Boehm and colleagues isolated DNA from 31 preserved anglerfish representing 10 deep-sea species. In four species, males attach to females temporarily. In the other six, fusion is permanent, with either one or multiple males attached to a female. The team also scanned the genetic blueprints of three species that live in shallow waters and don't fuse.

Compared with species that don't attach, species that fuse lack genes that



Male deep sea anglerfish fuse to much larger females during mating, such as this male *Melanocetus johnsonii* hanging from the belly of a female. The loss of key immune system genes may explain how the fish endure such mating.

The tuatara s genome holds clues to how the New Zealand reptile lives so long and with stands cool weather.

GENES & CELLS

Tuatara s genetic secrets divulged

Deciphered genome helps explain reptile s unusual traits

BY JAKE BUEHLER

The tuatara may look like a lizard, but it's not. The reptile is the last survivor of an ancient group of reptiles that flourished when dinosaurs roamed the world. Native to New Zealand, tuatara possess a range of remarkable abilities, including living as long as a century, being relatively impervious to many infectious diseases and having peak physical activity at shockingly low temperatures for a reptile.

The first look at the tuatara's complete genetic instruction book, reported online August 5 in *Nature*, reveals insights into how the animal manages these feats.

Tuatara (*Sphenodon punctatus*) were once found throughout New Zealand, but now survive in the wild mainly on offshore islands. The reptiles have suffered from habitat loss and invasive species such as rats, and are imperiled by a warming climate.

This peril — combined with the tuatara's status as a *taonga*, or special treasure, to the Indigenous Maori people — led researchers to prioritize compiling the reptile's genome.

The tuatara genome is huge, about 5 gigabases, or some 5 billion DNA base pairs long, evolutionary biologist Neil Gemmell of the University of Otago in Dunedin, New Zealand, and colleagues discovered. That's about two-thirds bigger than the human genome. And that's "unusually large" for a reptile, says Giulia Pasquesi, an evolutionary biologist at the University of Colorado Boulder who was not involved with the research. Lizard and snake genomes are usually about 2 gigabases, she says.

Based on the genetic analyses, the researchers confirmed that the tuatara is more closely related to snakes and lizards than to crocodilians, birds or turtles. The tuatara and its ancestors diverged from snakes and lizards about 250 million years ago, meaning the group predates even the oldest dinosaurs.

The team identified genes possibly involved in the tuatara's quirks. Tuatara have many genes involved in producing

help produce new antibodies that get better at binding to perceived threats in future encounters. Not having those antibodies might help a female that is exposed to multiple males throughout life, Boehm says. Some species that unite permanently also lack genes needed to make the parts of T cells that help identify foreign tissue and pathogens.

Two of the species in which multiple males can attach to a female may not make antibodies at all.

The team didn't do lab experiments to confirm how the missing genes affect the immune system. So it's hard to know what the missing genes mean. "How are [the fish] balancing ... reproduction and response to infections?" asks Natalie Steinel, an immunologist at the University of Massachusetts Lowell. "It seems, at least genetically, that they've put all their chips on reproduction."

Perhaps the fish have an adaptive immune system unlike that of other vertebrates or have evolved a nonspecific immune response that protects against infections but not parasitic sex. ■

selenoproteins, which help stave off aging and cellular deterioration, and have more of them than humans do.

The tuatara also appears to have an unusually high number of *TRP* genes, involved in making proteins tied to temperature sensitivity and regulation of body temperature. Those genes may explain how the animal has the lowest known optimal body temperature of any reptile, from 16° to 21° Celsius.

Although the new research goes a long way to dispelling some of the mystery surrounding the tuatara, there is much to learn about the scaly enigma. "Publishing the tuatara genome is like uncovering an ancient book," says coauthor and comparative genomicist Matthieu Muffato of the European Bioinformatics Institute in Hinxton, England. "We have started analyzing it, and started decoding some of the genetic information, but we are still a long way off from understanding the complete genome." ■

K. NOLL/STSCI, ESA, NASA

ATOM & COSMOS

Dead stars get slim as they gain weight

New observations confirm paradoxical quirk of white dwarfs

BY MARIA TEMMING

Telescope observations have confirmed a weird property of white dwarf stars: As they pack on more mass, they shrink in size.

White dwarfs, the stripped cores of dead sunlike stars, are thought to have this counterintuitive quality because they contain an exotic material called degenerate electron gas. The more massive a white dwarf, the tighter its electrons must squeeze together to create an outward pressure strong enough to prevent the star from collapsing under its own weight.

Astronomers had observed evidence of this size trend, predicted decades ago, in a smattering of white dwarfs. But data on thousands of stars now show that the rule holds up across a sweeping range of white dwarf masses, Vedant Chandra and colleagues at Johns Hopkins University report online July 28 at arXiv.org.

Understanding how white dwarfs contract as they gain mass could give insight into the origins of type 1a supernovas, says astronomer and coauthor Hsiang-Chih Hwang. These supernovas are thought to occur when a white dwarf gets so massive and compact that it explodes, but no one knows exactly how white dwarf stars detonate (*SN: 4/30/16, p. 20*).

The team examined the sizes and masses of more than 3,000 white dwarf stars observed by the Apache Point Observatory in New Mexico and the European Space Agency's Gaia space observatory. "If you know how far away a star is, and if you can measure how bright the star is, then you can get a pretty good estimate of its radius," says Chandra, an undergraduate physics student. But measuring stellar masses proved trickier because astronomers usually need to see a white dwarf gravitationally tugging another star to get an idea of the white dwarf's heft.

For solo white dwarfs, the researchers studied an effect of general relativity on starlight called gravitational redshift (*SN: 8/18/18 & 9/1/18, p. 12*). As light escapes a strong gravitational field, like the one around a dense white dwarf, the light waves get stretched out into redder wavelengths. The bigger a white dwarf's mass compared with its radius, the more extreme the stretching. That property allowed the researchers to estimate the masses of white dwarf s, given their radii.

A new study of white dwarfs, like the one inside the planetary nebula NGC 2440 (shown), has confirmed a strange property of these stellar remnants.

The new white dwarf measurements closely match theoretical predictions for the smaller sizes of heftier stars. White dwarfs with about half of the sun's mass were about 1.75 times as wide as Earth, while those with slightly more mass than the sun came in closer to 0.75 times Earth's width.

It is reassuring to see white dwarfs following the general expected trend of downsizing as they pack on more mass, says Alejandra Romero, an astrophysicist at the Federal University of Rio Grande do Sul in Porto Alegre, Brazil. Future observations of more white dwarfs could help verify the finer points of this mass-radius relationship, she says — like whether hotter white dwarf stars are, as theory predicts, more puffed up than cooler stars of the same mass. ■

ATOM & COSMOS

To predict solar outbursts, use physics

Forecast successes point to a mechanism behind big solar flares

BY EMILY CONOVER

Forecasting space weather is a guessing game. Predictions of outbursts from the sun are typically based on the amount of activity on the sun's roiling surface.

But a new technique predicts the violent eruptions of radiation known as solar flares based on the physics behind them, researchers report in the July 31 *Science*. When applied to old data, the method predicted several powerful flares, though it also missed some.

Radiation released in solar flares and associated eruptions of charged particles, or plasma, can disrupt radio communications, throw off satellites, take down power grids and endanger astronauts (*SN: 9/30/17, p.* 6). More accurate forecasts could allow operators to switch off sensitive systems or otherwise prepare.

Current prediction methods rely on tracking flare-linked phenomena such as sunspots, dark regions on the sun's surface with powerful magnetic fields. But that leads to some false alarms.

In contrast, the new method is rooted in the intricacies of how and when the sun's tangled loops of magnetic fields rearrange themselves, in a process known as magnetic reconnection.

On the sun's surface, magnetic field lines — imaginary contours that indicate the direction of the magnetic field at various locations — loop and cross over one another like well-mixed spaghetti. When the lines break and reconnect, a burst of energy is released, producing a flare. The details of how and under what conditions this happens have yet to be unraveled.

Physicist Kanya Kusano of Nagoya University in Japan and colleagues propose that the largest flares result when two arcing magnetic field lines join, forming an m-shaped loop, as a smaller loop forms near the sun's surface. This "double-arc instability" leads to more magnetic reconnection, and the m-shaped loop expands, unleashing energy.

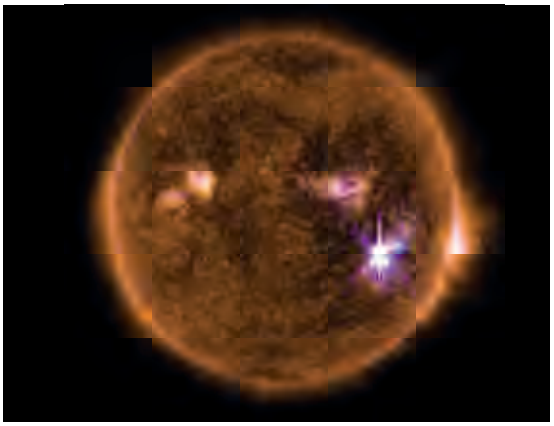
Using over a decade of data from NASA's Solar Dynamics Observatory spacecraft, the team identified regions on the sun with high magnetic activity. For each region, the team determined whether conditions were ripe for a flare-inducing double-arc instability, and then aimed to predict the most powerful flares, X-class flares. The method predicted seven of nine flares stronger than X2, the second weakest X-class subdivision.

The successful predictions suggest the team has identified the physical process underlying some of the largest outbursts.

The unsuccessful predictions are likewise illuminating: The two missed flares had no associated ejection of plasma from the sun's surface. "This kind of instability is maybe not a good way to explain these other flares," says solar physicist Astrid Veronig of the University of Graz in Austria, who wrote a commentary on the result, also published in *Science*. They may instead have resulted from magnetic reconnection high above, instead of close to, the sun's surface.

Solar physicist KD Leka of NorthWest Research Associates in Boulder, Colo., also notes that the method couldn't predict how soon flares will occur after the right conditions first happen and didn't identify slightly weaker X1 flares, which can also be damaging. ■

A new method can predict where large solar flares, like this one in September 2017 (brightest purple spot), are likely to occur.



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ATOM & COSMOS

How to find wormholes

Gravitational wave detectors could locate spacetime tunnels

BY EMILY CONOVER

Gravitational wave detectors have already spotted mysterious black holes. But something even stranger might be next: wormholes.

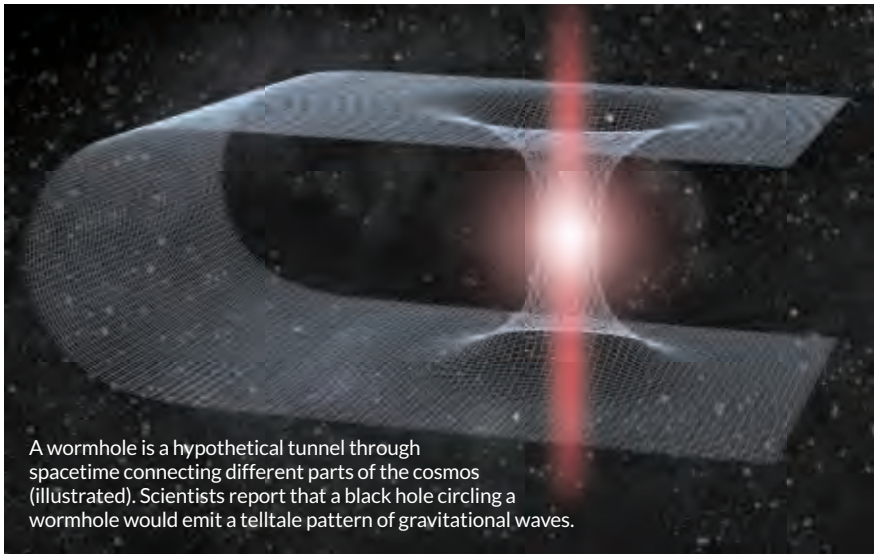
A black hole spiraling into a wormhole would create an odd pattern of ripples in spacetime that the LIGO and Virgo gravitational wave observatories might be able to pick up, physicists report July 17 at arXiv.org. The waves would blink off and on as the black hole passed through the wormhole and then came back.

Wormholes are hypothetical objects in which spacetime is curved into a tunnel that connects distant cosmic locales or potentially different universes. From the outside, wormholes can appear similar to black holes. But while an object that falls into a black hole is trapped there, something that falls into a wormhole could traverse through it to the other side.

There's no evidence that wormholes exist. "These are speculative for sure, with a capital S," says William Gabella, a physicist at Vanderbilt University in Nashville. But if wormholes are real, there's a chance of detecting them via gravitational waves.

Gabella and colleagues considered a black hole with a mass five times the sun's, orbiting a wormhole about 1.6 billion light-years from Earth. As it swings around the wormhole, the team calculated, the black hole would begin by spiraling inward as if it were orbiting another black hole. At first, the resulting gravitational waves would look like a standard signature for two black holes, a pattern of waves that increase in frequency over time called a chirp.

But when it reaches the wormhole's center, called the "throat," the black hole would pass through. If the black hole emerged in a distant realm, such as another universe, the gravitational waves



A wormhole is a hypothetical tunnel through spacetime connecting different parts of the cosmos (illustrated). Scientists report that a black hole circling a wormhole would emit a telltale pattern of gravitational waves.

in the first universe would abruptly die off. In the second universe, the black hole would shoot outward before spiraling back in and passing back through the wormhole to the first universe.

As the black hole returns, it would initially spiral outward from the wormhole, perhaps producing an "antichirp," a pattern of gravitational waves opposite to a chirp's, before plunging back in with a chirp. The black hole would continue bouncing between the two universes, causing repeated bursts of gravitational waves punctuated by silence. Once the black hole lost enough energy to gravitational waves, its journey would end as it settled down in the wormhole's throat.

"You can't reproduce that with two black holes, so it's a clear-cut signal of a wormhole," says physicist Dejan Stojkovic of the University at Buffalo in New York, who was not involved with the research. The waves "should be sticking [out] like a sore thumb," he says.

According to the general theory of relativity, which describes gravity as the result of the curvature of spacetime, wormholes are possible. But actually detecting one would imply the existence of a strange type of matter that physicists don't understand. That's because a substance with negative mass would be necessary to prop open a wormhole's throat to prevent it from collapsing, and no known type of material fits the bill.

Advanced LIGO, or Laser Interferometer Gravitational-Wave Observatory, in the United States and Advanced Virgo in Italy detect ripples from black holes or dense stellar corpses called neutron stars.

Scientists are now skilled at spotting the mergers of such objects, having confirmed more than a dozen since 2015, with more awaiting confirmation. But at some point, physicists will need to focus on more unusual possibilities, says physicist Vítor Cardoso of Instituto Superior Técnico in Lisbon, Portugal. "We need to look for strange but exciting signals." ■

ATOM & COSMOS

Antarctica offers clear views of the sky

High point on the continent may be an ideal place for a telescope

BY MARIA TEMMING

An observatory in the heart of Antarctica would have the world's clearest views of the night sky yet known.

If built on a tower a few stories tall, an optical telescope in East Antarctica would discern celestial features about half the size of those typically seen at Earthbound observatories, researchers report in the July 30 *Nature*. The telescope would achieve such sharp vision by peering above the atmosphere's lowermost layer, the boundary layer, responsible for much of the undulating air that muddles telescope images.

The thickness of Earth's boundary layer varies. At midlatitudes, it can be hundreds of meters thick, limiting the vision of premier optical telescopes in places like the Canary Islands and Hawaii. Those telescopes usually cannot pick out celestial features smaller than 0.6 to 0.8 arc seconds — the apparent width of a human hair from about 20 meters away.

"But in Antarctica, the boundary layer is really thin," says Bin Ma, an astronomer at the Chinese Academy of Sciences in Beijing, "so it is possible to put a telescope above."

Ma and colleagues took the first measurements of nighttime atmospheric blur from East Antarctica's highest point, called Dome A. From April to August 2019, instruments on an 8-meter-tall tower at the Chinese Kunlun Station tracked how Earth's atmospheric turbulence distorted incoming starlight. A nearby weather station also monitored atmospheric conditions, such as temperature and wind speed.

The boundary layer was, on average, about 14 meters thick; as a result, the light sensors at the top of the 8-meter-tall tower were free of boundary layer blur only about one-third of the time. But when these instruments were above the layer, atmospheric interference was so low that a telescope could pick out details on the sky 0.31 arc seconds across, on average. The best recorded atmospheric conditions would let a telescope see features as small as 0.13 arc seconds.

"One-tenth of an arc second is extremely good," says applied physicist Marc Sarazin of the European Southern Observatory in Garching, Germany. But, he notes, building an observatory in Antarctica would be "a huge challenge."

Researchers have found similarly excellent visibility above the boundary layer at another spot in East Antarctica called Dome C. But the boundary layer there is about 30 meters thick — making it more difficult to build an observatory above it. An optical telescope planned for construction on a 15-meter-tall tower at Kunlun could take advantage of Dome A's stellar views above the boundary layer, Ma says. Such crisp telescope images could aid in studies of everything from solar system bodies to distant galaxies. ■

ESTT/ISTOCK/GETTY IMAGES PLUS

EARTH & ENVIRONMENT

Seismic noise from humans plummets

Here s what the pandemic related lull is teaching researchers

BY CAROLYN GRAMLING

Widespread global lockdowns resulting from the COVID-19 pandemic reduced the amount of seismic noise produced by humans by up to 50 percent in some places.

This quiet period began in late January and hit its peak from March to May. It was the longest and most prominent reduction of seismic waves from human activities in recorded history, researchers report online July 23 in *Science*.

Around the world, seismometers don't just pick up loud echoes of earthquakes rumbling through the subsurface. The instruments also detect many subtle reverberations, such as the hum caused by groundwater circulating underground or by ocean swells (*SN: 10/2/04, p. 212*), as well as the periodic tremors that sometimes signal an impending volcanic eruption (*SN: 6/20/20, p. 14*). Seismometers can even detect ground vibrations generated by everyday human activities, such as traffic, construction and parades or football games.

The link between seismic vibrations and noise from human activity is more intuitive than it might seem, says seismologist Thomas Lecocq of the Royal Observatory of Belgium in Brussels. "When we ask people if they heard an earthquake, we often ask, 'Did it sound like a truck passing by?' People associate the rolling sound of a truck with the vibration they feel."

But distinguishing the patterns indicating natural hazards from other seismic signals is tricky. Some patterns have historically stood out: Human-caused rumbles tend to rise and fall with the workweek and subside on holidays. Previous analyses of these signals have tended to be local. As a result, researchers haven't ever mapped the global scope of human seismic noise, Lecocq says.

To assess the change in human-caused seismic noise due to the lockdowns, Lecocq and colleagues focused on seismic signals with frequencies between 4 and 14 hertz. Lower seismic frequencies tend to be more heavily influenced by oceans and weather, Lecocq says, and signals with higher frequencies tend to be more easily absorbed and dampened by the sediments the signals pass through.

Of 268 seismic stations around the world, 185, or 69 percent, showed dramatic reductions in human-caused noise. And the noise reductions' locations shifted along with the lockdowns as the pandemic swept across the globe, appearing first in China, then Europe and then the rest of the world.

The strongest reductions, as would be expected, were in heavily populated areas. A station in Sri Lanka, for example, showed a 50 percent reduction in seismic noise from human activities. Even Sunday nights in New York City's Central Park — normally a relatively quiet time for the city — were 10 percent seismically quieter during the restrictions.

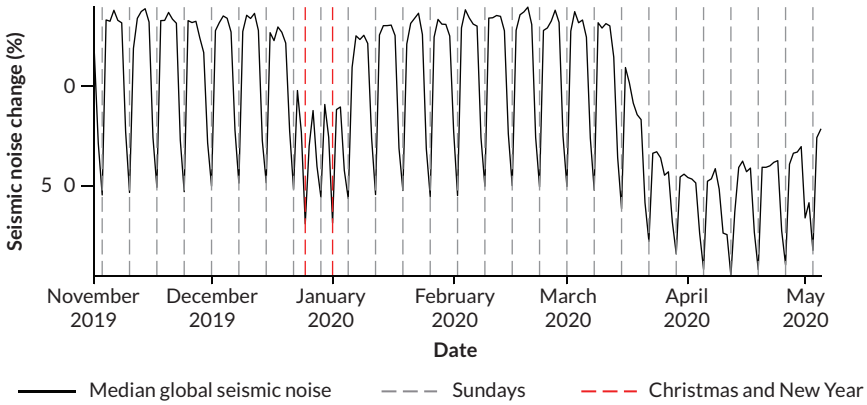
The quiet period also revealed just how prevalent human seismic noise is. Smaller earthquakes that would normally have required computer processing to identify in an urban seismometer's data became much easier to spot. For example, a magnitude 5 earthquake that struck near Petatlán, Mexico, on April 7 was easier to pick out thanks to a 40 percent reduction in human noise in the region.

Researchers have tended to think that the vast majority of recorded human seismic signals come from less than one kilometer away, or don't penetrate deep into the Earth. But the quiet period revealed that seismic waves from human activities have a much larger reach than once thought, Lecocq says. For example, the team found that a seismometer placed 380 meters underground near Auckland, New Zealand, was not only registering human activity, but saw that activity halved during the lockdowns.

Understanding human-caused seismic patterns could help scientists remove some of that noise and possibly be better able to zoom in on natural hazards in the future, Lecocq says.

That's an intriguing possibility, but "it will take time for the scientific community to actually demonstrate that," says Zhongwen Zhan, a seismologist at Caltech who was not involved in the new research. Even more intriguing, he says, is that the study highlights "how seismology can be used to monitor human activities and population dynamics." ■

Global change in average humanca used seismic noise, November 2019 May 2020



A hush falls From March to May 2020, global levels of human seismic noises (black line, representing seismic frequencies between 4 and 14 hertz) dropped up to 50 percent from previous levels due to pandemic related lockdowns. Human activity already tends to decline on Sundays (dashed gray lines) and during the Christmas and New Year holidays (dashed red lines), but dropped even further at the height of stay at home orders.

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HUMANS & SOCIETY

Smallpox goes back to the Viking era

DNA shows the disease has plagued people for over 1,000 years

BY ERIN GARCIA DE JESUS

Some Vikings may have died from one of humankind's deadliest pathogens: the virus that causes smallpox.

Researchers collected DNA from viruses in the remains of northern Europeans living during the Viking Age, some of whom were likely Vikings themselves, and found that these people had been infected with extinct versions of the variola virus that causes smallpox. That finding, reported in the July 24 *Science*, pushes back the proven record of smallpox infections in people by around 1,000 years, to the year 603.

Researchers had previously discovered traces of variola virus DNA in a mummy from the mid-1600s found in Lithuania, which put the common origin of modern strains in the 16th or 17th century.

It is still uncertain when the virus first began to infect people. Smallpox is estimated to have killed as many as 500 million people during the 20th century and is the only human pathogen to have been eradicated globally.

Written records from over 3,000 years ago have documented smallpoxlike symptoms, and scientists have identified possible smallpox skin lesions on mummified remains. But it's difficult to prove that a smallpox virus was the cause.

"This is really exciting work," says Ana Duggan, an evolutionary geneticist at McMaster University in Hamilton, Canada, who was not involved in the research. "Our understanding of this historical and devastating disease just got a lot wider. We are uncovering [variola virus] diversity that was unknown and unappreciated until right now."

Martin Sikora, a computational biologist at the University of Copenhagen, and colleagues isolated viral DNA from the teeth and bones of 1,867 humans who lived about 31,000 to 150 years ago. Of those people, 13 had remnants of the variola virus. Eleven of those people — including some thought to be Vikings — had lived in northern Europe, western Russia or Great Britain during the Viking Age more than 1,000 years ago. The two other people had lived in western Russia during the 19th century and were infected with variola virus strains closely related to modern versions.

The team reconstructed nearly complete genetic blueprints of four of the 11 ancient viruses and found that the Viking-era strains belong to a now-extinct group of variola viruses. During that period, smallpox may have been widespread throughout Europe and could have caused serious disease, Sikora says. It's also possible that if Vikings were infected, they spread the disease as they traveled.

Though the ancient variola viruses are now gone, remnants of their DNA can help uncover humans' extensive relationship with pathogens. "These kinds of pandemics have been part of our history," Sikora says. "What we see today is only the tip of the iceberg of what was around." ■

HUMANS & SOCIETY

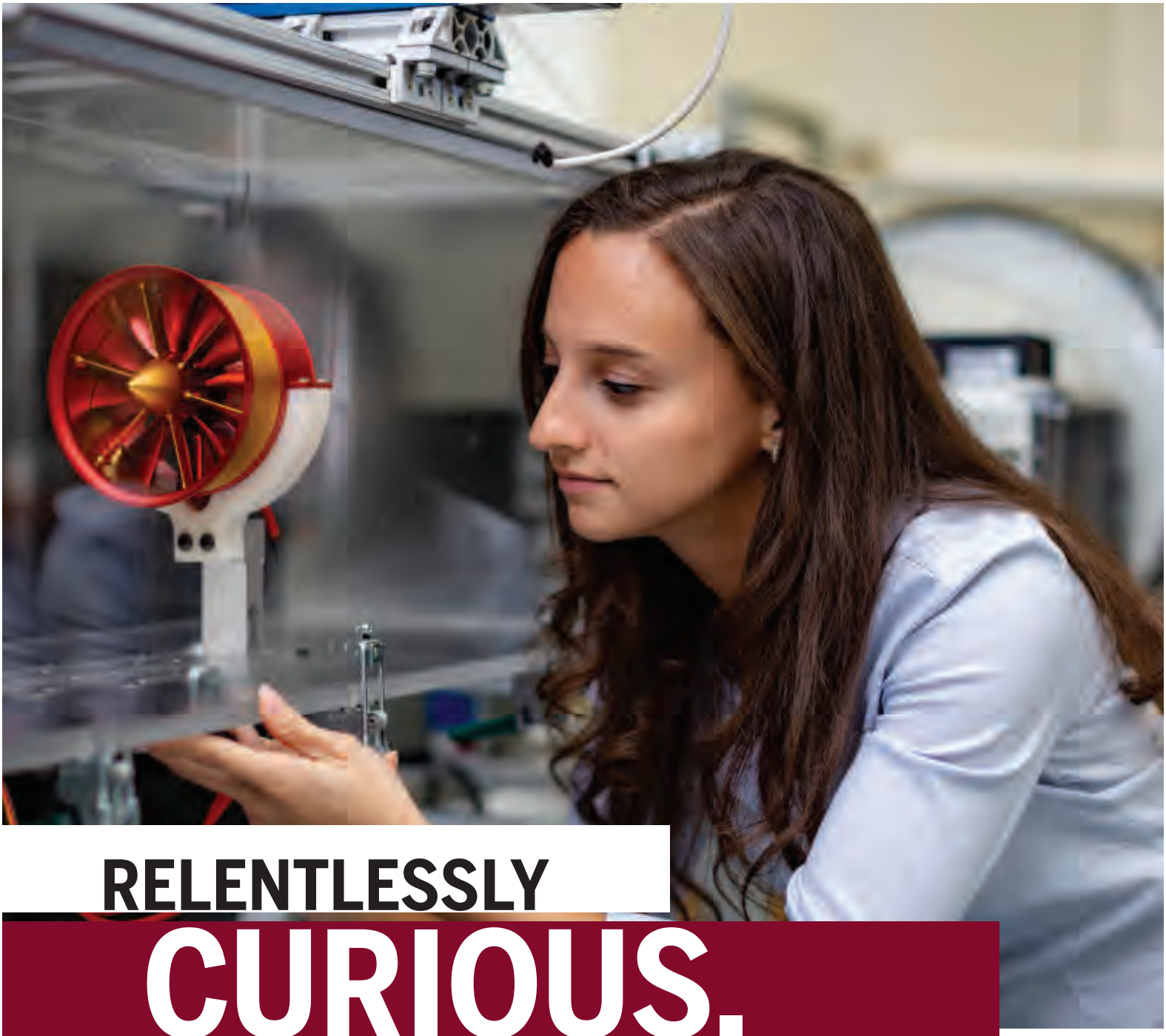
Inca offering found in Lake Titicaca

A stone box fished out of Lake Titicaca adds an intriguing twist to what s known about the Inca s religious practices and beliefs. Divers exploring a reef found the box, which held a tiny llama or alpaca carved from a shell and a gold sheet rolled into a cylinder about the length of a paper clip (shown at right). The objects meaning is unclear.

The discovery s location indicates that the Inca regarded all of Lake Titicaca, on the border between Bolivia and Peru, as a sacred place or deity, not just the lake s fabled Island of the Sun, archaeologists suggest in the August *Antiquity*.

The Spanish described the Inca, whose empire lasted from 1400 to 1532, as believing their ancestors came from the Island of the Sun, about 30 kilometers south of the box s lo cation. Until now, the island was the only Lake Titicaca locale where other stone boxes bearing figurines and gold sheets had been found. Similar items come from sites of Inca child sacrifices in other parts of the Andes. The researchers say there may have been a connection between human sacrifices intended to appease deities and events held at Lake Titicaca, including the submerging of ritual offerings. *Bruce Bower*

T. SEGUIN/UNIV. LIBRE DE BRUXELLES



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LIFE & EVOLUTION

Orb weavers may spin poisonous webs

Droplets on silk strands contain neurotoxins, researchers report

BY CHRISTIE WILCOX

Orb weaver spiders are known for their big, beautiful wheel-shaped webs. These webs do more than just glue a spider's meal in place, a new study suggests — they may also swiftly paralyze their catch.

Biochemical ecologist Mario Palma of São Paulo State University's Institute of Biosciences in Rio Claro, Brazil, has long suspected that these webs contain neurotoxins. The idea first came to him about 25 years ago, when he lived near a rice plantation. He often saw fresh prey, like bees or flies, in orb weaver webs. The hapless animals weren't just trapped — they convulsed and stuck out their tongues, as if they'd been poisoned. If he pulled the insects free, they struggled to walk or hold up their bodies.

These odd behaviors struck Palma as the effects of neurotoxins.

Now, thanks in large part to the work of his Ph.D. student Franciele Esteves, Palma thinks he has found those paralyzing toxins. Palma, Esteves and colleagues analyzed the active genes and the proteins in the silk glands of banana spiders (*Trichonephila clavipes*) — a kind of orb weaver — and found neurotoxins, the team reports in the Aug. 7 *Journal of Proteome Research*.

The prey-catching webs of other orb weaver species probably have similar neurotoxins, Palma says.

Neurotoxin proteins also showed up on the silk of webs collected in Rio Claro, packed into fatty bubbles in microscopic droplets on the strands. When the researchers rinsed substances from webs and injected the runoff into bees, the animals became paralyzed in less than a minute.

Palma suspects that fatty acids in the droplets dissolve an insect's waxy exterior, the chief barrier to topical toxins.

The webs of orb weavers such as banana spiders (shown) may chemically subdue prey.

"Toxic webs would certainly make sense," says David Wilson, a venom researcher at James Cook University in Smithfield, Australia. But he would like to see evidence that the web toxins work quickly on contact before concluding their primary role is to subdue prey. Alternatively, they might act as antimicrobials (*SN: 11/23/19, p. 9*) or help deter ants and other animals that steal from webs or eat the spiders. ■

LIFE & EVOLUTION

Eaten beetle exits the other end alive

Hardy insect actively escapes from frog s digestive tract

BY JONATHAN LAMBERT

For most insects, the sticky, slingshot ride straight into a frog's mouth spells the end. But not for one stubborn water beetle.

Instead of succumbing to digestive juices, an eaten *Regimbartia attenuata* swims through the stomach, scurries along the intestines and climbs out the amphibian's butt, alive and well.

Surviving digestion-by-predator is rare, but not unheard of. Some snails survive the trip through a fish or bird by sealing their shells and waiting it out. But a study in the Aug. 3 *Current Biology* is the first to document prey actively escaping through a predator's backside.

"This is legitimately the first article in a while that made me say, 'Huh! How weird!' " says Crystal Maier, an entomologist at Harvard University's Museum of Comparative Zoology.

After reporting in 2018 that bombardier beetles can force toads to vomit the insects back up by releasing a mix of hot, noxious chemicals (*SN: 3/3/18, p. 10*), Shinji Sugiura of Kobe University in Japan had a hunch that *R. attenuata* also has some interesting evasive behaviors. The ecologist paired a beetle with a frog that the insect encounters while swimming through Japanese rice paddies.

The frog made easy prey of the beetle. Although the amphibian lacks teeth, a trip through the acidic, oxygen-poor digestive system should be sufficient to neutralize the insect. But as Sugiura monitored the frog, he saw the shiny black beetle slip out from the frog's behind and scurry away, seemingly unharmed.

After more than 30 additional beetle-frog pairings, Sugiura found that over 90 percent of beetles survived being eaten. Other creatures known to survive digestion-by-predator typically do so less than 20 percent of the time. Most beetles escaped within six hours, though one intrepid individual made the journey in just six minutes.

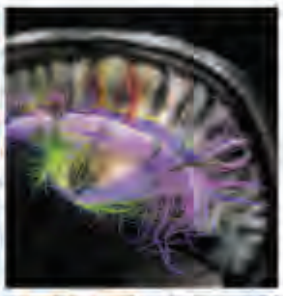
"I was very surprised," he says. "I was expecting that the frogs might just spit out the beetles or something."

By using wax to immobilize some beetles' legs, Sugiura verified that the insects were actively escaping from a frog's digestive tract. No immobilized beetle survived, and the carcasses took a day or longer to pass through the frogs.

An aquatic lifestyle likely prepared the water beetle to survive digestion, Sugiura says. A streamlined, but sturdy, exoskeleton may shield the insect from digestive juices, and an ability to breathe underwater via air pockets tucked under the wings likely prevents suffocation. ■

Watch a beetle escape from a frog at **bit.ly/SN_Beetle**

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LIFE & EVOLUTION

Microbes awaken after epic nap

Even after 100 million years buried in the seafloor, some microbes can wake up.

In an analysis of seafloor sediments dating from nearly 102 million to 4.3 million years ago, most of the sam pled microbes turned out to be dormant, not dead, researchers report July 28 in *Nature Communications*.

The microbes came from sites beneath the South Pacific Gyre, where there are few of the nutrients needed to fuel phytoplankton blooms that support a cascade of ocean life. As a result, very little organic matter makes its way to settle on the seafloor.

But oxygen in the water does seep deep into the sediments. So Japanese researchers wondered whether any aerobic, or oxygen liking, microbes found there might be revivable.

The team fed the microbes nutrients and tracked the organisms activity. Aerobic microbes in the sediments were a highly diverse group and nearly all of them responded quickly to the food. By 68 days after the experiment s start, the total number of microbial cells had increased from as few as about 100 cells per cubic centimeter to 1 million cells per cubic centimeter. Even in the old est samples, up to 99.1 percent of the microbes were revived.

That such ancient microbes can still be metabolically active, the researchers say, just goes to show that scientists are still fathoming the conditions under which life on Earth can survive. *Carolyn Gramling*

LIFE & EVOLUTION

Penguin poop spotted from space ups the tally of emperor penguins

Patches of penguin poop spotted in new satellite images of Antarctica reveal a handful of small, previously overlooked emperor penguin colonies. Eight new colonies, plus three newly confirmed ones, bring the total to 61, researchers report online August 4 in *Remote Sensing in Ecology and Conservation*.

The tally increases the estimated emperor penguin population by roughly 10 percent, or 55,000 birds.

The estimate is based on images from the European Space Agency s Sentinel satellites, which can capture images at a resolution of 10 meters by 10 meters. That s better than the resolution of previous satellites used to find the telltale reddish brown stains of penguin guano against the white snow and ice of Antarctica.

Unfortunately, the new colonies tend to be in regions highly vulnerable to climate change, including a few out on sea ice, says study coauthor Peter Fretwell, a ge ographer at the British Antarctic Survey in Cambridge, England. *Carolyn Gramling*

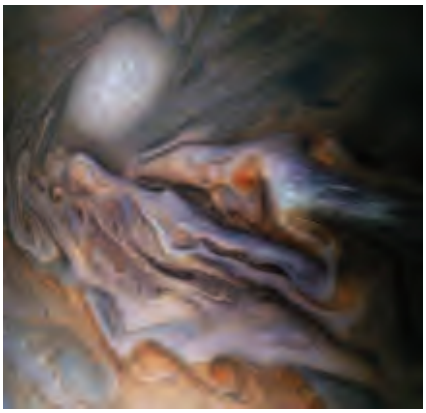
ATOM & COSMOS

Juno spies a new type of lightning crackling across Jupiter s clouds

Small, frequent lightning storms zip across Jupiter s cloud tops, NASA s Juno spacecraft has revealed.

The flashes are about 15 times as frequent as high energy superbolts pre viously spotted on the planet, scientists report in the Aug. 6 *Nature*. Superbolts originate 50 to 65 kilometers below Jupiter s cloud tops, where liquid water droplets form. Scientists think superbolts form like lightning on Earth does: Collid ing ice crystals and water droplets charge each other up, then stretch the charge between them when they separate.

But the newfound lightning appears to come from just 18 kilometers below the cloud tops, where it s too cold for liquid water to exist alone. The shallow light ning must have a different origin than the deeper lightning. Perhaps ammonia in the upper cloud decks acts as antifreeze, creating droplets of ammonia and water combined. Juno has also seen evidence that violent storms in deeper cloud layers sometimes toss ice crystals high above where they re normally found. When those crystals collide with the ammonia water droplets, together they may charge up and create lightning, the researchers reason. *Lisa Grossman*



These wispy, white clouds on Jupiter may mark where ice crystals are thrown upward by storms; such crystals may help form lightning.

ATOM & COSMOS

Scientists can t agree on how clumpy the universe is

The universe is surprisingly smooth.

A new measurement reveals that the universe is less clumpy than predicted, physicists report in a series of papers posted online July 30 at arXiv.org.

The researchers studied the orienta tion of 21 million galaxies with the Kilo Degree Survey at the Paranal Observatory in Chile. As light from those galaxies streams through the universe, the trajectory is bent by massive objects, a phenomenon called gravitational lens ing. This lensing causes the elongated shapes of galaxies to appear slightly aligned, rather than oriented randomly.

When combined with additional data from other sky surveys, that apparent alignment quantifies how much the mat ter in the universe is clumped together. The researchers found that the universe is about 10 percent more homogenous, or smoother, than predicted based on light released just after the Big Bang.

If the measurement is correct, the mismatch could hint at a hole in the standard model of cosmology, the theory that describes how the universe has changed over time. When combined with a similar puzzle about how fast the universe is expanding, physicists are beginning to suspect the universe is put ting them on notice. It s a bit of a riddle, says cosmologist Hendrik Hildebrandt of Ruhr Universit t Bochum in Germany, a coauthor of the studies. Is [the uni verse] just telling us, You re stupid and you didn t do your measurement right, or Hey, I m more complicated than you thought ? *Emily Conover*

Government Melts Over 270 Million Silver Dollars

But collectors get an unexpected second chance

Actual size is 38.1 mm

It's a ***crime.***

Most Americans living today have never held a hefty, gleaming U.S. silver dollar in their hands.

Where did they go? Well, in 1918, to provide aid to the British during WWI, the U.S. government melted down nearly half of the entire mintage—over 270 million silver dollars. If all those missing silver dollars could be stacked, they would tower over 400 miles into the sky! If laid in a chain, they would span 6,400 miles—enough to stretch from New York to Los Angeles more than 2½ times!

These vanished coins were not just any silver dollar–they were America's largest circulated coin, the beloved Morgan Silver Dollar. Each Morgan Dollar is struck from nearly an ounce of 90% fine silver and measures a massive 38.1mm in diameter. Morgan Silver Dollars were the engine of the American dream for decades. Created by famed American coin designer, George T. Morgan, they feature Lady Liberty's radiant profile and a majestic eagle, symbols of American strength and prosperity. Since their inception in 1878, they jingled in the pockets of famous and infamous Americans like John D. Rockefeller and Teddy Roosevelt, and desperadoes Jesse James and Al Capone. Today, Morgan Silver Dollars are one of the most collected coins in America.

Lady Liberty takes a Final Bow

Just three years after the massive meltdown, the government gave the Morgan Silver Dollar a final chance to shine. In 1921, facing a serious shortage, the mint struck Morgan Silver Dollars for one more brief, historic year. Today, the last-ever 1921 Morgan Silver Dollar belongs in the hands of collectors, history buffs, or anyone who values the artistry and legacy of this American classic.

A Never-Ending Hunt for Collector Quality

Millions *more* silver dollars were melted over the past ninety years and today, private hoards account for virtually all the surviving Morgan Silver Dollars. We should know—we're constantly on the hunt for these historic Silver Dollars, and jump at the chance to secure coins in collector-worthy condition. And what luck—we've managed to locate more than a thousand 1921 Morgan Silver Dollars, all in fantastic Extremely Fine (XF) condition. These coins actually circulated in American commerce nearly 100 years ago!

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It's been estimated that as few as 15% of all the Morgan Dollars ever minted have survived to the present day. And the number grows smaller with each passing year. The 1921 Morgan Silver Dollar is the last of its kind. But you can get one now before they're only a memory. Your chance to own this legend won't last long, so get yours today—and at a fantastic value!

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Today, you can secure your very own 1921 Morgan Silver Dollar—the last Morgan Silver Dollar ever struck—for the incredibly low price of just $34.95 each! Plus, you can buy with complete confidence. If you aren't completely satisfied with your Morgan Silver Dollars, you can return your coins within 30-days for a full refund (less s/h). So don't wait—order your 1921 Morgan Silver Dollars today!

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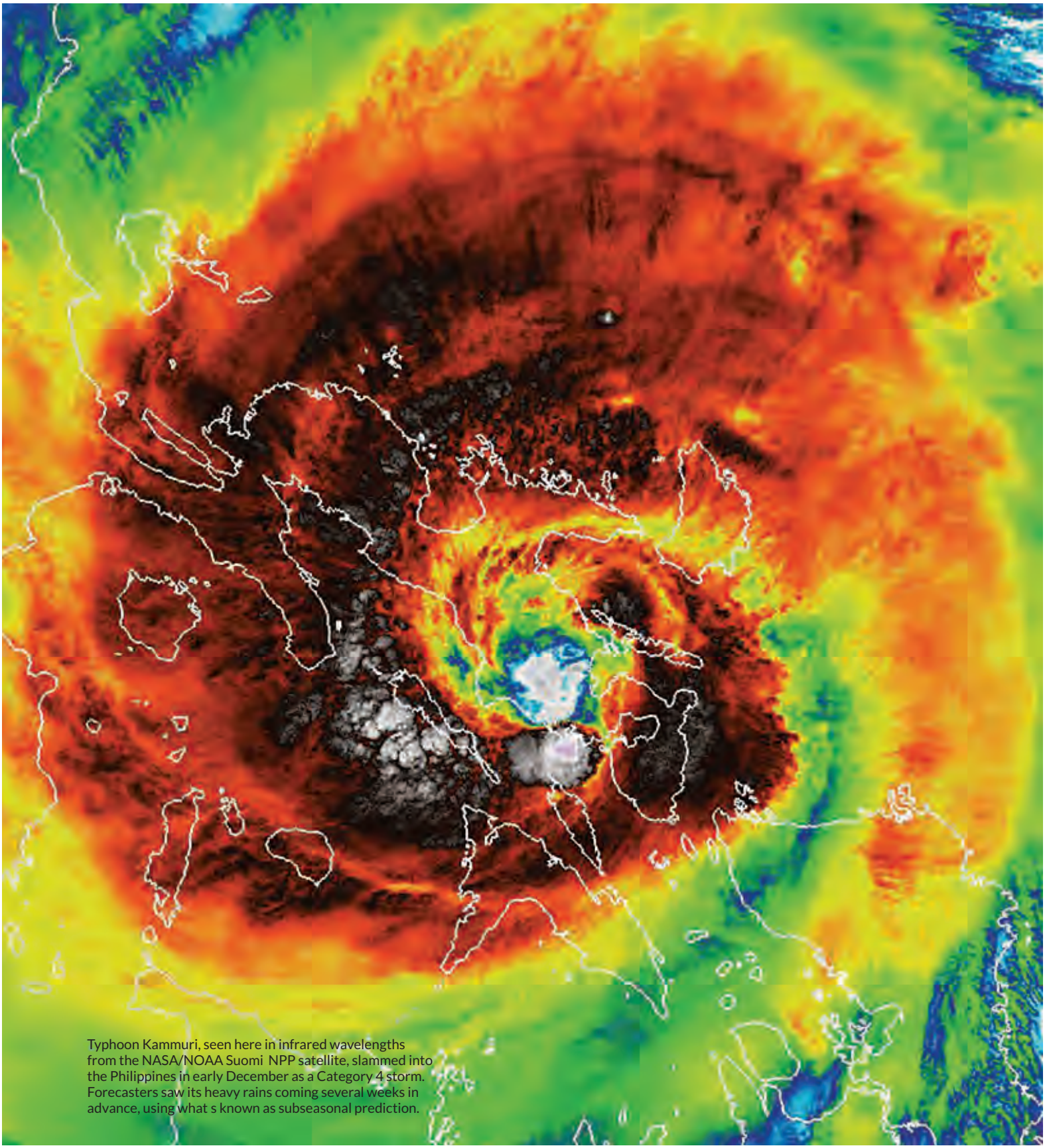


Typhoon Kammuri, seen here in infrared wavelengths from the NASA/NOAA Suomi NPP satellite, slammed into the Philippines in early December as a Category 4 storm. Forecasters saw its heavy rains coming several weeks in advance, using what s known as subseasonal prediction.

CLOSING A GAP IN WEATHER FORECASTING

Researchers hope to improve three week predictions

By Alexandra Witze

Weather forecasters in the Philippines got the tip-off in the second week of November 2019. A precipitation forecast that peered further into the future than usual warned that the islands faced torrential rains more than three weeks away. The meteorologists alerted local and national governments, which sprang into action. Mobile phone and broadcast alerts advised people to prepare to evacuate.

By the time the Category 4 Typhoon Kammuri lashed the Philippines with heavy rains in early December, the damage was much less than it could have been. Having so much time to prepare was key, says Andrew Robertson, a climate scientist at Columbia University's International Research Institute for Climate and Society in Palisades, N.Y. "It's a great example of how far we've come" in weather forecasting, he says. "But we still need to go further."

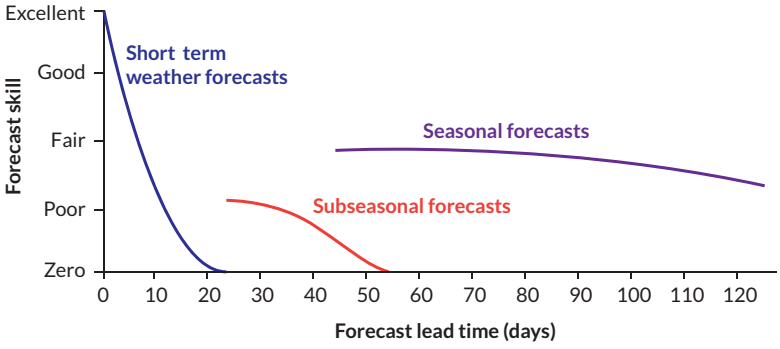
Such efforts, known as "subseasonal forecasting," aim to fill a crucial gap in weather prediction. The approach fits between short-term forecasts that are good out to about 10 days in the future and seasonal forecasts that look months ahead.

A subseasonal forecast predicts average weather conditions three to four weeks away. Each day of additional warning gives emergency managers that much more time to prepare for incoming heat waves, cold snaps, tornadoes or other wild weather. Groups such as the Red Cross are starting to use subseasonal forecasts to strategize for weather disasters, such as figuring out where to move emergency supplies when it looks like a tropical cyclone might hit a region. Farmers look to subseasonal forecasts to better plan when to plant and irrigate crops. And operators of dams and hydropower plants could use the information to get ready for extra water that may soon tax the systems.

Subseasonal forecasting is improving slowly but steadily, thanks to better computer models and new insights about the atmospheric and oceanic patterns that drive weather over the long term. "This is a new frontier," says Frédéric Vitart, a meteorologist at the European Centre for Medium-Range Weather Forecasts in Reading, England.

Room to improve
Short term weather predictions and longer term seasonal forecasts are relatively good. People need something in between, so researchers are trying to improve subseasonal forecasts, which look ahead a few weeks, using information from many sources, including predictable weather systems.
SOURCE: WPO/NOAA

A place for subseasonal forecasting



OPPOSITE: NOAA, NASA, WILLIAM STRAKA III/UWM CIMSS SSEC; THIS PAGE: C. CHANG

The inb etween

Weather forecasters are always pushing to do better. They feed weather observations from around the world into the latest computer models, then wait to see what the models spit out as the most likely weather in the coming days. Then the researchers tweak the model and feed it more data, repeating the process again and again until the forecasts improve.

But anyone who tells you it will be 73° Fahrenheit and sunny at 3 p.m. four weeks from Monday is lying. That's just too far out in time to be accurate. Short-term forecasts like those in your smartphone's weather app are based on the observations that feed into them, such as whether it is currently rainy in Northern California or whether there are strong winds over central Alaska. For forecasting further into the future, what the rain or winds were like many days ago becomes less and less relevant. Most operational weather forecasts are good to about 10 to 14 days but no further.

A few times a year, forecasters draw up seasonal predictions, which rely on very different types of information than the current weather conditions that feed short-term forecasts. The long-term seasonal outlooks predict whether it will be hotter or colder, or wetter or drier, than normal over the next three months. Those broad-brush perspectives on how regional climate is expected to vary are based on slowly evolving planetary patterns that drive weather over the scale of months. Such patterns include the intermittent oceanic warming known as El Niño, the extent of sea ice in the Arctic Ocean and the amounts of moisture in soils across the continents.

Between short-term and seasonal prediction lies the realm of subseasonal prediction. Making such forecasts is hard because the initial information that drives short-term forecasts is no longer useful, but the longer-term trends that drive seasonal forecasts have not yet become apparent. "That's one of the reasons there's so much work on this right now," says Emily Becker, a climate scientist at the University of Miami in Florida. "We just ignored it for decades because it was so difficult."

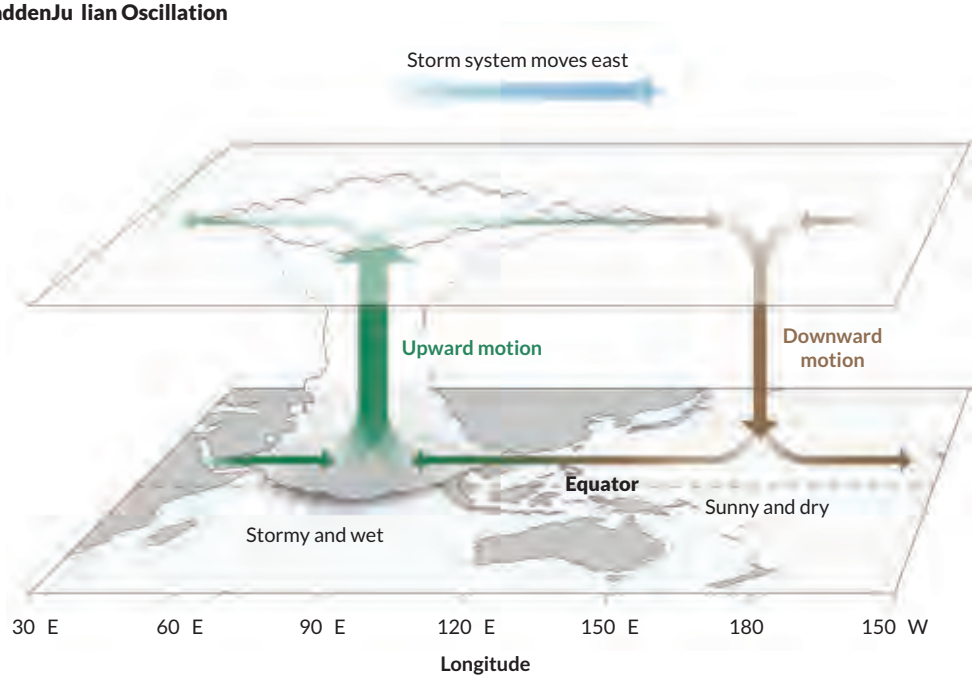
A global impact

Part of the challenge stems from the fact that many patterns influence weather on the subseasonal scale — and some of them aren't predictable. One pattern that scientists have been targeting lately, hoping to improve predictions of it, is a phenomenon known as the Madden-Julian Oscillation, or MJO.

The MJO isn't as well-known as El Niño, but it is just as important in driving global weather. A belt of thunderstorms that typically starts in the Indian Ocean and travels eastward, the MJO can happen several times a year.

An active MJO influences weather around the globe, including storminess in North America and Europe. Subseasonal forecasts are more likely to

MaddenJu lian Oscillation



FIONA MARTIN/CLIMATE.GOV

Distant effects
The Madden Julian Oscillation is a pattern of storms that usually forms several times a year in tropical latitudes and can have weather repercussions around the globe. The MJO travels eastward along the equator as winds push warm, wet air high into the atmosphere, where the air dries out, cools and descends back toward the surface.

Early warnings of Typhoon Kammuri s approach enabled safe evacuations of many thousands of residents of the Philippines in early December 2019.

be accurate when an MJO is happening because there is a major global weather pattern that will affect weather elsewhere in the coming weeks.

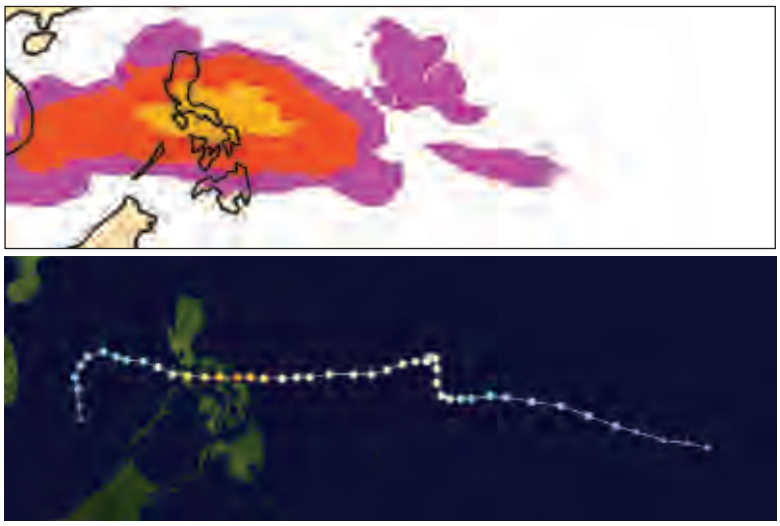
But there's still a lot of room for prediction improvement. The computer models that simulate weather and climate aren't very good at capturing all aspects of an MJO. In particular, models have a hard time reproducing what happens to an MJO when it hits Southeast Asia's mix of islands and ocean known as the Maritime Continent. This realm — which includes Indonesia, the Philippines and New Guinea — is a complex interplay of land and sea that meteorologists struggle to understand. Models typically show an MJO stalling out there rather than continuing to travel eastward, when in reality, the storms usually keep going.

At Stony Brook University in New York, meteorologist Hyemi Kim has been trying to understand why models fail around the Maritime Continent. Many of the models simulate too much light precipitation in the tropics, she found. That light drizzle dries out the lower atmosphere, contributing to the overly dry conditions favored in these models. As a result, when the MJO reaches the Maritime Continent, the dryness of most models prevents the system from marching eastward, Kim and colleagues reported in August 2019 in the *Journal of Geophysical Research: Atmospheres*. In real life, that rain doesn't happen. With this better understanding of the difference between models and observations in this region, researchers hope to build better forecasts for how a particular MJO might influence weather around the world.

"If you can predict the MJO better, then you can predict the weather better," Becker says. Fortunately, scientists are already making those tweaks, by developing finer-grained computer models that do a better job capturing how the atmosphere churns in real life.

Meteorologist Victor Gensini of Northern Illinois University in DeKalb led a recent project to use the MJO, among other factors, to forecast tornado outbreaks in the central and eastern United States two to three weeks in advance. As the MJO moves across and out of the Maritime Continent, it triggers stronger circulation patterns that push air toward higher latitudes. The jet stream strengthens over the Pacific Ocean, setting up long-range patterns that are ultimately conducive to tornadoes east of the Rocky Mountains. In the June *Bulletin of the American*

On target
A forecast made in the second week of November (top) foresaw heavy rains coming more than three weeks later over the Philippines, which did indeed arrive as Typhoon Kammuri (actual path shown, bottom).



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Meteorological Society, Gensini's team showed that it can predict broad patterns of U.S. tornado activity two to three weeks ahead of time.

High above the poles

Another weather pattern that might help improve subseasonal forecasts is a quick rise in temperature in the stratosphere, a layer of the upper atmosphere, above the Arctic or Antarctic. These "sudden stratospheric warming" events happen once every couple of years in the Northern Hemisphere and much less often in the Southern Hemisphere. But when one shows up, it affects weather worldwide. Shortly after a northern stratosphere warming, for instance, extreme storms often arrive in the United States.

In August 2019, one of these rare southern warmings, the largest in 17 years, began over the South Pole. Temperatures soared by nearly 40 degrees Celsius, and wind speeds dropped dramatically. This event shifted lower-level winds around Antarctica toward the north, where they raised temperatures and dried out parts of eastern Australia. That helped set up the tinder-dry conditions that led to the devastating heat and fires across Australia in late 2019 and early 2020 (*SN: 2/1/20, p. 8*).

Thanks to advanced computer models, forecasters at Australia's Bureau of Meteorology in Melbourne saw the stratospheric warming coming nearly three weeks in advance. That allowed them to predict warm and dry conditions that were conducive to fire, says Harry Hendon, a meteorologist at the bureau.

Stratospheric warming events last for several months. As with an MJO, a subseasonal forecast made while one of them is happening tends to be more accurate, because the stratospheric warming affects weather on the timescale of weeks to months. Meteorologists call such periods "forecasts of opportunity," because they represent times when forecasts are likely to be more skillful. It's like how it's easier to predict your favorite baseball team's chances for the season if you know they've just hired the best free agent around.

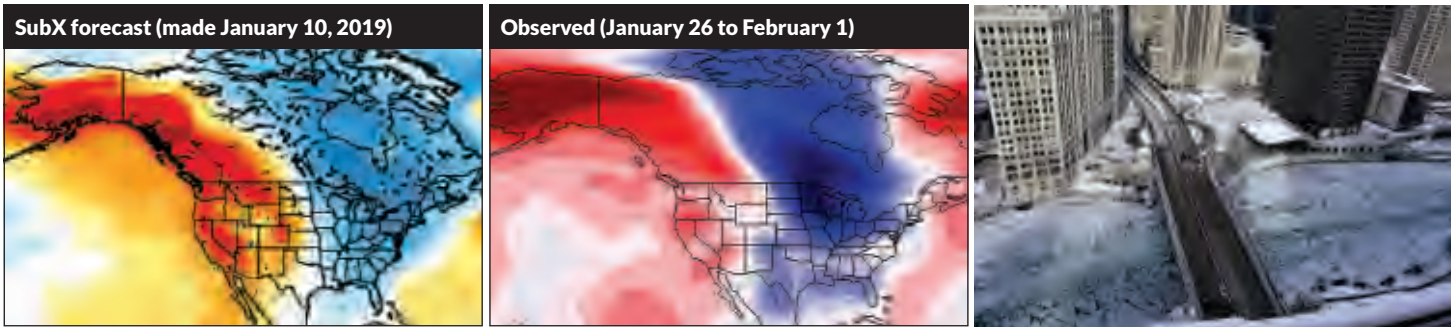
A clearer picture

Now, researchers are pushing wherever they can to eke out improvements in subseasonal forecasts. The European forecast center where Vitart is based has been issuing subseasonal predictions since 2004, which have been improving with time. The U.S. National Oceanic and Atmospheric Administration began issuing similar predictions in 2017; they are not as accurate as the European forecasts, but have been getting better over time. Meanwhile, scientists have launched two big efforts to compare the various forecasts.

Vitart and Robertson lead one such project, under the auspices of the World Meteorological Organization in Geneva. Known as S2S, the meteorological shorthand for "subseasonal to seasonal," the project collects subseasonal forecasts from 11 weather prediction agencies around the world, including the European center and NOAA. The forecasts go into an enormous database that researchers can study to see which ones performed well and why. Kim, for instance, used the database, among others, to understand why models have a hard time capturing the MJO's march across the Maritime Continent.

The second effort, known as SubX, for the Subseasonal Experiment, uses forecasts from seven models produced by U.S. and Canadian research groups. Unlike S2S, SubX operates in nearly real time, allowing forecasters to see how their subseasonal predictions pan out as weather develops.

That proved useful in early 2019, when SubX forecasts foresaw, weeks before it happened, the severe cold snap that hit the United States in late January and early February. Temperatures dropped to the lowest in more than two decades in some places, and more than 20 people died in Wisconsin, Michigan and elsewhere.



Cold calculations
Using a collection of forecasts known as SubX, scientists were able to predict an early 2019 cold snap descending on North America (left, turquoise) several weeks ahead of time (actual event, center, blue). The Chicago River froze (right) during the strongest cold wave in this part of the world in decades.

Nachiketa Acharya (front row, white sweater), Andrew Robertson (behind Acharya) and other climate scientists work with farmers and other residents of Bihar, a state in northern India, to develop and disseminate longer term weather forecasts so that residents can plan when to plant and irrigate their crops.

FROM LEFT: N. ACHARYA; C. CHANG

Having an extra week's heads-up that extreme weather is coming can be huge, Robertson says. It gives decision makers the time they need to assess what to do — whether that's watering crops, moving emergency supplies into place or prepping for disease outbreaks.

In just one example, Robertson and colleagues recently developed detailed subseasonal forecasts of monsoon rains over northern India. He and Nachiketa Acharya, a climate scientist at Columbia University, described the work in January in the *Journal of Geophysical Research: Atmospheres*.

In 2018, the scientists focused on the Indian state of Bihar, where the regions north of the Ganges River are flood-prone and the regions to the south are drought-prone. Every week from June through September, the team worked with the India Meteorology Department in New Delhi to produce subseasonal rainfall forecasts for each of Bihar's regions. The forecasts went to the state's agricultural universities for distribution to local farmers. So when the summer monsoon rains arrived nearly 16 days later than usual, farmers were able to delay planting their rice and other crops until closer to the time of the monsoon, Acharya says. Such subseasonal forecasts can save farmers both time and money, since they don't need to pay for irrigation when it's not needed.

Acharya is now working with meteorologists in Bangladesh to develop similar subseasonal forecasts for that country. There the monsoon rains typically start around the second week in June but can fluctuate — creating uncertainty for farmers trying to decide when to plant. "If we can predict the monsoon onset by around the mid or end of May, it will be huge," Acharya says.

Subseasonal forecasts can also help farmers improve productivity in regions such as western Africa, says Shraddhanand Shukla, a climate scientist at the University of California, Santa Barbara. He leads a new NASA-funded project that is kicking off to help farmers better time their crop planting and watering. The effort will combine satellite images of agricultural regions with subseasonal forecasts out to 45 days. If farmers in Senegal had such information in hand back in 2002, Shukla says, they could have better managed their plantings in the run-up to a drought that killed many crops.

As global temperatures rise and climate changes, meteorologists need to keep pushing their models to predict weather as accurately as possible as far in advance as possible, Vitart says. He thinks that researchers may eventually be able to issue forecasts 45 to 50 days in the future — but it may take a decade or more to get to that point. New techniques, such as machine learning that can quickly winnow through multiple forecasts and pinpoint the most accurate one, may be able to accelerate that timeline.

"There's no single breakthrough," Becker says. "But there are a lot of little breakthroughs to be made, all of which are going to help." ■

Explore more

■ Andrew W. Robertson and Fr d ric Vitart (eds). *Sub Seasonal to Seasonal Prediction*. Elsevier, 2019.

Erasing the Shadow of Early Trauma

Puberty can heal stress responses impaired by a distressing childhood

By Esther Landhuis

A researcher slips stickers under some colored cups on a lazy Susan, then gives the tray a whirl. When the spinning stops, a preschooler must find the hidden stickers. Most children remember where the stickers are, but a few have to check every single cup.

The game tests working memory, which is among the set of mental skills known as executive function that can be impaired in children who faced trauma early in life.

Adversity wreaks havoc, and from there, "you have a system that responds differently," says Megan Gunnar, a developmental psychobiologist at the University of Minnesota in Minneapolis who has spent two decades studying the impact of early-life adversity in adopted children. The focus of this work is extreme adversity, such as being orphaned, rather than everyday challenges, which might teach beneficial resilience (see Page 31).

A childhood characterized by hardship, negligence or abuse can also alter the neuroendocrine system that regulates how the body responds to stress. Problems in the stress response can set kids on a path toward behavior struggles along with increased risk for depression, diabetes and a host of other health problems.

But recent studies offer hints that such a difficult future may not be inevitable. As Gunnar and others have shown, impaired stress responses can return to normal during puberty, raising the possibility that imbalances created by early trauma can be erased. The research is prompting a new view of puberty as an opportunity — a chance for people who had a shaky start to reset their physiological responses to stress.

A sense of safety

When the brain perceives a threat — even a temporary one such as a stressful exam or a high-stakes competition — levels of the hormone adrenaline shoot up, setting off the "fight-or-flight" reaction. Breathing and heart rate soar. Palms get sweaty. Sight and other senses sharpen. Before long, the brain sends chemical messengers to stimulate adrenal glands near the kidneys to release cortisol.

Cortisol sends sugars into the blood for quick energy. The hormone also slows digestion, immune responses, growth and other processes considered nonessential in a fight-or-flight situation.

When the threat passes, the fight-or-flight response ends, at least in a person whose stress response is working as it should. Adrenaline and cortisol levels fall, heart rate slows and other systems resume business as usual.

When Gunnar started her doctoral work in the 1970s, researchers had already mapped out the key actors in the stress response. The neuroendocrine signals involved form the HPA axis, short for hypothalamic-pituitary-adrenal. When rodents and monkeys face early-life adversity, the HPA axis gets thrown off-kilter. As methods became available for measuring cortisol from samples of saliva — rather

A spin the pots task, with colored cups and hidden stickers, tests working memory, which can be impaired in children who experience early hardship.

OPPOSITE: KATTY HUERTAS; THIS PAGE: N.H. BRITO *ET AL/FRONTIERS IN PSYCHOLOGY* 2014

than having to collect blood or urine — Gunnar set out to study how the HPA axis influences the brain and behavior in humans.

From experiments with newborn babies in the mid-1980s, Gunnar showed that having a secure parent relationship is important for a healthy neuroendocrine system and helps babies deal with stressful situations, such as getting immunizations. "You can go to the doctor as a baby and get a big shot in one leg and the other leg, and you're crying your head off ... but [the HPA axis] doesn't kick off," Gunnar says. However, shots or no shots, if babies get separated from their parents for even a few minutes, "their HPA axis shoots up like a rocket."

Gunnar wondered what happens if that sense of safety is disrupted longer-term. She tried studying maltreated and impoverished children, but separating the effects of early hardship from later difficulties is not easy. "The way you start out in life tends to continue," Gunnar says. A report published last November by the U.S. Centers for Disease Control and Prevention points to the long-term consequences: Compared with their peers, adults who experienced childhood trauma are more likely to smoke, drink heavily, have dropped out of high school and develop heart disease and a host of other chronic conditions.

A trip in the mid-1990s set Gunnar on a new path to answer that tricky research question. She ventured with a research team to an orphanage in eastern Romania, where young children were raised in overcrowded, inhumane conditions. "You walk into these wards, and all of a sudden you're mobbed by kids saying 'Mama, mama, mama' ... reaching their arms up to get held," says Gunnar, who had two school-age sons at the time. "It was awful. I just wanted to bring them all home."

What she did bring back to Minnesota, along with that searing memory, was a set of small vials, each containing a saliva sample from a 2- or 3-year-old orphan. To her surprise, the children's cortisol levels — the end product of the neuroendocrine cascade — were lower than the average toddler's. That finding offered a window into the effects of long-term parental deprivation on stress responses.

Adoptee struggles

To single out the effects of early hardship, Gunnar needed children who had started life in deprivation but then moved into healthy, supportive environments after infancy. Such children would be the ideal human analog for all of the animal studies on early adversity, she thought. It dawned on her that this group exists: adopted orphans.

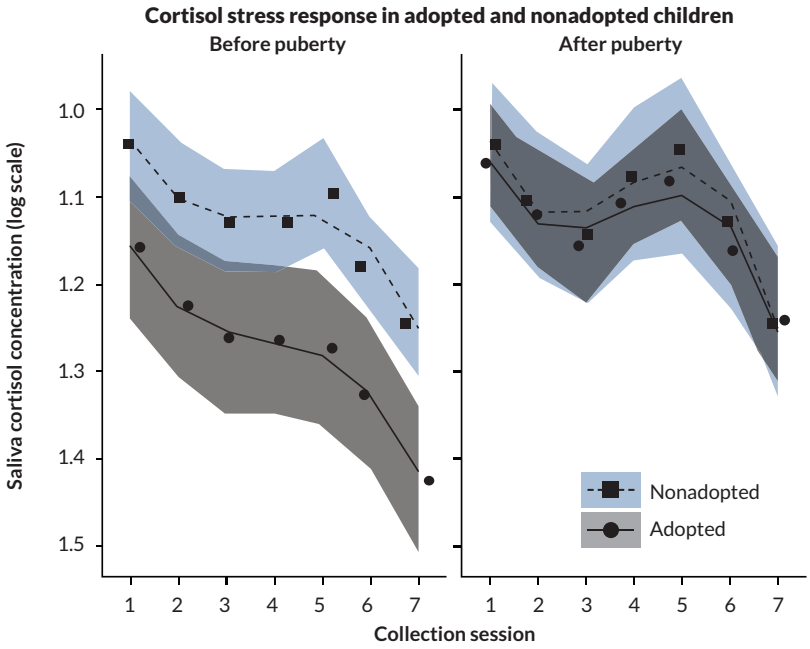
Gunnar shared her idea with members of the adoption unit at the Minnesota Department of Human Services. With the department's support and funding, she surveyed Minnesota parents who had adopted children internationally in the 1990s, and invited families to join a university registry and participate in research.

Many parents in the study had noticed early on that their adopted children had behavioral problems. And when the youngsters came to the university lab for problem-solving and sorting tests, including the lazy Susan task and the famous marshmallow test of delayed gratification (*SN: 8/4/18, p. 14*), the children struggled with attention and self-regulation.

Like the Romanian orphans, these kids had lower cortisol levels than nonadopted children who had no behavioral problems. In the face of sustained hardship, which has the potential to encourage dangerously high levels of cortisol, a weak stress response — that is, producing less cortisol — could be "nature's way of preserving the brain and body," Gunnar speculates.

Studying the adoptees over time, she found that preschoolers with low cortisol often entered kindergarten with attention problems. A blunted stress response persisted into middle childhood, even after an average of seven to eight years in a household with healthy caregiving.

That was disheartening, says Russell Romeo, a psychobiologist at Barnard College in New York City. "We'd always thought that maybe if these



Teen time shift
Before puberty (left chart), adopted children, who grew up with early life trauma (gray curve), had blunted stress responses relative to kids living with biological parents (blue curve). By the time puberty ended (right chart), the adopted children showed normal cortisol patterns before, during and after a stressful task. Saliva was collected 20 minutes and 5 minutes before the task, then 5, 20, 40, 60 and 80 min utes after the task. The researchers converted the data to a logarithmic scale, which shows nega tive numbers. The actual cortisol levels are between 0 and 1 micro grams per deciliter.
SOURCE: C.E. DEPASQUALE, B. DONZELLA AND M.R. GUNNAR/ *J. CHILD PSYCHOL. PSYCHIATRY* 2019

T. TIBBITTS

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individuals get out of the adverse situations, they could start recalibrating their stress reactivity."

But research Romeo had done in the mid-2000s gave Gunnar reason to think she just needed to look further down the road of the children's lives.

High time for change

Romeo was studying rats to see if stress affects adolescent and adult brains differently. In one set of experiments, he subjected adult rats and prepubescent rats to acute stress — 30 minutes trapped inside a wire mesh container — and recorded their levels of corticosterone (the rat version of cortisol) before, during and after the confinement. Both groups produced similar hormone spikes when stressed, but in the juvenile rats, levels took much longer to return to normal.

When Romeo observed how the animals reacted to extended periods of stress — 30 minutes of restraint each day for seven days — the pattern was different. After the animals were released from the restraints, stress hormones surged higher in young rats than in adults. But the rats that were near puberty returned to baseline more quickly than the older animals. Taken together, Romeo's studies suggested that neuroendocrine stress responses get shaped during puberty to emerge differently in adulthood.

In earlier work, researchers at McGill University in Montreal showed that moving adolescent rats

Building resilience

Hardships early in life can mean a difficult road ahead. But some small amount of stress may help kids build mental toughness to handle the stresses of everyday life, such as big exams or performances (*SN: 6/8/19, p. 12*).

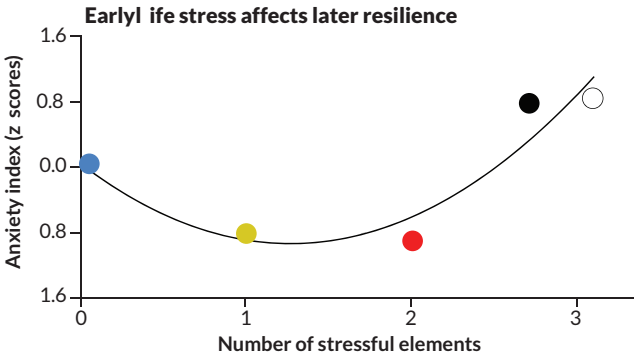
We learn to handle stress by handling stress, says Megan Gunnar, a developmental psychobiologist at the University of Minnesota in Minneapolis.

If a stressful experience shows the world is tough but we can deal with it, perhaps with the help of family and friends, she says, we are tougher the next time. On the other hand, feeling crushed by an intense stressor, such as abuse or a parent s death, can impart a sense of helplessness that leaves young people fearful of it happening again, Gunnar says.

In a 2010 study, researchers surveyed 2,398 U.S. adults to understand how pain and stress affect resilience. Participants answered questions about their mental health and overall well being, and indicated whether they had experienced cumulative lifetime adversities, including a serious illness or divorce in the family. The upshot: People who faced some adversity reported less distress and more life satisfaction compared with those who either experienced heavy adversity or sailed through childhood with ease.

Experiments in monkeys suggest that this is more than a correlation. A team led by David Lyons, a behavioral neuro scientist at Stanford University, reported causal evidence last November in *Scientific Reports*. Since it can be unethical to ran domly assign humans to stressful conditions, the team tested the effects of varying doses of stress in squirrel monkeys that had not yet reached puberty.

The monkeys in the control group enjoyed a typical lab life — housed in a cage with mom and siblings, plus plenty of water, food and toys. A second group faced a mild stressor one hour of separation from siblings once daily for 10 days. The stress dose went up a notch for the third group, which had daily separation from siblings and no access to mom during that hour. Two additional groups experienced daily separation from mother and siblings, plus an injection as an additional stressor.



Some better than none Groups of lab monkeys exposed to mild or moderate stress (yellow and red dots) showed lower anxiety later than animals exposed to no stress (blue) or heavy stress (black and white). SOURCE: K.J. PARKER *ET AL/SCIENTIFIC REPORTS* 2019

Ten weeks later, each monkey was moved with its mother to an unfamiliar cage. The researchers assessed the monkeys willingness to let go of mom and explore the new digs. The team also analyzed blood levels of the stress hormone cor tisol before and after the time spent in the new cage. On the whole, monkeys in the groups that faced one or two stressors clung less to their mothers and more readily explored their new surroundings — showing less anxiety — than both the no stress and the two high stress groups.

Cortisol patterns also reflected this trend: Cortisol levels were closer to normal in monkeys exposed to mild or moder ate stress than in monkeys from the other groups.

Growing up healthy means learning how to deal with mild challenge and change, Lyons says. *Esther Landhuis*

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into "enriched" environments — larger cages with more toys and cagemates — could reset stress responses that had been thrown out of whack by early-life trauma.

These findings heartened Gunnar. "Maybe I should be looking at puberty," she thought. It could be a time to recalibrate.

So her team invited 280 7- to 14-year-olds — 122 children adopted from institutions and 158 from socioeconomically comparable biological families — into the lab to complete two stressful tasks. One involved challenging mental math. For the second task, each child prepared a five-minute speech introducing themselves to a new class of students. The children were told that their speech, given in front of a video camera and a mirror, would be rated by judges. Some kids spoke with confidence, while others looked nervous. "We did have one who burst into tears," Gunnar says. But "we don't torture them. If we think they're too nervous, we help them quit."

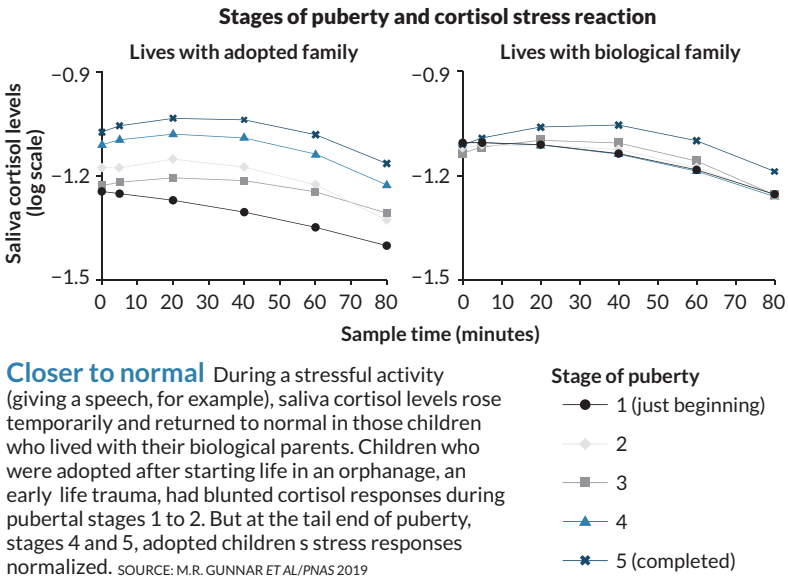
Before and after the speech and math tasks, researchers collected saliva samples from each child to measure cortisol levels. Participants' pubertal status was assessed on a 1-to-5 scale: Stage 1 meant no noticeable body changes and stage 5 meant sexual maturation was complete.

Among kids in early puberty (stages 1–2), adopted kids had blunted cortisol levels before and after the tasks compared with children who lived with their biological parents. This result confirmed Gunnar's previous research on preschool-aged international adoptees. In the late puberty group (stages 4–5), cortisol patterns looked similar for adopted and nonadopted kids.

To confirm HPA recalibration had occurred within the same child, rather than just comparing across age groups, Gunnar and colleagues brought participants in for the same tests one and two years later, for a total of three annual sessions.

The results, reported in the Nov. 26 *Proceedings of the National Academy of Sciences*, show the body can recalibrate its response to stressors during puberty. In other words, something happens in puberty — but not earlier in childhood — that allows the brain to shift back to normal stress responses that had been skewed by early trauma.

Matthew Duggan, a therapist in Long Beach, Calif., who specializes in childhood and adolescence, is encouraged by the findings and thinks they could apply to a wide range of children who have trouble managing their emotions and connecting with others because caretakers abused or ignored them early in life. There may be "a window ... where things might be able to change," Duggan says. "And we have some data here to suggest that at a biological level, that is a possibility. For me, that's really hopeful to see."



Closer to normal During a stressful activity (giving a speech, for example), saliva cortisol levels rose temporarily and returned to normal in those children who lived with their biological parents. Children who were adopted after starting life in an orphanage, an early life trauma, had blunted cortisol responses during pubertal stages 1 to 2. But at the tail end of puberty, stages 4 and 5, adopted children s stress responses normalized. SOURCE: M.R. GUNNAR *ET AL*/*PNAS* 2019

Duggan says Gunnar's study would have been even more useful if it had assessed participants' behavior change — for example, by interviewing parents, teachers or the adolescents themselves.

How might puberty combine with better caregiving and support to reshape neuroendocrine stress responses? Romeo speculates that it stems from the fact that the hypothalamus and other brain areas, such as the prefrontal cortex, that control our reactions to stress are among the regions that rewire and strengthen connections during adolescence.

Whether those changes in the stress response will ultimately harm or help a young person is hard to predict, Gunnar says. Mental health and resilience emerge from an ever-changing combination of genes and life experiences — some of which set the body awry early on. But adolescence could potentially erase some of the damage, her research shows. Gunnar and others hope to reveal more of the underlying biology behind the reboot. ■

Explore more

■ Megan R. Gunnar and Brie M. Reid. Early deprivation revisited: Contemporary studies of the impact on young children of institutional care. *Annual Review of Developmental Psychology*. 2019.

Esther Landhuis is a freelance science journalist in the San Francisco Bay Area.

T. TIBBITTS

EXPERIENCES

In Endangered, the survival of a species is in your hands

Saving endangered species isn't easy. Doing so requires the cooperation of many people — from scientists and conservation organizations to governments and local residents — as well as a bit of luck. That's as true in real life as it is in Endangered, a new board game from Grand Gamers Guild.

Endangered is a cooperative game for one to five players. Each person takes on a role — zoologist, philanthropist, lobbyist, environmental lawyer or TV wildlife show host — and players work together to convince at least four ambassadors to save a species. (In a one-player game, two roles are played simultaneously.) If you get too few "yes" votes, or let habitat destruction spread too much, or if your animal population dies out, everyone loses.

In the board game Endangered, players assume various roles, including philanthropist, environmental lawyer and zoologist, to save an endangered species from extinction.

The game starts with a set of animals in their habitat, either tigers or sea otters, depending on which of the game's two story lines you play. Each player's turn consists of a series of phases. In the first, a player takes actions, such as moving animals to let them mate or obtaining money. In the offspring phase, animal reproduction is controlled by the role of a die. The die also controls where habitation destruction — either deforestation or pollution — spreads. A card draw then brings on other events, from clear-cutting of forests to a shark attack to an animal rescue.

After each player takes a turn, the year ends. And after a set number of years, the ambassadors are consulted. Each ambassador has a different preset list of conditions that must be met to vote "yes."

The game is modular, and each story line has its own challenges and adorable, animal-shaped wooden meeples. (A third story line, giant pandas, is available in an expansion pack, and a Kickstarter that began this month is raising funds for additional animal packs, such as polar bears and California condors.) Each story line has three levels of difficulty, which, combined with the multiple role-playing options, provide plenty of variety throughout multiple plays of the game.

But while the game is fairly simple to set up and learn, winning proved deceptively difficult. Just when I thought I'd get enough ambassadors on my side, I found myself losing all my tigers or awash in pollution.

> I wanted a theme that players can relate to, something engaging and emotional.
>
> **JOE HOPKINS**

The game's scenarios, while simplified, recognize real-world problems for these animals. Poachers and habitat fragmentation indeed threaten tigers, just as oil spills and *Toxoplasma gondii* parasites endanger sea otters. "I wanted a theme that players can relate to, something engaging and emotional," says Joe Hopkins, the game's designer.

Endangered's publisher, Marc Specter, notes that the game's developers consulted with the Center for Biological Diversity to ensure scientific accuracy. And Specter says he plans on donating some of the profits from Endangered to the nonprofit organization.

If there is any downside to the game, it's that Endangered can never hope to encompass the truly vast scope of the extinction problem. A study published in the June 16 *Proceedings of the National Academy of Sciences*, for example, estimates that 515 land-dwelling vertebrate species alone are on the brink of extinction. And scientists have warned that the planet is in the midst of the sixth mass extinction (*SN: 11/28/15, p. 26*).

But Endangered does hold an important lesson for how to move forward. Saving species is not something that scientists or philanthropists or lawyers or any other single group can do on its own. Only by working together do we have any chance of success. — *Sarah Zielinski*

S. ZIELINSKI

Learn more about Endangered at **bit.ly/EndangeredGame**

CONVERSATIONS WITH MAYA

RAY KURZWEIL
Cofounder and Chancellor of Singularity University, Director of Engineering at Google

Maya Ajmera, President & CEO of Society for Science & the Public and Publisher of *Science News*, chatted with Ray Kurzweil, an alumnus of the Science Talent Search and a renowned inventor and futurist. Kurzweil also has written five best selling books, is Cofounder and Chancellor of Singularity University and is a Director of Engineering at Google. We are thrilled to share an edited summary of their conversation.

You are an alum of the 1964 Science Talent Search. How did the competition impact your life, and are there any particular moments that still stand out for you?

The Westinghouse Science Talent Search was the first time I was recognized nationally. President Johnson had just been elected and we met him at the White House. He told us his goal was that our generation would never see the horrors of war.

The Science Talent Search was also the first time I had an opportunity to learn about other high level research projects. There was no internet, and no way to find out about other students research. For my project, I built a computer and programmed it to find melodies and to invent new melodies.

You ve had an extraordinarily varied career, from inventor to researcher to author, including your current role at Google. Can you tell me more about your journey and how you ended up where you are?

I can actually start the century before me, the 19th century, because it was a strong motivator in my life. My mother s mother s mother, my great grandmother, created a school for women. If you were a girl in mid 19th century Europe and went to school at all, it would not go past ninth grade. My great grandmother s school went from kindergarten through the first two years of college. It was considered very controversial. Why would you want to educate a girl? My great grandmother traveled through Europe and lectured about the importance of educating women.

My great grandmother and my grandmother ran the school for 70 years, from 1868 to 1938. After that, my family left Europe because of Hitler s advance into Vienna. When I was 5, my grandmother showed me a typewriter and explained how it worked; this experience led to me become an inventor.

I would collect small devices left around my neighborhood, from broken bicycles to broken radios, and I would put together a compilation of all the devices I found. I had this idea that if I could just figure out how to put things together, I could solve every problem how to overcome disease, how to go into outer space.

By the time I was 12, I found computers. While that s hardly remarkable today, at that time there weren t many computers around.

You have had a large role in inventing a dizzying array of technologies, from the synthesizer to the flatbed scanner. What invention are you most proud of?

I would have to say the reading machine for the blind because it had the biggest impact, in terms of seeing the results of real users. It follows the idea that you can substitute one sense for another.

What is your advice for young people?

It s in high school where students first start getting very serious ideas. In the last generation we saw college students who dropped out and started companies like Apple and Google, and we re seeing many students doing that today. It s really a time to be inventive. Not every invention has to be successful, but we now have technology that enables every age to be creative.

WEINBERG CLARK PHOTOGRAPHY

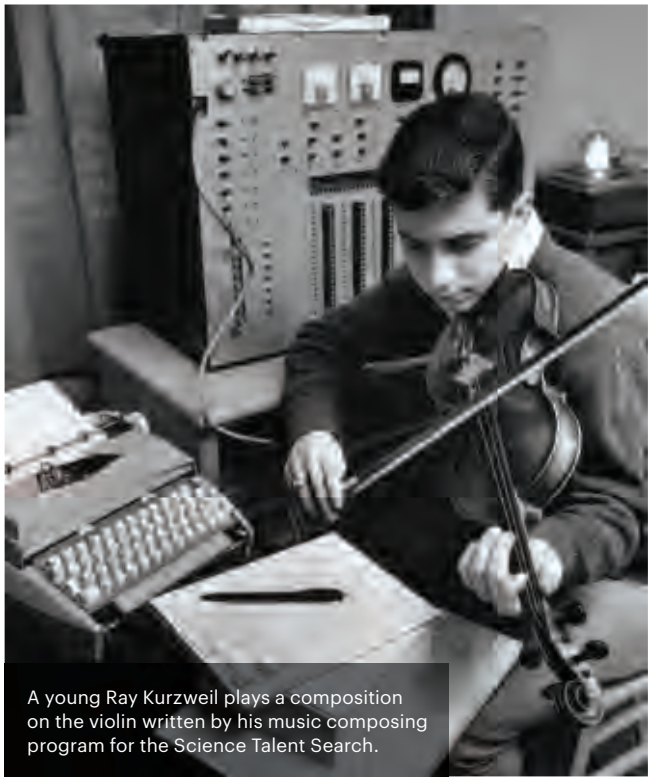
Technology has so many different capabilities, and there are many more opportunities than certainly when I started. I encourage young people to imagine how things could be dif ferent if the technology available was a little more advanced, and then try to imagine how the technologies will advance. If you go through my technology projects, each one was done at a time where the technology would be feasible a few years from the date that I conceived of it.

As a futurist, you popularized the idea of singularity, when artificial intelligence overtakes human thinking. Can you talk a little bit about that theory and what you expect the future to look like?

I got into futurism because often inventions are developed at the wrong time. They are created too late when many other people have something similar. Or they re done too early and you never get where you re going in a reasonable amount of time.

But as a futurist, I can talk about where technology will be in five years, 10 years, 20 years. One thing that has become clear to me is that computers will take over human thinking, although not all at once. As computers get more capable, they will ultimately be able to do everything that people can do.

What we have found is that once a computer can do some thing, such as play a board game, it performs way beyond any human. The expectation is that computers will pass the Turing test, meaning that computers will be able to think like a human, by 2029 and at that point computers actually will do everything that humans can do far better than any human.



A young Ray Kurzweil plays a composition on the violin written by his music composing program for the Science Talent Search.

SSP

People view computers as something we re competing with, but we will actually integrate with this intelligence by extending our human neocortex with them. By the early 2030s, I believe we ll be able to integrate our neocortex to the cloud, which will have advanced AI. And we ll be able to actually take advantage of that.

There s also a very traditional part of you. You are an author who has written best selling books about the future. What is your process?

I have a certain process of planning for the future, which has to do with exponential growth. It has actually been very accurate. My 2010 essay How My Predictions Are Faring examines 147 predictions I made in the 1990s. Eighty six percent of these predictions were correct to the exact year. The other 14 percent were only off by a few years. Combining this method of prediction with my imagining of how these technologies will actually impact our lives is what goes into my books.

You wrote a book for young people called *Danielle: Chronicles of a Superheroine*. What is that book about?

The book is designed to be read alongside two companion nonfiction books, which I ve written. One book is called *A Chronicle of Ideas*, which presents Danielle s unique spin on 482 concepts presented. And the second book is called *How You Can Be a Danielle*, which is basically a guide to help you become a Danielle.

I grew up with a fundamental belief that the power of hu man ideas can change the world, and when we find an idea that can overcome a problem, we need to implement it. And that s Danielle s philosophy.

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

Some people, like myself, are devoted to inventing. My father was devoted to music since he was 5. Other people don t have something they are devoted to yet. My advice to young people is to explore different fields and find something that excites them.

There are so many challenges in the world today. What s keeping you up at night these days?

I do worry about the downsides of technology. Biotech, nanotech, artificial intelligence. I do strongly believe that technology is greatly enhancing human life. In my upcoming book, *The Singularity Is Nearer*, I have a chapter that shows just how dramatically every aspect of human life has improved over the decades and over the centuries. But technology could also be used by a totalitarian state to enforce its power. I think that s why it s important that we keep the promise of technology in mind.

We are going through a terrible time with the pandemic, but I do think that applying scientific ideas will enable us to get out of this.

JULY 4, 2020 & JULY 18, 2020

Mars dust up

Predicting dust storms on Mars will help keep rovers and future astronauts safe on the planet s surface, ***Lisa Grossman*** *reported in Mars dust storm danger* (SN: 7/4/20 & 7/18/20, p. 24).

The story reported that scientists struggle to understand how dust gets lifted into the air. "Have they considered static electricity? A static charge on the dust particles would create repulsion between separate particles and between particles and the ground, levitating them enough to be moved by the winds," reader **Bruce Merchant** wrote.

Yes, electric fields formed by colliding dust grains can help increase the amount of dust in the atmosphere. Though electric forces alone are not enough to explain dust lift on Mars, the forces "are critical in the dust-lifting process and should be taken into account," says **Germán Martínez** of the Lunar and Planetary Institute in Houston. Electric forces also loft dust into Earth's atmosphere, **Grossman** notes. Studies in the Moroccan desert have suggested that electric fields can increase the amount of dust injected into the atmosphere by a factor of 10.

Merchant thought static electricity could have contributed to the demise of NASA's Phoenix Mars Lander and Mars Exploration Rover Opportunity. "Do any current or planned missions to Mars include sensors that could detect and measure static electrical activity?" he asked.

Electric fields associated with dust lifting could affect the performance and lifetime of hardware on Mars, **Grossman** says, "although I don't think it was the critical factor for Phoenix or Opportunity." No past mission has measured electric fields, nor will any of the three missions launched in 2020. The European Space Agency's Schiaparelli lander was supposed to take such measurements, but the lander crashed into the Red Planet in 2016. The ExoMars mission lander slated to launch in 2022 will measure electric fields. "That'll be a precious piece of information," **Martínez** says.

Red Planet preppers

Future Mars explorers will need protections from microgravity and radiation, ***Maria Temming*** *reported in Packing for Mars* (SN: 7/4/20 & 7/18/20 p. 18).

Reader **Henry Jones** wondered if a protective magnetic field could be created to surround a Mars-bound spaceship.

NASA is investigating whether it's possible to build a device that would generate a magnetic field to repel radiation, as Earth's magnetic field does. The idea "is in its infancy," says **Jennifer Fogarty**, chief scientist of NASA's Human Research Program at Johnson Space Center in Houston. "We're all rooting for it.... It would be amazing for something like that to arrive. I can't depend on it, though."

Gassy with a chance of bubbles

Scientists spotted visible light emanating from gas blobs, called Fermi bubbles, that sandwich the plane of the Milky Way galaxy, ***Emily Conover*** *reported in New eyes on the Milky Way s giant gas bubbles* (SN: 7/4/20 & 7/18/20, p. 5).

"Has there been a survey of Fermi bubbles around other galaxies?" reader **Eric Anderson** asked.

Yes, researchers have looked for Fermi bubbles around nearby galaxies, **Conover** says, but the bubbles are not easy to spot. "There is some evidence for bubbles around the neighboring Andromeda galaxy, about 2.5 million light-years away," she says.

Whats in a name?

Astronomers identified two unusual bursts of light, one known as CSS161010 and the other nicknamed the Koala, ***Emily Conover*** *reported in The cosmic Cow now has company* (SN: 7/4/20 & 7/18/20, p. 12).

"A 'cute' nickname for CSS161010 would be Tenten, for the obvious reason, but also because (thanks to a Google search) it is the name of a female character in [the] Japanese manga series ... *Naruto*," reader **Oliver Del Signore** wrote. "If Tenten or some other nickname is eventually assigned, I hope *Science News* will include a short update in a future issue."

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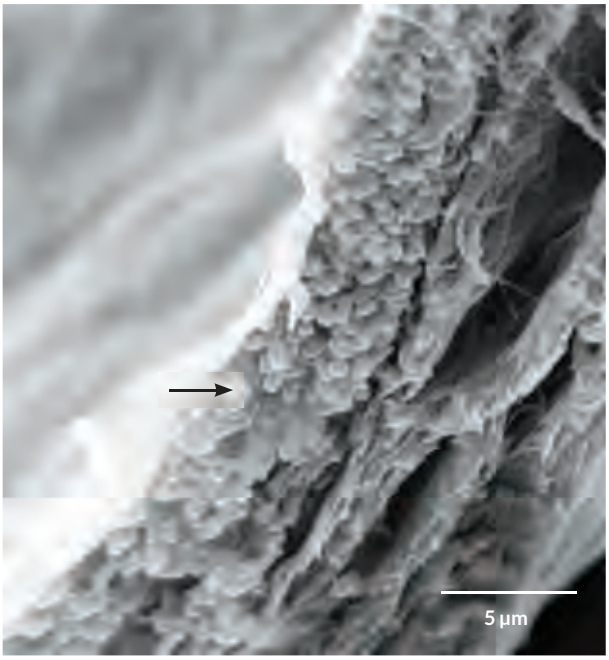

Deep sea fishes sport superdark skin

In the depths of the ocean, it might take more than a little light to illuminate some of the planet's darkest fish.

Some deep-sea fishes, including the Pacific blackdragon (*Idiacanthus antrostomus*) above, have ultrablack skin capable of soaking up almost all light, researchers report online July 16 in *Current Biology*. The skin may help the animals hide from predators or sneak up on prey, and might inspire new designs for superdark materials used in telescopes or fabric.

Little light reaches the deep sea, but bioluminescent creatures can brighten the inky darkness. An analysis of 18 ultrablack deep-sea fish species reveals that they have a layer (black arrow in the electron micrograph image, left) of circular melanosomes just under the skin's top layer. The pigment-containing structures are so tightly packed, the skin can absorb up to 99.95 percent of light.

Other dark-colored fish tend to have more gaps between melanosomes. Those spaces lead to more light being reflected and a more visible fish, say Karen Osborn, a marine biologist at the Smithsonian National Museum of Natural History in Washington, D.C., and colleagues. — *Erin Garcia de Jesus*

FROM TOP: K. OSBORN/SMITHSONIAN NATIONAL MUSEUM OF NATURAL HISTORY; A.L. DAVIS *ET AL*/*CURRENT BIOLOGY* 2020