Florence Nightingale's Data Dive | A Safe Distance for COVID-19?

ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ MAY 9, 2020 & MAY 23, 2020

Coping With Climate Change

SPECIAL REPORT

How to prepare for a warmer world

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COVER A child walks in his flooded neighborhood in Arnold, Mo., on May 4, 2017, after more than a week of rainfall. *Michael B. Thomas/Getty Images*

FROM TOP: SGT. JOSE AHIRAM DIAZ-RAMOS/USDA; J. SCHUBERT; HUBBLE, NASA, ESA, A. SIMON/GSFC, THE OPAL TEAM, J. DEPASQUALE/STSCI, L. LAMY/OBSERVATOIRE DE PARIS

Adapting to climate change, our next global challenge

The coronavirus pandemic is challenging human resiliency like nothing else in our lifetimes. And when we come out on the other side of this crisis, we'll have to address another existential challenge: adapting to climate change.

Some adaptations are already happening. In the last few years, people have responded to climate change–driven fires, floods and hurricanes by rethinking how and where to live. The city of Boston's Climate Ready Boston initiative has created a master plan to help residents cope with increasingly common storm surges and rising sea levels (*SN: 8/17/19, p. 16*). California is trying to figure out how to harden its power grid to reduce the risk of wildfires (*SN: 2/15/20, p. 22*). Most Americans say they see signs of climate change where they live (*SN Online: 11/25/19*).

In this issue, we delve into the science behind key questions in adapting to climate change. Does it make sense to stay in place and develop mitigation measures, as Boston is doing? Freelance writer Mary Caperton Morton examines how data can help people learn the risks in their neighborhood and reviews practical fixes to help protect homes (Page 28). *Science News* earth and climate writer Carolyn Gramling traveled to Orlando, Fla., as it prepares for its new role as a "destination city" for people driven from hurricane- and flood-ravaged coasts (Page 22). And freelance writer Christie Aschwanden digs into the data to find out which personal actions make the most impact in reducing carbon emissions. As she points out, it's OK to start small (Page 34).

This is our spring double issue. Along with the special coverage on climate resiliency, subscribers will find a little treat from us to you: our *Science News* poster celebrating the periodic table. Enjoy! The next issue of the magazine will be in your mailbox in early June.

And of course, you can always find the latest news on our website, sciencenews.org, including our in-depth coverage of the coronavirus pandemic. Stay safe and stay in touch; we're always happy to hear from you. Write to us at feedback@sciencenews.org. — *Nancy Shute, Editor in Chief*

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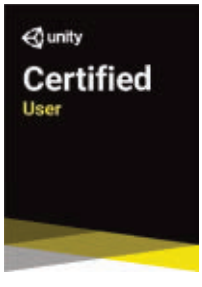

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Excerpt from the May 16, 1970 issue of *Science News*

50 YEARS AGO

Once again for *Ra*

Last year ... a seven-man international crew was abandoning a disabled boat made of papyrus that in two months had taken them 2,700 miles westward in the Atlantic toward Mexico.... Nevertheless explorer-anthropologist Thor Heyerdahl, designer and pilot of the *Ra*, refused to admit defeat.... Late this week, Heyerdahl and his crew were awaiting suitable weather to set off on a second attempt at an Atlantic crossing.

UPDATE: On July 12, 1970, Heyerdahl's crew crossed the Atlantic in a second papyrus vessel called *Ra II*. Heyerdahl wanted to show that ancient Egyptians could have reached the Americas centuries before Europeans did. No evidence of ancient New World Egyptians has been found. But the idea that early civilizations traveled long distances by sea was right. Egyptian and Mesopotamian glass beads reached southern Scandinavia via sea trade by around 3,400 years ago. And seagoing traders connected Viking Age Scandinavians with Muslims in West Asia and the Mediterranean more than 1,000 years ago.

The coloring on this peacock spider's abdomen inspired Joseph Schubert to name the species *Maratus constellatus*, in honor of Vincent van Gogh's "The Starry Night."

THE SCIENCE LIFE

How an arachnophobe became an arachnologist

Joseph Schubert spends hours at a time lying in the dirt of the Australian outback watching for tiny flickers in the sparse foliage. The 22-year-old arachnologist is searching for flea-sized peacock spiders, and, he admits, he's a little obsessed.

But it wasn't always so. Schubert grew up fearing spiders, with parents who were "terrified" of the eight-legged crawlers. "I was taught that every single spider in the house was going to kill me, and we should squish it and get rid of it," he says.

Then Schubert stumbled across some pictures of Australia's endemic peacock spiders, a group named for the adult males' vivid coloring and flamboyant dance moves aimed at wooing a mate. He was hooked.

"They raise their third pair of legs and dance around and show off like they are the most amazing animals on the planet, which in my eyes they are," Schubert says. He decided to pursue a career in arachnology. And despite not yet having completed his undergraduate degree in biology, he is working part time at Museums Victoria in Melbourne and already has made a mark.

Of the 86 known peacock spider species, 12 have been described by Schubert, including seven named in the March 27 *Zootaxa*. Those seven were found at a range of sites across Australia, from the barren dunes and shrublands of Victoria state's Little Desert in the southeast to the red rocks and outback gorges of Kalbarri National Park, north of Perth, in the west.

"I am very lucky to work in this field," Schubert says. "I get to pull out my microscope and observe things that nobody has ever documented before."

Sometimes, Schubert finds a peacock spider by looking for draglines of silk glimmering in the sunlight. As these tiny spiders, of the genus *Maratus*, leap from leaf to leaf in search of insect prey, they extend these safety lines behind them in case they fall.

On a really lucky day, Schubert might spy a male spider mid-boogie, lifting its iridescent abdomen and vigorously waggling its legs in the air as it jerks back and forth in an arachnid tribute to the moonwalk. That usually happens during the Australian springtime in September and October, as the males become sexually mature and take on brightly colored forms. Schubert named one blue species with yellow spots *M. constellatus*, because it reminded him of Vincent van Gogh's painting "The Starry Night."

Still not over his arachnophobia entirely, Schubert is grateful that peacock spiders, while venomous to their prey, are harmless to humans. He's handled hundreds of these spiders and suspects their mouthparts are too small to puncture human skin.

Less charismatic spiders are still a challenge for Schubert's nerves. "But if I can prepare and mentally tell myself that a spider is not looking to hurt me," he says, "then I can put myself in the mental position to handle it."

—John Pickrell

J. SCHUBERT

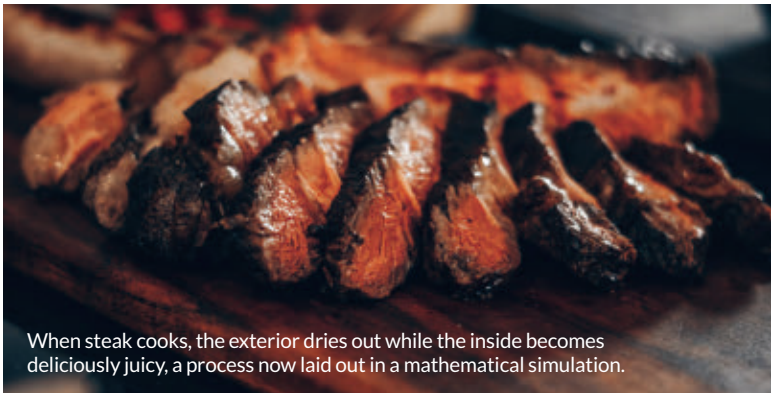
THE EVERYDAY EXPLAINED

Math is the secret to a juicy steak

Applied mathematician Hala Nelson and her colleagues wanted to cook the perfect steak. So they decided to use math.

The researchers created a mathematical simulation of a lean slab of beef roasting in an oven. That simulation successfully reproduced the temperatures and moisture levels seen within meat in laboratory experiments previously performed by food scientists, the team reports in the March *European Physical Journal Plus*.

In the simulation, the steak consists of a two-dimensional network of proteins filled with fluid. Mathematical equations determine what happens in the simulation of meat as it cooks. As observed in experiments, the proteins are deformed, water evaporates and the steak shrinks. The steak's exterior dries out, while liquid moves toward the center, making the interior nice and juicy. Based on how well-done you prefer your steak, or how moist you want it inside, you can use the study results to determine how to cook the meat to perfection, says Nelson, of James Madison University in Harrisonburg, Va. At least if your kitchen provides conditions similar to those used in the lab and the simulation. — *Emily Conover*



When steak cooks, the exterior dries out while the inside becomes deliciously juicy, a process now laid out in a mathematical simulation.

The powdered food additive maltodextrin (right) gets color from a blue dye made from beets.

TEASER

Beets bleed red, but chemists turn it blue

Chemists have made red beet juice blue.

That trick could have commercial uses. Natural colorings for cosmetics and food are in demand, but biology's blue pigments are tough to bottle. The brilliant blues of blue jays and butterflies are a result of light scattering, so there's no pigment to isolate. And juicing blueberries isn't an option, as the pigment doesn't last.

But chemists can add alternating single and double bonds to a molecule's chemical structure to make it absorb different color wavelengths. That can "create molecules that absorb yellow/orange light and ... look blue," says Erick Leite Bastos of the University of São Paulo. Beet pigment has some of these bonds, but not enough to appear blue.

Bastos and colleagues replaced part of the beet pigment's molecular structure with 2,4-dimethylpyrrole, a compound with alternating bonds, to extend the pattern and create a blue hue, the team reports April 3 in *Science Advances*. The dye, called BeetBlue, held up under acidic conditions that fade or alter many blue colorants. It added a pop of color to fabric, yogurt and hair in lab tests and was nontoxic to zebrafish embryos and human cell cultures. — *Carmen Drahl*

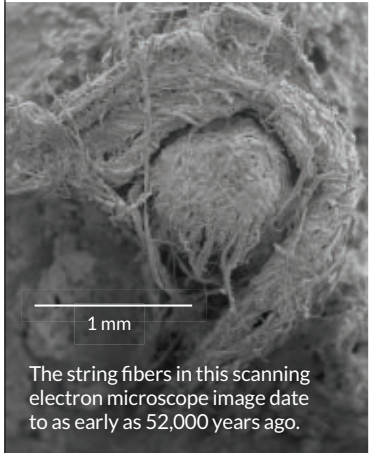
THE –EST

Neandertals made the world's oldest known string

In a new twist on Neandertals' Stone Age feats, our close evolutionary relatives wound bark fibers into strings that could have been used to make clothes, rope, nets and other practical but perishable items, a new study suggests.

A 6.2-millimeter-long fragment of string made from three groups of bark fibers was found attached to a stone tool at a Neandertal site in France. That tool was embedded in sediment dating from 52,000 to 41,000 years ago.

Researchers previously had unearthed stone tools attached to individual, twisted fibers at the site, the Abri du Maras rock-shelter. But as a piece of woven string, the new discovery — described April 9 in *Scientific Reports* — represents the oldest direct evidence of string making. Microscopic and molecular studies indicate the fibers come from the inner bark of a tree such as a pine.



The string fibers in this scanning electron microscope image date to as early as 52,000 years ago.

The ancient string adds to recent evidence suggesting Neandertals thought and behaved no differently than Stone Age *Homo sapiens* did (*SN: 4/25/20, p. 12*).

Previously, the oldest known cords were made in western Asia by humans, who twisted wild flax fibers into twine as early as about 32,000 years ago. — *Bruce Bower*

CLOCKWISE FROM TOP: EMERSON VIEIRA/UNSPLASH; M-H. MONCEL; AVALON_STUDIO/E+/GETTY IMAGES PLUS; E.L. BASTOS

BODY & BRAIN

What is a safe social distance?

Six feet may not be enough to avoid spreading coronavirus

BY TINA HESMAN SAEY

In February, a man in Chicago brought food to two friends who had recently lost a family member and hugged them. The next day, the man attended the funeral, where he comforted other mourners. A few days later, he attended a family birthday party.

The man had symptoms of a mild respiratory illness. Later he would learn he had COVID-19 and had set off a chain reaction that sickened at least 16 people, three of whom died. At the time, the disease had yet to circulate widely in Chicago.

The case now serves as a cautionary tale in support of recommendations that people keep their distance from anyone outside their immediate household, researchers report in the April 17 *Morbidity and Mortality Weekly Report*. But how much distance is needed to avoid spreading the coronavirus?

Six feet (or two meters) has become the mantra. The World Health Organization and other experts have said SARS-CoV-2, the virus that causes COVID-19, is spread mainly by large droplets sprayed when people cough or sneeze, contaminating surfaces. So six feet, plus frequent handwashing, was thought to be enough to halt or at least slow the virus' spread.

But new evidence suggests that distance may not be enough. If SARS-CoV-2 is airborne, as scientists suspect, people could become infected by inhaling the virus in smaller, aerosol droplets exhaled simply by someone talking or breathing.

What's actually safe is unknown. It may depend on many factors, including whether people are inside or outdoors, whether they are wearing masks and how far the virus can really fly.

Say it, spray it

When people exhale, talk, sing, cough or sneeze, a cloud of droplets of various sizes exits the mouth or nose, says Lydia Bourouiba, an MIT fluid dynamicist. Researchers have worried mainly about bigger droplets — 5 to 10 micrometers in diameter or larger.

Bigger droplets can pack in more infectious organisms, raising the infection risk if someone comes into contact with them. But big droplets are thought rarely to travel more than a meter or two before hitting the ground or other surface.

Those droplets might infect people by direct contact, such as when someone coughs or sneezes in your face. But researchers think indirect contact is the main way people catch viruses, says Qingyan Chen, a mechanical engineer at Purdue University in West Lafayette, Ind., who studies how infectious diseases spread. Indirect contact might occur when an infected person uses a hand to cover a cough or a sneeze, then touches a cup or another object. If an uninfected person handles the object, the virus could transfer to that person's hands. An unwitting nose scratch, eye rub or finger food snack could then infect that person. That's why handwashing is so important.

Breathing in smaller aerosols, exhaled or coughed up by an infected person, may also cause infection. Tiny droplets have a hard time overcoming drag from air and are thought to hang around a person, within a meter or so (a few feet).

Hence the six-foot rule: It was thought to be far enough to be safe from both occasional long-range spit bullets and invisible clouds of smaller particles.

But droplets spewed from the lungs come in a continuum of sizes, from those visible to the naked eye to microscopic droplets, all churning through the air as a turbulent cloud, Bourouiba says.

"This cloud, in fact, changes everything about the dispersal of the drops that you don't really see," she says. The warm, moist exhaled air within the turbulent cloud has forward momentum from breathing, coughing or sneezing, carrying droplets of all sizes much farther than previously thought. In the case of a sneeze, droplets can travel up to eight meters (27 feet), Bourouiba reports online March 26 in *JAMA*. Even small droplets, along with any virus they carry, may spread throughout a room.

Coughs also can propel aerosols beyond six feet, evidence suggests. Over three flu seasons, fluid mechanics engineer Eric Savory of the University of

A sign in a park in Vancouver, Canada, warns pedestrians to keep their distance from each other to avoid spreading coronavirus. How far away is safe depends on the circumstances.

GOTOVAN/FLICKR (CC BY 2.0)

To get the latest news on COVID-19, visit www.sciencenews.org/coronavirus

Western Ontario in London, Canada, and colleagues asked people with flu, respiratory syncytial virus or cold-causing coronaviruses to cough into a large box. The team measured how fast and far the viruses traveled.

Even a meter away from the mouth, droplets in the cough still travel at about a meter per second. "It's not a speed you can avoid by turning your head away," Savory says. Volunteers who were ill, convalescent or healthy all coughed at about the same velocity. Study results were reported online April 18 in *Indoor Air*.

Small droplets slowed as they got farther from the mouth, Savory says. But his data don't indicate a safe distance. "A good guidance is you're lessening your risk [of infection] the farther you are away from someone."

Aerosol droplets containing infectious SARS-CoV-2 particles can hang around in the air for hours.

Hidden danger

The smallest airborne droplets may be more of a worry than once recognized.

Aerosol droplets containing infectious SARS-CoV-2 particles can hang around in the air for hours, a study in the April 16 *New England Journal of Medicine* found. The experiment, conducted under lab conditions, measured air samples for only three hours, but found infectious viruses. Some researchers have criticized the study because the virus-laden droplets were made using a medical machine, not by methods that more closely mimic breathing.

But people experience the spread of aerosol particles every day, says William Ristenpart, a chemical engineer who studies the spread of airborne particles at the University of California, Davis. If someone on one side of a large room lights a cigarette, puts on perfume or opens a box of chocolate chip cookies, the smell eventually reaches the other side of the room. Turbulence created by air mixing carries aerosol droplets around the room. No cough or sneeze is necessary.

In an April 1 report, U.S. National Academies of Sciences, Engineering and Medicine researchers also concluded that the coronavirus might spread through aerosol particles.

Add to that the fact that people can spread the virus before developing symptoms or without ever having symptoms. Almost half of people who tested positive for COVID-19 in Iceland had no symptoms when diagnosed, researchers report online April 14 in the *New England Journal of Medicine*.

People without symptoms aren't coughing and sneezing. But they are talking and breathing.

Simply talking face-to-face with an infected but asymptomatic person may be enough to spread the virus, Ristenpart and colleagues propose April 3 in *Aerosol Science and Technology*. Standing six feet apart may cause people to raise their voices to be heard. People speaking louder produce more aerosols and larger droplets, Ristenpart and colleagues reported in 2019. "There's a compelling case that one should be suspicious of conversation as a possible vector for transmission," he says.

Speech generates hundreds of big, wet drops, other researchers report online April 15 in the *New England Journal of Medicine*. But that study was not able to measure droplets smaller than 20 micrometers across, says Harvard biologist Matthew Meselson, who wrote a commentary on the study. Other research has found that talking produces thousands of aerosols from the lungs for every saliva droplet from the mouth, he says.

It's too early to tell whether aerosols and big droplets produce different severities of infection, he says. The pandemic may change doctors' and researchers' view of how respiratory viruses in general spread, Meselson says. "I think we'll find we really were behind the curve when it comes to thinking about how disease is transmitted through the air."

What's safe?

Findings about aerosol and symptom-free spread led the U.S. Centers for Disease Control and Prevention to recommend on April 3 that everyone wear masks in public. With medical-grade masks in short supply, that has led to a rush to create homemade cloth or 3-D printed masks, but few studies have assessed such masks' effectiveness.

A mask of any sort may help the wearer release fewer droplets into the air, helping to protect other people. But a mask "does not replace social distancing," Bourouiba says. And with social distancing, there are no easy answers for how far is a safe distance.

Indoors, heating and air conditioning units may bring in fresh air and cycle out virus-laden air. But they may also draw virus toward certain parts of a room, as might ceiling fans. So it may be hard to know how best to avoid contact.

In a grocery store, for example, a six-foot distance between patrons may limit the spread of larger droplets, says Meselson. "It's better than two feet, and 10 feet is better than six, but for aerosol, I don't know what to say." Aerosol particles can linger long after a shopper has gone home, potentially infecting workers or people who visit the store later. His advice: "Try not to go into any enclosed space if you have any reason to believe there was an infected person inside."

For walking around outside, six feet is probably a safe distance, particularly if people are wearing masks. "When you're walking, you're walking through your exhaled breath with every step, but it's quite well diluted," says Julian Tang, a virologist and fluid dynamicist at the University of Leicester in England. And there is little side-to-side air movement, so stepping off the path to walk by someone else carries little risk, he says. "It's quite transient. They're coming towards me, and then they're gone."

But the idea of a "safe" distance outdoors depends on if, and which way, the wind is blowing. A breeze may carry virus-laden breath farther than six feet, says Donald Milton, an infectious disease specialist at the University of Maryland School of Public Health in College Park. "If there's a strong breeze blowing, probably nobody should be downwind from each other." ■

EARTH & ENVIRONMENT

Tree rings tell a story of megadroughts

Southwest's recent dry spell is one of the worst in 1,200 years

BY CAROLYN GRAMLING

The drought in southwestern North America that lasted from 2000 to 2018 is among the most severe to strike the region in the last 1,200 years, a new study finds. Tree ring–based reconstructions of past climates reveal there was only one 19-year period drier than this recent one: a powerful "megadrought" in the late 16th century. The recent drought, researchers say, was made 47 percent more severe by human-caused climate change.

Tree rings are yearly growth bands that vary in width depending upon the availability of water. Using tree ring records from 1,586 sites across the western United States and northwestern Mexico, researchers created a climate history for the region going back to about the year 800. Between about 850 and 1600, several decades-long, intense megadroughts struck the region, on a scale not seen again until the present day, hydroclimatologist Park Williams of Columbia University and colleagues report in the April 17 *Science*.

A particularly devastating drought that lasted from about 1575 to 1593 is recounted in both historical records and tree ring reconstructions alike, Williams says. "That was a really impressive event, and kind of the last gasp of the megadrought era," he says. That drought may have contributed to the abandonment of New Mexico pueblos and the spread of disease brought by Spanish conquistadors among Native Americans.

> The recent drought was made 47 percent more severe by human-caused climate change.

One of the biggest factors controlling precipitation in southwestern North America is the El Niño–Southern Oscillation, a natural cycle in which changes in tropical Pacific Ocean temperatures can alter regional weather patterns (*SN: 5/28/16, p. 13*). During "La Niña" episodes of this pattern, colder Pacific sea surface temperatures create atmospheric waves that block Pacific storms from reaching southwestern North America, reducing rainfall. The 16th century megadrought, for example, coincided with a powerful La Niña event.

"Over the last two decades, we've had a cluster of more La Niña–like years than El Niño–like years," Williams says.

But La Niña alone was not responsible for the recent drought's intensity, the team found. The scientists examined 31 climate simulations and stripped away underlying common temperature and precipitation trends related to human-caused climate change, leaving only natural variability. In that hypothetical modern world, the recent drought would have been less severe.

These findings add to mounting evidence that rising global temperatures in the last few decades have exacerbated the impact of reduced precipitation from La Niña events, for example, by further drying out soils and reducing snowpack and river flow, says paleoclimatologist Connie Woodhouse of the University of Arizona in Tucson, who was not involved in the study.

Williams notes that a wet 2019 offered a brief respite to the region—just as megadroughts in the past contained the odd wet year. Dry conditions resumed in 2020, and climate simulations for the next few decades predict both increasing temperatures and reduced precipitation in this part of the world.

"The take-home is that the West is in a serious drought; not [just] the worst in 50 years, but on a millennial-type timescale of importance," Williams says.

Natural variability, like an El Niño year that could bring more rain to the region, could help alleviate drought over the next century, Williams adds. But "as time goes on, it's going to take more and more good luck to end these types of droughts, and less and less bad luck to go into one of these droughts again." ■

Using tree rings, such as the ones seen in this cross section of a ponderosa pine from north of Tucson, Ariz., researchers determined that the 2000–2018 drought in southwestern North America was one of the region's most severe in the last 1,200 years.

P. WILLIAMS

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HUMANS & SOCIETY

Lucy had a brain that grew slowly

Prolonged childhood probably arose before the genus *Homo*

BY BRUCE BOWER

Lucy's kind had small, chimplike brains that grew at a slow, humanlike pace.

This discovery, reported April 1 in *Science Advances*, shows for the first time that prolonged brain growth in hominid youngsters wasn't a by-product of having unusually large brains. An influential idea over the last 20 years has held that extended brain development after birth arose in the genus *Homo* about 2.5 million years ago, so that mothers — whose pelvic bones and birth canal had narrowed by that time to enable efficient upright walking — could safely deliver babies.

But *Australopithecus afarensis*, an East African hominid best known for Lucy's skeleton, also had slow-developing brains that reached only about one-third the volume of people's brains today, say paleoanthropologist Philipp Gunz of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, and colleagues. *A. afarensis* lived about 4 million to 3 million years ago, meaning slow brain growth predates *Homo*.

The hominid species *Australopithecus afarensis* (a reconstructed adult, shown) foreshadowed the long period of childhood brain growth typical of people today, a new study suggests.

Too few *A. afarensis* infants have been studied to calculate the age at which this species attained adult-sized brains, Gunz cautions. The brains of human infants reach adult size by nearly age 5, versus an age of about 2 or 3 for chimps.

Gunz and colleagues estimated brain volumes based on the braincases of six *A. afarensis* adults and two children, both estimated to have been about 2½ years old. The kids had brains that were smaller than adult *A. afarensis* brain sizes in a proportion similar to human children's brains at the same age relative to adult humans' brains.

Those data suggest that, for Lucy's species, "infant brain size [relative to that of an average adult] may have been proportionally even smaller than in human infants," says biological anthropologist Zachary Cofran of Vassar College in Poughkeepsie, N.Y. If so, that pattern would strongly point to an extended period of brain growth for *A. afarensis*.

Extended growth may have eased physical and nutritional burdens on *A. afarensis* moms caring for infants, especially if food was scarce, Gunz say. It also "likely provided a foundation for the evolution of long childhoods in the human lineage."

His group used CT scans to study the *A. afarensis* braincases. The team made

ATOM & COSMOS

New class of particles appears in 2-D

Some types of anyons may be useful for quantum computing

BY EMILY CONOVER

Sometimes, two dimensions are better than three.

In our 3-D world, there are two classes of elementary particles: bosons and fermions. But in two dimensions, theoretical physicists predict, there's another option: anyons. Now, scientists report evidence that anyons exist and behave unlike any known particle. Using a tiny "collider," researchers flung presumed anyons at one another to help confirm their identities, physicists report in the April 10 *Science*.

All known elementary particles can be classified as either fermions or bosons. Electrons, for example, are fermions. Photons, particles of light, are bosons. The two classes behave differently: Fermions avoid one another, while bosons can clump together.

Anyons are predicted to fall somewhere in between, not entirely avoiding one another or clumping up. Since we don't live in two dimensions, Gwendal Fève, a physicist at the Laboratoire de Physique de l'Ecole Normale Supérieure in Paris, and colleagues searched for anyons within a 2-D layer of material. There, anyons could show up as "quasiparticles," disturbances within a solid material that behave like particles. Such quasiparticles can form when gangs of electrons emulate another variety of particle, sort of like how a school of fish can move in a coordinated fashion to mimic a strange, shimmery creature, confusing predators.

Scientists had already seen evidence for anyons within 2-D materials in a strong magnetic field. Quasiparticles in these materials have a charge that is a fraction of an electron's, as predicted for anyons. But scientists hadn't yet confirmed that the quasiparticles fully qualify as anyons: Researchers hadn't seen the expected bunching behavior in between that of bosons and fermions.

In the new study, anyons traveled within a 2-D plane sandwiched inside a layered material. The researchers created two streams of anyons, directed so that they would collide and then exit along one of two paths.

Antisocial fermions would have gone their separate ways after the collision. Bosons would have clumped at the same exit. Fève's group saw clumping, but the amount of clumping, and how it changed as the scientists varied the rate at which anyons were sent into the collider, was consistent with predictions for anyons.

"It's quite conclusive. It's a very

LORENZA PHOTOGRAPHY/ALAMY STOCK PHOTO

3-D digital reconstructions of impressions made by the brain on the skull's inner surface. These endocast reconstructions show folds and creases in brain tissue typical of humans or chimps, though preservation varies. Scans also let the team assess the youngsters' ages by revealing microscopic layers of dental enamel that form daily in childhood.

One child's endocast had a crease and a set of grooves toward the back of the brain that are found in chimps. Humans lack these markings due to expanded neural tissue that integrates visual and sensory information. Neither child had evidence of humanlike frontal brain organization.

Much remains to be learned about *A. afarensis*' pace of brain growth, says paleoanthropologist Aida Gomez-Robles of University College London. Because brain sizes of *A. afarensis* individuals can't be tracked from infancy into adulthood, the results don't conclusively determine growth rates, she says. Earlier interpretations of hominid brain organization based on endocasts have sparked debate, so Gomez-Robles is withholding judgment on the brains of Lucy's kind. ■

carefully performed experiment, and it's a very hard experiment," says theoretical physicist Bernd Rosenow of the University of Leipzig in Germany. In 2016, he and colleagues had proposed such an experiment.

When anyons swap places or loop around one another, physicists predict, the quasiparticles' quantum states are altered. Identifying this process, known as braiding, would more fully clinch the case for anyons' existence, says physicist Chetan Nayak of Microsoft Quantum and the University of California, Santa Barbara.

Braiding some types of anyons may be a useful method for building better quantum computers. Current versions of those computers are highly susceptible to mistakes slipping into calculations. Like a neat plait that keeps unruly hair in line, braided anyons could store information in a manner that is resistant to such errors. ■

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LIFE & EVOLUTION

Oxpeckers alert rhinos to danger

Birds' calls made the mammals aware of approaching humans

BY GLORIA DICKIE

Red-billed oxpeckers hitching rides on black rhinos are a common sight in the African bush. The birds feed from lesions full of parasites on a rhino's hide. New research suggests that the relationship between the two species is mutualistic. Shouty and shrill oxpeckers can serve as an alarm bell, alerting rhinos to the presence of people, scientists report online April 9 in *Current Biology*. That could help the animals evade poachers, the researchers propose.

"Rhinos are as blind as bats," says Roan Plotz, a behavioral ecologist at Victoria University in Melbourne, Australia. Even in close proximity, a rhino can struggle to spot danger. But the oxpecker takes notice, unleashing a sharp warning call.

In South Africa's Hluhluwe-iMfolozi Park, Plotz and Wayne Linklater of California State University, Sacramento approached 11 black rhinos (*Diceros bicornis*) by foot on the open plain on 86 occasions. Rhinos with a red-billed oxpecker (*Buphagus erythrorynchus*) tagging along were better at detecting the pair's presence than those without.

"Rhinos without oxpeckers on their back were able to detect our approaches just 23 percent of the time whereas rhinos with oxpeckers detected [us] every single time," Plotz says. Rhinos listening to the oxpeckers' heads-up also picked up on the approaching scientists from about 61 meters away, more than twice as far as the lone rhinos did.

In response to the birds' alarm calls, the rhinos became vigilant — standing up from a resting position, for example — and turned to face downwind, their sensory blind spot. Rhinos then ran away, walked downwind to investigate or maintained a vigilant stance.

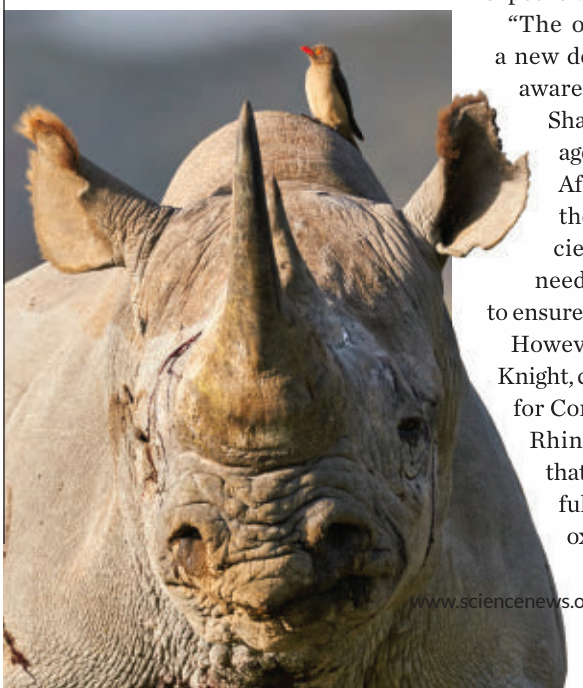
Black rhinos were once the most numerous rhino species in the world. Though poaching has slowed since a peak in 2015, just 5,500 black rhinos remain in the wild and conservationists are searching for solutions to protect the species.

Red-billed oxpecker populations have also declined. For decades, farmers have treated livestock with pesticides to kill ticks, inadvertently poisoning oxpeckers that feed on ticks from the cattle and causing the birds to die out in some regions. In turn, many black rhinos must navigate the landscape without their avian companions. Plotz thinks conservationists should consider reintroducing oxpeckers to rhino populations.

"The oxpeckers are clearly adding a new depth and dimension to rhino awareness levels," says ecologist Jo Shaw, Africa rhino program manager at World Wildlife Fund South Africa. "This emphasizes further the complex webs between species within ecosystems and the need for conservationists to work to ensure all functions remain intact."

However, wildlife ecologist Michael Knight, chair of the International Union for Conservation of Nature's African Rhino Specialist Group, cautions that a lot of poaching occurs during full-moon nights, when sleeping oxpeckers would be less help. ■

Red-billed oxpeckers can warn black rhinos of potential dangers that the rhinos don't see.



ATOM & COSMOS

Auroras could heat up Saturn

Mystery of the planet's warm atmosphere may be solved

BY LISA GROSSMAN

Saturn's auroras may heat the planet's atmosphere like an electric toaster.

Data from NASA's Cassini spacecraft show that Saturn's upper atmosphere is hottest where its auroras shine, a finding that could help solve a long-standing mystery about the outer planets.

Saturn's upper atmosphere is much hotter than scientists first expected based on the planet's distance from the sun. In fact, the upper atmospheres of all of the solar system's gas giants — Saturn, Jupiter, Uranus and Neptune — were thought to be about –120° Celsius. But data from the Voyager spacecraft, which flew past the outer planets in the 1970s and '80s, showed a surprisingly toasty upper atmosphere of 125° to 325° C on Saturn, and even hotter on Jupiter and Neptune.

Something must inject extra energy into these planets' atmospheres. "Trying to explain why these temperatures are so high has long been a goal in planetary atmospheric physics," says planetary scientist Ron Vervack of Johns Hopkins University's Applied Physics Laboratory in Laurel, Md.

Cassini data may point to an answer, planetary scientist Zarah Brown of the University of Arizona in Tucson and colleagues say April 6 in *Nature Astronomy*.

After orbiting Saturn for 13 years, Cassini finished its mission with a series of dips between the planet and its rings before plunging into the atmosphere in late 2017. During those orbits, Cassini probed Saturn's upper atmosphere by watching stars in the background. Measuring the amount of starlight that the atmosphere blocks told Brown and colleagues how dense the atmosphere is at different points, a clue to temperature.

The team mapped Saturn's atmospheric temperatures across the whole planet and at different depths.

The atmosphere is hottest around 60° N and 60° S latitudes — roughly where glowing auroras show up. Auroras sparkle when charged particles, typically from the sun, interact with a planet's magnetosphere, the region defined by the planet's magnetic field. Unlike Earth's auroras, Saturn's glow mainly in ultraviolet light.

The auroras' light doesn't emit much heat on its own, but is accompanied by electric currents that can generate heat like the wires in a toaster. This process also happens in Earth's atmosphere.

If Jupiter's, Uranus' and Neptune's auroras also coincide with extra heat, then auroras may explain hot atmospheres across the solar system.

Saturn's auroras (one shown in ultraviolet light at the top of this composite image) may be warming the planet's upper atmosphere.

"The real test of whether they're right," Vervack says, will be seeing what happens on Uranus or Neptune, whose magnetospheres are more complicated than Saturn's. "Being able to see how our understanding from Saturn holds up when we get to these more complicated systems is going to be really key to knowing if we've licked this problem or not." ■

ATOM & COSMOS

'Oumuamua may be from a dead planet

Simulations show how the interstellar visitor could have formed

BY CHRISTOPHER CROCKETT

The solar system's first known interstellar visitor has a new proposed origin story. The enigmatic celestial object known as 'Oumuamua might be a shard of a planet ripped apart by its star's gravity, researchers suggest April 13 in *Nature Astronomy*.

Ever since 'Oumuamua showed up in our solar system in 2017, astronomers have struggled to explain its origin, suggesting that it might be a wayward asteroid, comet or even alien spacecraft.

Searching for other explanations, astronomers Yun Zhang of Côte d'Azur Observatory in Nice, France, and Douglas Lin of the University of California, Santa Cruz developed computer simulations in which planetary bodies got too close to their parent stars.

In these simulations, objects ranging in size from comets to rocky planets orbit relatively lightweight stars. The scientists found that if these bodies come within about 600,000 kilometers of their star — Mercury never gets closer to our sun than 80 times that distance — then the star's gravity shreds the objects and flings the fragments into interstellar space.

If 'Oumuamua were such a fragment, that might explain its odd shape, its tumbling motion and why it sped up as it left the solar system. The simulated planetary shards tumble and tend to be cigar-shaped, similar to 'Oumuamua. As 'Oumuamua got heated by our sun, buried ice could have produced water vapor. The gas could then have escaped through porous rock and generated a little thrust akin to a tiny rocket, giving our fleeting visitor a nudge as it rounded the sun.

This plausible origin story links 'Oumuamua's strange properties to planet formation throughout the galaxy, says Yale astronomer Gregory Laughlin.

However, Harvard astronomer Avi Loeb sees a plot hole. Based on this one encounter, astronomers can roughly estimate how many other 'Oumuamua-like objects must be whizzing around the galaxy. To account for that number, "one needs each star to produce roughly a quadrillion such objects." But planetary shredding should be rare, requiring the bodies to pass through a tiny sliver of space around a star, he says.

And that's assuming a doomed object doesn't evaporate rather than break up, Loeb says. "The statistics of such events makes the proposed scenario unlikely." ■

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ATOM & COSMOS

Pandemic postpones black hole work

Event Horizon Telescope team focuses on mining existing data

BY LISA GROSSMAN

The scientists behind the first picture of a black hole are squeezing everything they can from the data they've got.

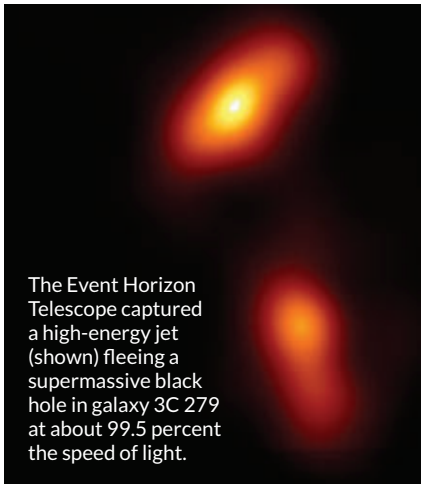
A year after presenting a portrait of the supermassive black hole in the galaxy M87 (*SN: 4/27/19, p. 6*), the Event Horizon Telescope team faces a two-year data drought due to technical snafus, security snags and a global pandemic.

"The coronavirus has set us back a bit," says astrophysicist Sheperd Doeleman of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., the founding director of the EHT. "Nothing is immune, not even black holes."

The delay may push back answering questions about how black holes shoot speedy jets of charged particles into space and could postpone getting a clear view of the black hole at the center of the Milky Way. But the team is still analyzing existing data and making plans to expand the observatory in the future.

The EHT is a global network of radio telescopes that together form a telescope that's effectively the size of Earth. Spanning the globe lets the EHT zoom in on a black hole's event horizon, the region beyond which not even light can escape.

In 2019, the EHT team revealed the first direct image of a black hole's event horizon: an asymmetric ring of light representing the shadow of the black hole on its glowing disk of plasma. The image was made from data taken in 2017, with seven telescopes at five sites.



The Event Horizon Telescope captured a high-energy jet (shown) fleeing a supermassive black hole in galaxy 3C 279 at about 99.5 percent the speed of light.

J.-Y. KIM ET AL/ASTRONOMY & ASTROPHYSICS 2020

The results confirmed aspects of Einstein's general theory of relativity and bolstered physicists' understanding of black holes. But some surprising pieces were missing: M87's supermassive black hole shoots jets of plasma light-years into space, yet the EHT saw no sign of the jets.

In 2020, EHT scientists had hoped to bring the number of observatories in the network to 11. The team also planned to start observing at higher frequencies of radio emission, which can penetrate the plasma around black holes more easily.

"I think that's kind of a game changer," says EHT team member Kazu Akiyama, an astrophysicist at the MIT Haystack Observatory in Westford, Mass., of those future observations. Adding more sites would provide sharper images, letting the team zoom in on M87's jets. And peering through plasma in the Milky Way could help clarify astronomers' view of our own galaxy's supermassive black hole.

The 2020 observations, scheduled for March 25 through April 5, were canceled due to the coronavirus pandemic. The team had done a dry run as recently as January, sending astronomers to some of the most remote parts of the world to make sure telescopes were ready. But by the time astronomers would have had to set out to the observatories again, travel restrictions and lockdowns were in effect.

"It was only with the greatest reluctance, but with safety paramount, that we canceled the observations," says Doeleman. "We're happy to be part of the solution, actually, by not traveling. But it is still heartbreaking."

The 2019 observations were also canceled for a variety of reasons, from technical issues to bad weather to fuel thieves blocking the road to a telescope.

So the team is now sifting through already collected data. "We still have a lot of excellent science even in the 2017 dataset," says EHT deputy director Michael Hecht of the Haystack Observatory. And "the 2018 dataset is mostly unutilized to this point."

One result from the 2017 data is the sharpest view yet of a jet zipping away from a supermassive black hole in a galaxy called 3C 279. Unlike M87, which is about 55 million light-years from Earth, 3C 279 sends its light from about 5 billion light-years away. That great distance let astronomers see features of the black hole's jet that are too close to see at M87.

"We're really looking at the deepest region of the jet ... because we have a very sharp eye," Akiyama says. At just a few light-years from the black hole's maw, the jet is already moving at about 99.5 percent the speed of light, the EHT team reports online April 7 in *Astronomy & Astrophysics*. Astronomers have seen such jets zoom along at extremely high speeds far from their black holes, but it was thought that jets needed more of a runway to accelerate to such great speeds.

"What was surprising is that, even for the inner region of the jet, the jet is already accelerated very close to light speed," the maximum speed at which matter can move, Akiyama says.

The team is also still working on parsing the structure of the magnetic field near M87's giant black hole, which will be a clue to how that black hole's jets form. And the team hopes to publish details about the Milky Way's supermassive black hole by the end of 2020, says Akiyama, though he couldn't say what.

Meanwhile, Doeleman is looking further into the future. Over the next decade, he and colleagues want to add 10 or so telescopes to the network. The EHT has relied on telescopes that already existed, and the team had to make observations work from wherever those telescopes were. Now that scientists know the EHT works, they can select locations for smaller telescopes — perhaps even in space — to get even better views.

"The announcement last year showed everyone what the EHT is capable of," Doeleman says. "We have a freedom we didn't have before." ■

ATOM & COSMOS

Supernova breaks brightness record

Stellar explosion may be the first of its kind to be observed

BY MARIA TEMMING

The brightest supernova ever seen may be the first known example of a rare type of stellar explosion.

The supernova, spotted in 2016 in a galaxy about 4.6 billion light-years away, radiated about 5 sexdecillion (5 followed by 51 zeros) ergs of energy. That's about twice the amount of radiation emitted by the previous record-holder and hundreds of times more energetic than normal supernovas. At its brightest, this supernova was as bright as all the stars in the Milky Way put together.

The blast could have been a pulsational pair-instability supernova, scientists report April 13 in *Nature Astronomy*. Those are thought to occur when an extremely massive supernova collides with a shell of material cast off by the star before it exploded.

"There's no single, well-established case of such a supernova," says Philipp Podsiadlowski, an astrophysicist at the University of Oxford not involved in the work. "This could be one." Computer simulations of the event may help confirm the nature of the star's demise.

The supernova, named SN2016aps, was identified in observations from the Pan-STARRS survey. Astronomer Matt Nicholl and colleagues monitored the supernova's fading light for about two years. The amount of stellar debris left over from the supernova indicates that the star was at least 50 to 100 times as massive as the sun. The stars behind ordinary supernovas are only about 10 solar masses.

The telescope observations also revealed a surprising amount of hydrogen in the wreckage. More massive stars generally lose hydrogen faster than smaller stars. "So, for stars in this 100-solar-mass regime, you expect that all the hydrogen is long gone well before it explodes," says Nicholl, of the University of Birmingham in England. This finding suggests that two smaller stars still containing hydrogen merged into a supersized star that underwent a pulsational pair-instability supernova.

This exotic type of supernova is predicted to happen only to stellar juggernauts. Inside extremely massive stars, "the temperature in the core can get so high that photons ... get converted into pairs of particles — electrons and positrons," Nicholl says. When these photons, or particles of light, disappear, "you lose some of the pressure in the core, and it starts to contract. This can lead to thermonuclear runaway, like an atom bomb going off."

That explosive reaction can release enough energy to blow off the outer layers of the star into an enormous shell. When the star ultimately goes supernova, the explosion collides with the shell and releases huge amounts of radiation. ■

LIFE & EVOLUTION

How to deduce a whale shark's age

Cold War nuclear test residue helps calculate life span

BY MARIA TEMMING

Measuring radioactive carbon in vertebrae helped researchers determine the ages of whale sharks in a new study.

Radioactive residue from Cold War nuclear tests has given scientists a cipher to decode the ages of whale sharks.

As they age, whale sharks (*Rhincodon typus*) accrue pairs of alternating stripes of opaque and translucent tissue on their vertebrae, similar to how trees grow rings. Scientists hadn't known whether the vertebrae gain a band each year or every six months, making it difficult to gauge how fast the sharks grow or how long they live.

But a new study of carbon-14 in the vertebrae of two sharks that lived in the 20th century suggests that bands form annually, researchers report April 6 in *Frontiers in Marine Science*. Nuclear weapons tests in the 1950s and 1960s produced that carbon-14, which built up in the atmosphere and oceans. By matching the amount of carbon-14 in different growth bands with the known carbon-14 levels in surface seawater in different years, the team estimated when each band formed.

The total number of growth bands in each dated vertebra indicated that a 10-meter-long male whale shark found in Taiwan was about 35 years old when it died. A female of about the same length found in Pakistan was about 50 years old.

Whale sharks are known to grow as long as about 18 meters, so there are probably even older whale sharks out there, says Steven Campana, a fisheries scientist at the University of Iceland in Reykjavík.

Campana's team used growth band counts to figure out the ages at death of 18 other whale sharks. Young whale sharks grow about 20 centimeters per year, on average, the team estimates, based on the lengths of sharks of different ages.

Life span and growth rates could inform conservation work, Campana says. "Long-lived animals like whale sharks almost certainly become mature at a relatively old age, and their populations are relatively slow to increase." So whale sharks may not bounce back from threats like overfishing as quickly as species with shorter life cycles.

Fisheries biologist Allen Andrews of the University of Hawaii at Manoa cautions that there is some uncertainty in the carbon-14 dating technique. For example, radioactive carbon from nuclear tests did not spread evenly throughout the oceans. Researchers could further study growth, he says, by tagging sharks, recapturing them and measuring how much the animals grew in the interim. ■

BODY & BRAIN

Mice express a range of emotions

Machine learning methods find subtle cues of pain, fear and joy

BY LAURA SANDERS

Though tricky for humans to see, mice's feelings are written all over their faces.

With machine learning tools, scientists reliably spotted expressions of joy, fear, pain and other emotions. The results, published in the April 3 *Science*, may provide a field guide for studying animal emotions.

The findings "lay the foundation for what I expect will be a game changer for neuroscience research on emotional states," says Kay Tye, a neuroscientist at the Salk Institute for Biological Studies in La Jolla, Calif.

Neuroscientist Nadine Gogolla of the Max Planck Institute of Neurobiology in Martinsried, Germany, and colleagues gave mice experiences designed to elicit distinct emotions. Sugar water evoked pleasure, a shock to the tail triggered pain, bitter quinine water created disgust, an injection of lithium chloride evoked a nauseated malaise and a cage where shocks previously had been delivered sparked fear. High-speed video cameras captured how mice's faces responded.

Observers can see that something is happening, Gogolla says. But translating subtle facial clues into emotions is hard.

Machine learning techniques handled the job. The methods spotted movements that came with good or bad experiences. For a mouse drinking sweet water, the ears move forward and fold toward the body, and the nose moves down toward the mouth. A mouse tasting quinine sends its ears straight back, and the nose curls slightly backward.

Nerve cell activity in the mice's brains also changed with emotions. These cells reside in the insular cortex, known to be involved in human emotions. By prodding these cells to fire signals, the team could prompt the mice to display certain expressions. Connections between brain activity and facial expressions may lead to insights into the neural basis of emotions, and what goes awry in disorders such as anxiety, the researchers say. ■

WAYNE OSBORN

HUMANS & SOCIETY

Key shift in human evolution identified

Fossil finds offer new details on the early days of *Homo erectus*

BY BRUCE BOWER

Members of three different hominid lines clustered at the bottom of Africa around 2 million years ago, signaling an evolutionary swing propelled by the spread of a highly successful, humanlike species, new fossil discoveries suggest.

Excavations at Drimolen, a set of caves in South Africa, uncovered two fossil braincases, one from *Homo erectus* and the other from *Paranthropus robustus*, say paleoanthropologist Andy Herries of La Trobe University in Melbourne, Australia, and colleagues. Both finds date to between 2.04 million and 1.95 million years ago, the scientists report in the April 3 *Science*.

The *H. erectus* fossil comes from a child who had a long, low braincase typical of adults from that species. The *P. robustus* braincase is that of an adult.

Researchers previously determined that two *Australopithecus* species, *A. africanus* and *A. sediba* (*SN: 8/10/13, p. 26*), inhabited nearby parts of South Africa approximately 2 million years ago.

Taken together, these discoveries indicate that a major transition in hominid evolution occurred in southern Africa between around 2.1 million and 1.9 million years ago, Herries' team says. During that stretch, climate and habitat fluctuations drove *Australopithecus* species to extinction. *H. erectus* and *P. robustus* weathered those ecological challenges, possibly outcompeting *Australopithecus* for limited resources, the researchers speculate.

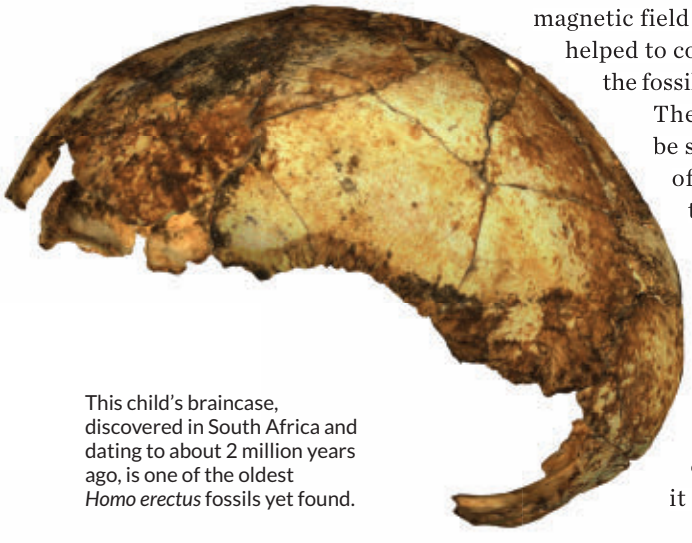
Given uncertainties in the estimates of the age ranges, each hominid lineage was probably not in the region for the exact same stretch of time, but the populations likely overlapped.

"These spectacular discoveries confirm what some of us have expected for some time, that three genera of [hominids] coexisted in southern Africa," says paleoanthropologist Darryl de Ruiter of Texas A&M University in College Station, who was not involved in the research.

Earlier work at several other South African cave sites had suggested that *H. erectus, P. robustus* and *A. sediba* all dated to nearly 2 million years ago. But many fossils from the first two species are fragmentary, and precise dating of cave sediments that held those finds has proved difficult.

Herries' team dated the fossil braincases at Drimolen using two techniques for calculating the time since sediments formed just below and above where the specimens were found. Evidence of previously dated reversals of Earth's magnetic field in Drimolen sediments helped to confirm age estimates for the fossils.

The *H. erectus* fossil may be slightly older than those of *A. sediba*, but a controversial proposal that *A. sediba* was an ancestor of the genus *Homo* remains in play, says de Ruiter. Researchers don't know how much earlier than 2 million years ago *A. sediba* originated or how far it ranged beyond its one known fossil site in South Africa. Even so, some other researchers consider *A. sediba* a dead-end species and regard East Africa as the best bet for where *Homo* originated.



This child's braincase, discovered in South Africa and dating to about 2 million years ago, is one of the oldest *Homo erectus* fossils yet found.

Excavators at South Africa's Drimolen site (shown with some unearthed animal bones) have recovered roughly 2-million-year-old fossils of two hominid species, *Homo erectus* and *Paranthropus robustus*.

Unearthing an *H. erectus* fossil dating to around 2 million years ago in South Africa considerably expands that species's range at an early stage of its evolution, says paleoanthropologist John Hawks of the University of Wisconsin–Madison. *H. erectus* fossils in western Asia date to about 1.8 million years ago (*SN: 11/16/13, p. 6*). And *H. erectus* may have made 2.1-million-year-old stone tools in China (*SN: 8/4/18, p. 7*).

"It's possible that this child from Drimolen is the earliest-known representative of the first global [hominid] species," says Hawks, who did not participate in the new study.

H. erectus' last known appearance was as late as 108,000 years ago on an Indonesian island, meaning it survived about 2 million years.

The Drimolen *H. erectus* fossil "marks the beginning of the most successful species of *Homo* ever known — present company included," paleoanthropologist Susan Antón of New York University writes in a commentary published with the new report in *Science*. ■

FROM TOP: A. HERRIES; A. HERRIES, JESSE MARTIN, RENAUD JOANNES-BOYAU

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EARTH & ENVIRONMENT

Mass bleaching hits Great Barrier Reef

Ongoing episode is the area's most widespread event on record

BY JOHN PICKRELL

Australia's Great Barrier Reef is experiencing its third mass bleaching in just five years — and it is the most widespread bleaching event ever recorded.

One-quarter of individual reefs surveyed aerially were severely affected, with more than 60 percent of corals bleached. Another 35 percent of the reefs had less extensive bleaching. The surveys were conducted along most of the 2,300-kilometer-long Great Barrier Reef over nine days in late March. The results were released on April 7.

"This is the second most severe event we have seen, but it is by far the most widespread," says marine biologist Terry Hughes, director of the ARC Centre of Excellence for Coral Reef Studies at James Cook University in Townsville, Australia. Hughes led the surveys along with scientists from the Great Barrier Reef Marine Park Authority.

What is most concerning this year is that the southern third of the reef, which escaped 2016 and 2017 bleaching events largely unscathed, is now extensively bleached, too. "For the first time we have seen bleaching in all three regions of the reef — the north, the middle and the south," Hughes says.

Bleaching occurs when corals experience periods of unusually high summer sea surface temperatures and eject the symbiotic algae that both nourish corals and give them some of their color. It's not a guaranteed death sentence, but many corals will not survive.

The first mass bleaching recorded on the Great Barrier Reef was in 1998, with the next in 2002. But bleaching in 2016, 2017 and now 2020 has scientists concerned, as there has been little time for reefs to recover in between episodes.

"We are seeing more and more bleaching events, and the gap between them is shrinking," Hughes says. "Those gaps are important because that's the opportunity for corals to rebound and make a recovery.... It takes about a decade for the fastest-growing corals to fully rebound."

> "If this continues over the next 10 years or so, there won't be much of a Great Barrier Reef left."
>
> **OVE HOEGH-GULDBERG**

Reefs in parts of the Great Barrier Reef had started to recover from the 2016 and 2017 bleaching events. Now scientists are worried that the progress may have been for nothing. Reefs "are just getting hammered by these repetitive, destructive heat waves," says Ove Hoegh-Guldberg, a coral reef researcher at the University of Queensland in Brisbane, Australia. "If this continues over the next 10 years or so, there won't be much of a Great Barrier Reef left."

Hoegh-Guldberg, who is the deputy director of the ARC Centre of Excellence for Coral Reef Studies but is not involved in the surveys, says that while the bleaching's extent is an "absolute tragedy, it's one we've been expecting." In February, the Great Barrier Reef saw its highest sea surface temperatures since records began in 1900, according to Australia's Bureau of Meteorology.

Hoegh-Guldberg argues that, aside from governments taking action to reduce greenhouse gas emissions, one thing that can be done is to map out reefs that are less exposed to the effects of climate change than others, such as reefs in areas protected by cool upwellings. These sites could provide coral larvae to regenerate bleached reefs and should be especially protected from other damage, such as from agricultural runoff, he says.

"That's one place I think we can do further work," Hoegh-Guldberg says. "Identify those areas that are least exposed to climate change and which have the greatest role to play in any renewal." But "the problem with that approach," he says, "is that we are running out of reefs that haven't yet bleached."

Another problem is that reefs' ability "to rebound has been compromised," he says. In 2019 in *Nature*, he and colleagues reported an 89 percent decrease in the number of coral larvae in 2018 from reefs that had been damaged in 2016 and 2017.

"We are in uncharted territory in terms of rebound potential," Hughes agrees. "We are not sure what the Great Barrier Reef will recover to anymore. The mix of species is changing and really quickly," he says. "Optimistically, if temperatures don't rise too much more, we'll still have a reef, but it's going to look very different." ■

In response to high sea surface temperatures, these stony corals in Australia's Great Barrier Reef ejected the nourishing algae that give the corals color. Many corals do not survive this bleaching.

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Hurricane Maria made landfall in Puerto Rico on September 20, 2017, knocking out power and flooding towns like Carolina (shown). Over the next few months, hundreds of thousands of people evacuated to the U.S. mainland, including Orlando, Fla.

SGT. JOSE AHIRAM DIAZ-RAMOS/USDA

Where will climate migrants go?

Orlando is taking the potential of future population influxes seriously

By Carolyn Gramling

Hurricane Maria roared across Puerto Rico in late September 2017. The storm caused an estimated $90 billion in damage, demolished the power grid (*SN: 2/15/20, p. 22*) and left more than half of the island's residents without safe drinking water.

Dachiramarie Vila recalls the smell of gasoline from generators choking the air.

"The smell was everywhere," says Vila, a 33-year-old mother of two, through a translator. "We felt that we were breathing all those gases night and day."

The storm flattened Vila's wooden home, forcing her family to move to her parents' house, which was also damaged. Then Vila's 13-year-old son began peeing blood, she says, probably from drinking contaminated water. There was little medical assistance available.

Desperate for help, Vila's mother, Maritza Garcia Vila,

traveled high into the mountains in search of a working cell phone tower because the storm had knocked out 95 percent of the island's towers. From there, she called Ana Cruz.

Cruz is the coordinator of the Hispanic Office for Local Assistance, or HOLA, part of the city government of Orlando, Fla. HOLA has helped new arrivals to the city find jobs, housing and health care since 2004.

But by the end of 2017, HOLA and Orlando faced a daunting task. Hurricane Irma had inundated many of Florida's coastal cities in early September, and two weeks later, Maria hit Puerto Rico. Those two storms sent as many as 250,000 evacuees, including Vila and her family, into Florida's narrow interior.

"We were caught off guard," says Chris Castro, a senior adviser to Orlando Mayor Buddy Dyer. That 2017 wave of climate migrants gave city managers a glimpse into a future for which they need to prepare.

Orlando is now gearing up to become a destination for future climate migrations, Castro says. "No local government, to my knowledge, is prepared ... to deal with the flux of environmental migrants and climate refugees," he adds. "It's now very much part of our thought process."

By 2050, scientists estimate, climate stressors — including hurricanes, wildfires, drought, extreme heat and flooding from rising seas — could compel between 25 million and 1 billion people around the world to leave their homes and jobs behind, some temporarily, some for good.

For Orlando and other potential destination cities, preparing for those influxes of people, while also bracing for the local impacts of climate change, is a multifaceted challenge. As a starting point, the cities need data, some sense of how many people might arrive. But one of the biggest hitches in planning for the future is that so little is known about where and when people will choose to migrate.

Scientists have devised ways to track and even anticipate modern-day human resettlements, as people move for economic reasons like jobs or for family reasons. There is also a growing body of research based on past migrations spurred by extreme climate events: the treks across the United States during the Dust Bowl era of the 1930s, for example, or the rush to Orlando following Hurricane Maria, or to Houston in the wake of Hurricane Katrina, which devastated New Orleans and much of the Gulf Coast in 2005.

But when it comes to projecting such movements into the future, as climate change rapidly transforms landscapes on a never-before-seen scale, "I don't think we know that much at the moment," says Amir Jina, an environmental economist at the University of Chicago. "It's hard to think of what's going to happen with long-term [climate] change."

Becoming a safe haven

As newcomers poured into Orlando in October 2017, HOLA set up a welcome station at the city's airport at Dyer's behest. Among the first to arrive were Vila and 10 family members — her husband and two children, mother and father, younger brother and pregnant sister with her husband and two children.

Leaving Puerto Rico "was very, very, very hard," Vila says. The family left with only a few suitcases. "We were desperate, with nothing."

Vila's mother headed straight to the HOLA table. "When her mother arrived, she started crying," recalls Cruz, who served as the translator during my conversations with Vila. "I told her to relax, that she was going to be fine."

Orlando is home to about 280,000 residents, plus many more temporary guests. Each year, some 50 million travelers pass through the city's airport, the busiest in the Sunshine State. Six-lane highways crisscross to speed tourists to Walt Disney World, Universal Studios, Sea World and other nearby theme parks.

But nothing like the 2017 rush of climate refugees had happened there before. Orlando and neighboring cities in central Florida groaned under the weight of so many new people in such a short time. The city's massive tourism industry turned out to be a silver lining, Castro says, with jobs and housing available, at least for the short term, in the region's many hotels. In a two-week period after Maria, every hotel room in the area was full.

City and emergency managers scrambled to find longer-term affordable housing, transportation, health care and other social services for the new residents. Teachers had to be hired, especially those who speak Spanish. An assistance center to help newcomers from hurricane-ravaged regions also opened in Kissimmee, half an hour's drive south.

Today, two and a half years later, perhaps a tenth of the estimated 250,000 climate migrants remain, Castro says. The

D. VILA

Dachiramarie Vila (center), her two children (shown), her husband and extended family left Puerto Rico in 2017 for Orlando, Fla., in the aftermath of Hurricane Maria.

rest returned to their homes in Puerto Rico, or sought some other safe haven.

But for Castro and other city managers in Orlando, the experience was transformative.

In 2019, the city kicked off an array of projects and partnerships to improve its resilience and plan for future climate migration booms. Among its partners is the East Central Florida Regional Planning Council, which represents eight counties, including Orlando's Orange County. Jenifer Rupert, in charge of the council's resilience efforts, says that Maria was a wake-up call for her organization, too. "I thought ... we really need to get better at the way we're handling this."

In addition to hurricane-related migrations, Rupert says, the council is concerned about waves of migrations as sea levels continue to rise. "What are we going to do when the state of Florida starts losing coastline, and people from Miami come up here?" Rupert asks. "What are we really putting in place now to start managing those types of numbers?"

Moving on A 2017 study projected 10 U.S. regions as the most likely destinations for people fleeing sea level rise by 2100. The top three areas could each see population booms of more than 250,000

SOURCE: M. HAUER/ *NATURE CLIMATE CHANGE* 2017

Austin-Round Rock, Texas
Orlando-Kissimmee-Sanford, Fla.
Atlanta-Sandy Springs-Roswell, Ga.
Houston-The Woodlands-Sugar Land, Texas
Dallas-Fort Worth-Arlington, Texas
Washington-Arlington-Alexandria, D.C.-Va.-Md.-W.Va.
Baton Rouge, La.
Charlotte-Concord-Gastonia, N.C.-S.C.
Philadelphia-Camden-Wilmington, Pa.-N.J.-Del.-Md.
Las Vegas-Henderson-Paradise, Nev.

Deciding on a destination

One might expect U.S. climate migrants to choose "climate beneficial" locations — cool, temperate places, such as Minneapolis or Seattle, rather than Florida or Texas, says Jina, the Chicago economist. "It seems counterintuitive: Instead of moving to more resilient cities, they're moving to a city that can only really be livable in the future if you can afford air conditioning."

But other factors tend to weigh more heavily in migration decisions: available jobs, health care, family and community, says Mathew Hauer, a sociologist at Florida State University in Tallahassee. "Most migration tends to be short-distance, for economic and social reasons, like a better-paying job."

Take Orlando. It's located in a state that is squarely in the path of rising seas and has seen record-breaking heat in the last year. But Orlando satisfies many of the other needs of possible climate migrants, at least in the short term. It is in the center of the state, far enough from the worst effects of possible storm surges and sunny-day flooding due to rising sea levels. It has jobs. And it has made an effort to be welcoming to migrants.

Taking a holistic look at what drives migration is known as "migration systems theory." Using that approach, in a study reported in 2017 in *Nature Climate Change*, Hauer identified 10 likely "climate destination" regions in the United States for the estimated 13.1 million people within the country who are expected to be displaced by rising sea levels by 2100. Based on his simulations, the top destinations include Austin, Orlando and Atlanta.

Hauer's study was the first to attempt to anticipate destination regions for U.S. climate migrants. He tracked large-scale, county-to-county migrations of people from 1990 to 2013 using annual tax data from the IRS. Then, based on observed patterns, which reveal residents' past choices, he projected where people are likely to go in the future.

Economists have used similar factors to create econometric models to forecast changes in populations. Such simulations can help local governments assess the need for everything from additional housing and transportation to shifting school district boundaries.

That approach has been around for a long time, and when it comes to simulating climate-related migrations, "it works to a certain extent," says Vivek Shandas, an urban planning researcher at Portland State University in Oregon. But more accurate simulations of widespread climate migration should consider one more dimension of the decision-making process, he says: how people might decide when it's time to leave.

In October 2017, Ana Cruz (left) of Orlando's Hispanic Office for Local Assistance greeted Puerto Ricans fleeing Hurricane Maria's destruction.

Making the call

That decision will likely be different depending on the type of climate trigger, Shandas says. A growing field of research called event ecology uses computer models to anticipate how an extreme event, such as a hurricane, might ripple through a community, altering population numbers and infrastructure. Those kinds of events — sudden, short-term and extreme, such as Katrina in 2005 — are called "pulse events."

Migrations spurred by pulse events are fairly easy to simulate. There's one point of origin, and scientists can make

HOLA

Dreams of Buffalo

In 2017, climate scientist Stephen Vermette of Buffalo State College in New York analyzed recent climate trends for the western part of the state to help the region begin its own resilience planning. Using data going back to 1965, he looked for trends in heat waves, warmer summers, precipitation and other possible signs of climate change.

To his surprise, Vermette says, none of those signs appeared in his analysis. In the future, western New York may "fare better than other parts of the country." He suspects that this is due to the nearby Great Lakes, which may exert a cooling effect on the region during future summers.

He hasn't been able to simulate future lake effects on the region's climate, but his findings drew media attention. Local and national press touted the possibility that Buffalo could become a climate refuge. In particular, Buffalo and other cities that are less affected by, for example, rising seas, may become particularly attractive to businesses that are looking for a stable place to thrive far into the future.

"Investors or the high-tech industry, versus people who just need to get out of the way of a hurricane — those are very different scenarios," says urban planning researcher Vivek Shandas of Portland State University in Oregon. "I've had investment bankers say to me, 'Santa Barbara is burning, Martha's Vineyard is going underwater … where do I invest money right now?' "

Vermette says that he hopes Buffalo city officials will embrace the idea of a climate refuge future. "Buffalo could position itself to take advantage of its situation," he says.

— *Carolyn Gramling*

knowledgeable guesses about where people might go from that point of origin based on proximity to other cities, family connections and job availability. Pulse event migrations also tend to occur shortly after the triggering event.

But ongoing climate change can boost the frequency of pulse events. For example, climate change is increasing the risk of deadly and destructive wildfires, such as those that struck California in 2017, 2018 and 2019. Each event may trigger some migration, but over time those who stayed behind may also begin to wonder whether they, too, should move to a safer haven.

Such slower, longer-term manifestations of climate change, or "press events," can be more challenging when it comes to anticipating both when and where people may choose to move. Rising sea levels are the textbook example of a press event (*SN: 2/29/20, p. 18*). And it's with these events that people's different risk tolerances most come into play.

"There are different thresholds that people are willing to put up with," Hauer says. "For some, [that threshold comes] much sooner than when there's water at the doorstep." Many people will face the dire choice between individual migration, community-based movement away from the risk, known as "managed retreat," or even deciding to find ways to stay in place (see Page 28).

There's no template for what will happen in response to widespread sea level rise, which will affect many different places at once. "We haven't yet lived in a world with high tide flooding multiple days a month," Jina says. "It will change housing prices, as well as whether or not people reinforce coasts."

Hauer notes that his destination city study, published in April 2017, came just a few months before Hurricane Harvey poured torrents of rain onto southeastern Texas, including Houston. Does that event push Houston off the future destinations list? Not necessarily, he says. Post-Harvey resilience efforts in Houston can alter the calculus.

And there are many other lingering unknowns when it comes to assessing people's decisions. "We know very little about how different age groups would respond to different stimuli," Hauer says. "Or how different climate impacts will interact with each other, [such as] how migration to Atlanta might affect migration to Miami."

Seeking urban resilience in Orlando

Despite these challenges, climate migration is "something that we have to face," says Yue "Gurt" Ge, an expert in risk and resilience management at the University of Central Florida in Orlando. Finding some way to assess the scale of the issue will be essential to creating climate adaptation strategies for his city, he says.

It's 3 p.m. in late February 2020, and the university's new Urban Resilience team is holding its second meeting in a brand-new, glossy high-rise in downtown Orlando. This interdisciplinary team is the brainchild of Ge and emergency management expert Naim Kapucu, head of the university's school of public administration.

Ge, a slight, energetic man, eagerly ushers a group of about a dozen waiting scientists into the conference room, where they sit at long white tables and introduce themselves. Half a dozen more people are Skyping in. It's a diverse group, with expertise in everything from artificial intelligence to wine. Resilience, reducing the impact of disasters, is the common link.

Ge is anxious to build connections within the team. Periodically, he steps in, noting how each person is connected to the larger effort. Interdisciplinary teams have insights, he says. Perhaps as important, they get funding. He says he hopes to identify research projects for the team, as well as build partnerships to better implement best practices.

First on the table might be developing a formal, research-driven way to count climate migrations to Orlando — a necessary ingredient for any city's resilience plan. "We can contribute by proposing scientific studies, surveys, focus groups with climate refugees," Ge says. The airport, local community organizations and shelters could be helpful in

providing data. HOLA, he says, is a valuable ally in this effort as well. "When they accommodate or house these people, then they do have some numbers to tell us."

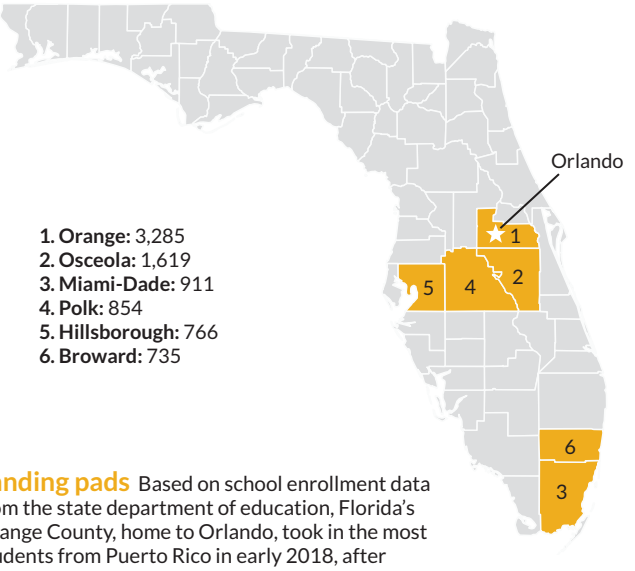
Finding good data to track migration remains a challenge. The IRS changed the way it records tax data in 2017, unfortunately "breaking" the time series that Hauer had previously used, he says. Those data also are collected annually, giving only a long-term picture of migrations. That's also true of, for example, data on state-to-state migrations and changes to the workforce collected by the U.S. Census Bureau.

For one measure of short-term movement, the Center for Puerto Rican Studies at Hunter College at the City University of New York used student enrollment data from state departments of education to show that many Florida counties saw a rise in Puerto Rican enrollees between December 2017 and February 2018, months after the hurricane. Overall, Florida saw a 12 percent increase, to 11,554 students from Puerto Rico enrolled in schools. Other states that saw rises included New York, New Jersey, Pennsylvania and Massachusetts.

Social media, including Facebook and Twitter, may also be useful for tracking large-scale migrations due to climate events that occur on short timescales. Yago Martín, who studies urban resilience at UCF, and colleagues devised a way to use geotagged tweets to identify and track movements of over a thousand Puerto Rican residents in Maria's aftermath. The methodology holds promise for tracking future migrations, the team reported in February in *Population and Environment*.

The good news is that large research institutions are beginning to recognize the need to fund climate migration research, says UCF sociologist Fernando Rivera, who heads the university's Puerto Rico Research Hub. He is gearing up to embark on a National Academy of Sciences–funded analysis of past and present climate migrations, focusing on changes in housing markets, financial services, health care, employment and economic development in the communities where migrants end up.

The study zooms in on three migration events: from Puerto Rico to Orlando in 2017; New Orleans to Houston in 2005 following Hurricane Katrina; and the pending resettlement of the few dozen residents of Isle de Jean Charles, one of Louisiana's coastal islands about to be drowned by rising seas. The goal, Rivera says, is to try to determine lessons for future destination communities, such as Orlando.



1. Orange: 3,285
2. Osceola: 1,619
3. Miami-Dade: 911
4. Polk: 854
5. Hillsborough: 766
6. Broward: 735

Landing pads Based on school enrollment data from the state department of education, Florida's Orange County, home to Orlando, took in the most students from Puerto Rico in early 2018, after Hurricane Maria. The top six counties are shown.
SOURCE: CENTER FOR PUERTO RICAN STUDIES/HUNTER COLLEGE. 2018

Willer Vélez (shown), part of the wave of Puerto Rican residents into Florida, opened Willer's Supermarket in Kissimmee in December 2017.

New home

Vila and her 10 family members moved together from hotel room to hotel room for several weeks after arriving in Orlando, unable to find permanent housing. Although they were able, barely, to afford the costs of this lifestyle, other Puerto Rican migrants were not so lucky. Monthly allowances for temporary housing provided by the U.S. Federal Emergency Management Agency to Maria evacuees dried up after about a year for many families.

Eventually, most of Vila's family returned to Puerto Rico. But she and her husband and their children stayed, deciding that the quality of life for their children would ultimately be better on the mainland. She and her husband found jobs: Her husband works in maintenance at their apartment complex. Vila worked at Disney World as a hostess until the parks closed due to social distancing restrictions from the COVID-19 pandemic. She recently completed coursework to become a medical assistant, graduating with high grades.

It's modest success, but Vila says she doesn't feel quite at home. Still, she says she has no plans to leave. For one thing, her son is now doing very well. And life, she adds, is "peaceful." ■

Explore more

■ David Wrathall *et al*. "Meeting the looming policy challenge of sea-level change and human migration." *Nature Climate Change*. December 2019.

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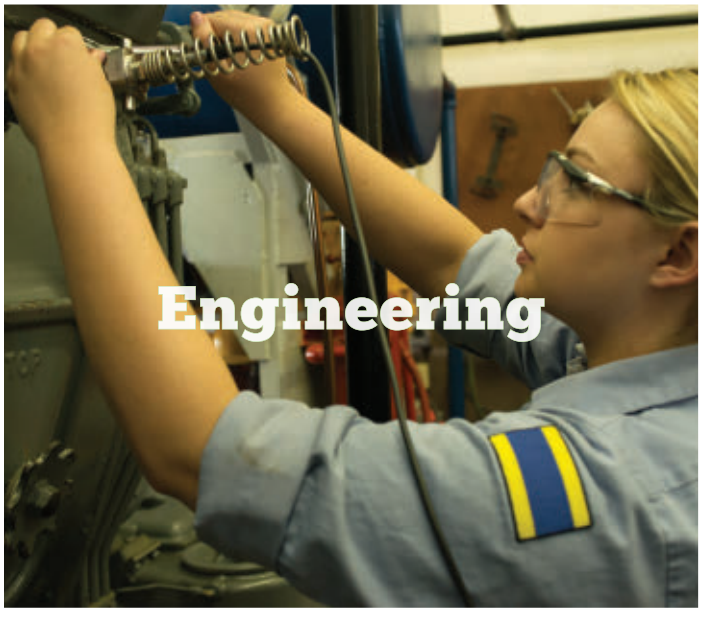

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This house near Boulder, Colo., probably survived the 2010 Fourmile Canyon Fire because its perimeter had "defensible space," cleared of dry vegetation and flammable materials.

How to Stay

Commonsense approaches can keep communities safer from flooding and fire risks

By Mary Caperton Morton

A decade ago, climate change projections pointed to a distant future, 50 or 100 years down the road. But with each storm and fire season seemingly more ferocious than the last, it's clear we're already facing the impacts of climate change: Sea levels are rising, and storms, wildfires and droughts are intensifying, fueled by warmer oceans and a warmer atmosphere.

In the coming decades, regions of the United States will be affected in different ways by flooding, severe storms, droughts and wildfires. Millions may be forced from their homes (see Page 22). But what about the people who choose to stay? What can they do to harden their homes, to improve the chance the structure will stand up against water and fire? How can people help their communities adapt to the everyday realities of climate change?

Predictive flood maps

Flooding is already the most common natural disaster in the United States, occurring in every state and killing more people each year than hurricanes, tornadoes or lightning. As warming drives sea levels higher, intensifies hurricanes and fuels more heavy rain events, more U.S. residents should expect to deal with flooding (*SN: 8/17/19, p. 16*), even at inland locations that have not flooded historically, says Glenn McGillivray, managing director of the Institute for Catastrophic Loss Reduction in Toronto. Climate models predict more extreme rainfall events over the next 80 years, across both wet and dry regions, according to a 2016 report in *Nature Climate Change*.

"There's a perception that your house will only flood if you live on the coast or right next to a big river. But some of the most destructive flooding events have occurred from heavy rainfall, which can happen anywhere," McGillivray says. "Pretty much everybody is at risk of overland flooding, but most people have no clue what their level of risk really is."

Flood risk for U.S. homeowners has traditionally been calculated by the Federal Emergency Management Agency as part of the National Flood Insurance Program. FEMA software lumps properties into three categories: inside a 100-year floodplain (an area with at least a 1 percent chance of flooding in a given year) or outside the floodplain in areas of moderate or minimal risk. A 2018 study in *Environmental Research Letters* found that FEMA's maps are outdated and underestimate the flood risk for over 28 million Americans.

"FEMA's maps create an illusion of safety for people outside the 100-year floodplain," says Sharai Lewis-Gruss, lead adaptation specialist for the First Street Foundation, a nonprofit in Brooklyn, N.Y.

"The maps are also historical — they only draw data from past flooding events," she says. And the databases are sometimes decades old. The maps don't account for projections of sea level rise, more intense hurricanes or increased rainfall.

To help people better understand their flood risk, in June the First Street Foundation plans to release Flood Factor, a

JOE AMON/GETTY IMAGES

mapping program that the organization says will "calculate the past, current and future flood risk of every property in America."

Flood Factor's National Flood Model, created through a collaboration of over 70 experts, will consider impacts from sea level rise and tidal flooding, hurricane and storm flooding, as well as flooding from swollen rivers and heavy rainfall events, Lewis-Gruss says. By applying various flood hazard scenarios, such as a Category 3 hurricane or 20 centimeters of rainfall, to specific properties and buildings, the model can calculate the historic and future impacts of floodwater for most, over 155 million, U.S. properties.

Residents will be able to plug a street address into the website and get a detailed report with color-coded maps showing the impact from past flooding events, the likelihood of future flooding scenarios, as well as a Flood Factor risk score from 1 (low) to 10 (extreme). The aim is to create "a personalized narrative for how flooding could affect your property this year, in five years and in 30 years," Lewis-Gruss says.

A perimeter of water-inflated barriers protected a house from flooding during a season of record-setting rainfall in Rosharon, Texas, in 2016.

Ready for the flood

After assessing your property's flood risk, the next step to prepare for flooding is to buy flood insurance, says Melissa Roberts, executive director of the American Flood Coalition, a nonprofit advocacy group in Washington, D.C. Flood damage is not usually covered by homeowners insurance, and federal law requires only people living inside 100-year floodplains to buy supplemental flood insurance.

"But we're seeing more flooding events outside of that zone, often from heavy rainfall," Roberts says. The American Flood Coalition "now recommends that everybody get flood insurance. The good news is, if you live outside that 100-year flood zone, it's often pretty affordable."

Installing temporary barriers across exterior doors and windows can help keep floodwater from entering a home.

Homeowners who take steps to physically protect their homes from flooding may get discounts on flood insurance premiums. Flood-control strategies can range from temporary measures that cost hundreds of dollars to pricier home redesigns. Not every homeowner needs to brace for historic hurricanes, but even heavy rain can do a lot of damage if water finds a way inside, Roberts says.

For people in need of quick, lower-cost options to keep the water out, several companies offer updated alternatives to sandbags, such as water barrier socks that expand in water to function much like sandbags, but without the mess. A larger-scale version swells to a 45-meter-long vinyl tube, several of which can be linked together to encircle an entire property. Another tactic involves placing removable watertight plastic barriers across ground floor doors and windows.

More permanent investments could involve installing sump pumps in the basement or low-lying areas of a property to remove floodwaters. But for solutions that depend on electricity, homeowners will also need to raise wiring and electrical outlets above flood levels and consider getting a generator or solar power system. Raising plumbing and heating and cooling systems away from the ground to minimize water damage to these costly components is also a good idea, Lewis-Gruss says.

The most expensive tactic is to raise an entire house above flood levels, usually by separating the house from its foundation, raising it with jacks and building a new foundation or propping the house up on posts or pilings. Costs depend on the size and construction of the home, but estimates range from $75 to $100 per square foot, or $187,500 to $250,000 for a 2,500-square-foot home.

In 2015, 50 centimeters of rain fell over five days in South Carolina, flooding Susan Lyons' Colonial-style house in the historic district of Charleston. Just 10 days later, a high tide brought even more water into her neighborhood. "After that double whammy, I had to file a federal flood insurance claim, my first in 30 years of living by the coast," she says. She replaced her home's HVAC system ductwork with waterproof PVC pipe and repointed the brick skirt around the foundation to keep water from seeping in through cracks.

"I learned that making physical improvements to your own house is complicated and expensive, but if you live in a flood zone, you're going to pay a lot now or pay even more later," Lyons says.

In 2016 and 2017, hurricanes Matthew and Irma delivered more flooding to Charleston. "It seemed like every season we were flooding. Repeated flooding is very traumatic," Lyons says. But despite the pattern, she felt the city council still viewed flooding as a rare event that people just had to deal with after the fact.

So Lyons helped start the advocacy group Groundswell! to get the mayor and city council to step up community flood-control measures. "We went from a few people around my dining room table to 300 families in a matter of weeks," she

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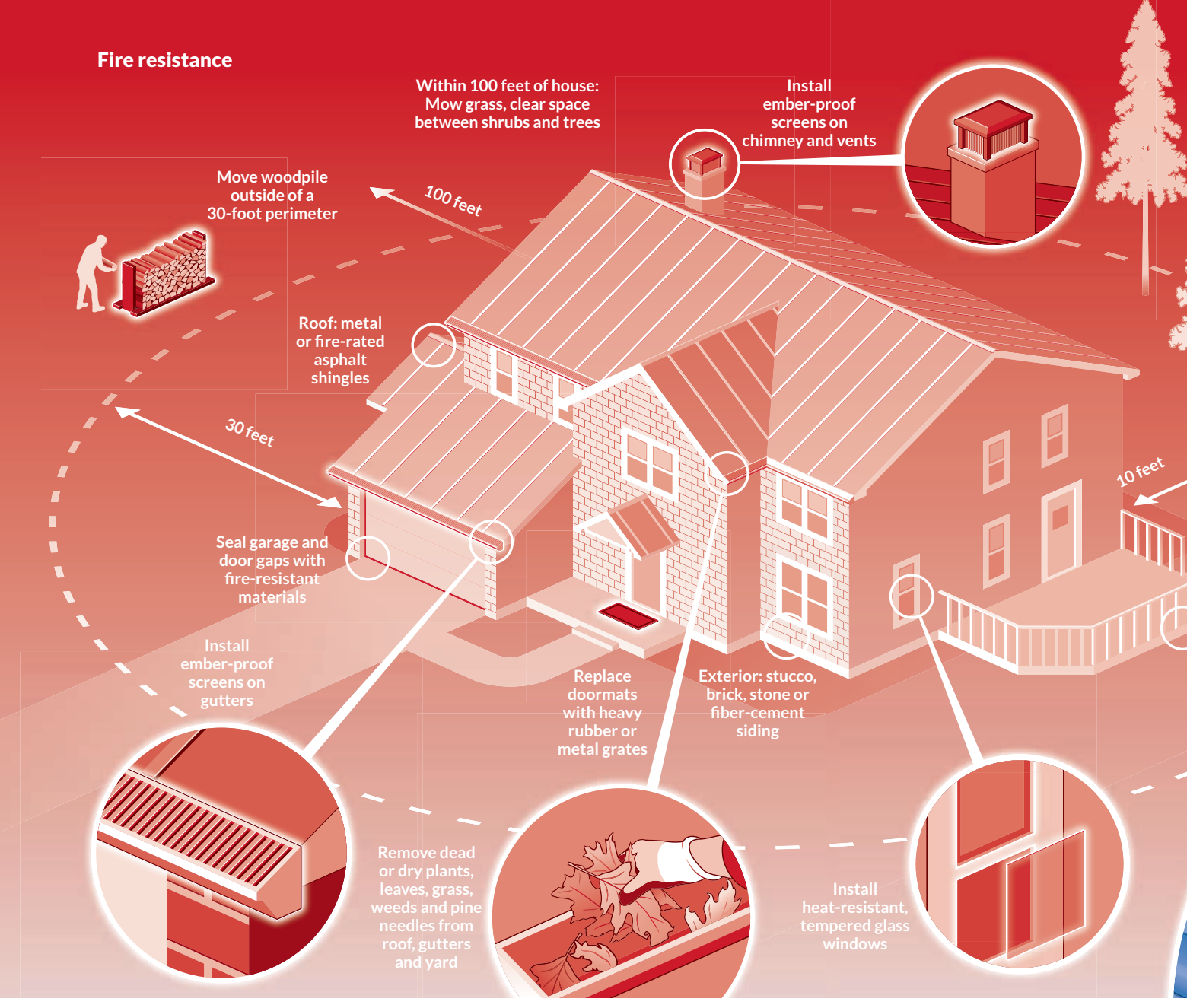


says. "People were eager to help and be helped. We made ourselves heard and amazingly it worked!" In 2018, Mayor John Tecklenburg announced that battling flood issues would be Charleston's top policy priority. The city is installing new drainage systems, pump stations and seawalls.

By banding together, neighborhoods and communities can work toward flood-control solutions that benefit as many people as possible to help keep individual homeowner costs down.

Community-level tactics may include adding or restoring floodable green spaces such as parks or marshlands (*SN: 8/17/19, p. 16*), building permanent flood barriers that protect blocks of houses and pressing local and state governments to take action.

"There are certainly actions individuals can take to protect themselves, but a lot ... are really costly and especially difficult for those who are already disadvantaged," Roberts says. "Flood control isn't something that should be left to individuals to deal with. Solutions have to involve everybody."

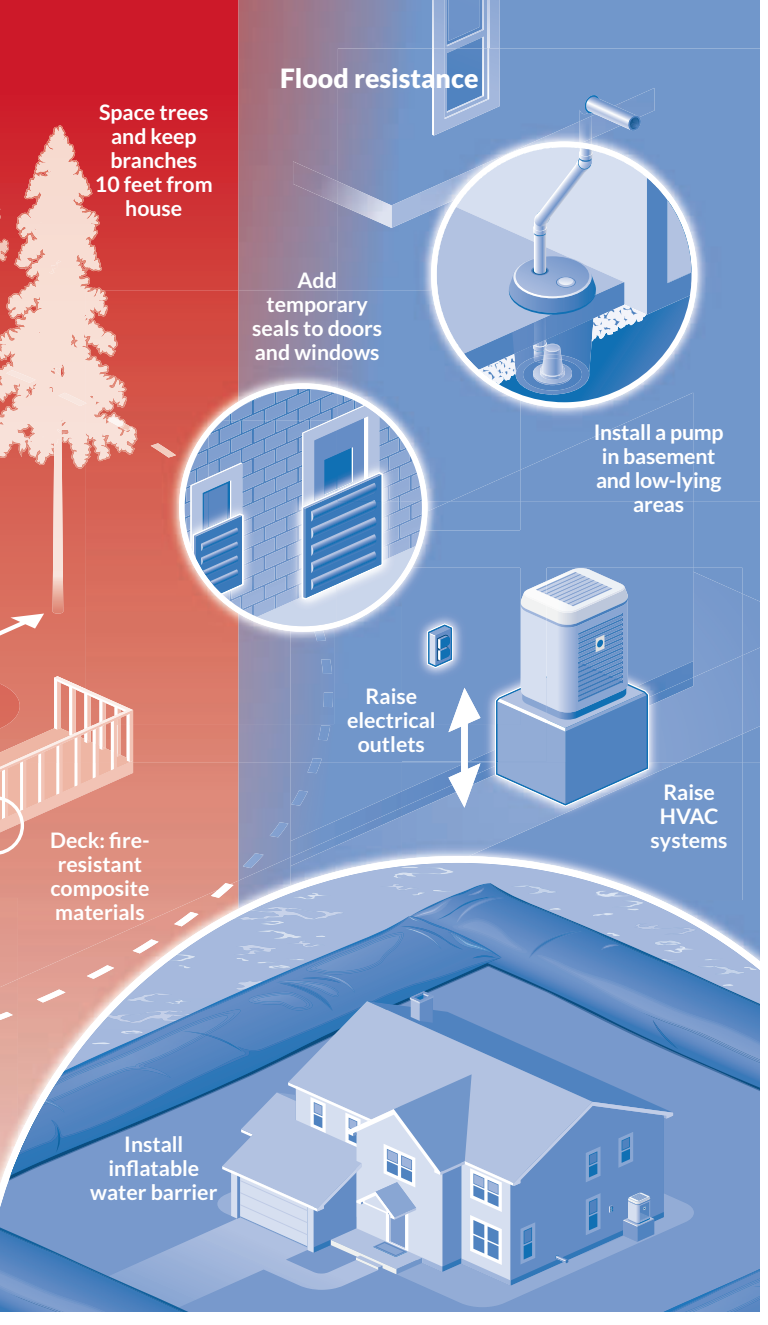
From floods to wildfires

When it comes to climate-driven natural disasters, fires are as frightening as floods. In 2017 and 2018, California wildfires killed 147 people, burned 3.5 million acres and destroyed over 34,000 structures in two of the worst fire seasons on record. And wildfires are expected to become more severe across the West, says Max Moritz, a wildfire specialist at the University of California, Santa Barbara. "Warming temperatures are melting snow sooner and drying out vegetation so that we're already seeing longer fire seasons and more available fuel."

Between 1990 and 2010, more than 12 million homes across the United States were built in what's known as the wildland-urban interface, where flammable vegetation meets human development and sources of ignition, such as vehicles or power lines, according to a 2018 analysis in the *Proceedings of the National Academy of Sciences* (*SN: 12/22/18 & 1/5/19, p. 8*).

All Western states are prone to wildfire, Moritz says, and

DAVID PREISS



A home can be made more resilient to fire by clearing a 100-foot defensible zone and closing up openings where embers could enter the building. To avoid flood damage, add temporary barriers and raise electrical equipment.

he's seen upward trends in the Midwest and Southeast, too, due to long-term drought, tree blights, insect-killed trees and a history of fire suppression that has allowed forest fuels to build up.

California has long led the charge in wildfire management, with the Department of Forestry and Fire Protection, or Cal Fire, overseeing more than 31 million acres of fire-prone landscapes. Since 2008, new construction in high and very high hazard zones must use noncombustible exterior materials and fire-resistant features such as covered gutters that prevent the accumulation of flammable leaves and needles. A few other states, such as Oregon and Washington, have adopted similar building codes.

The November 2018 Camp Fire that swept through Paradise, Calif., showed the benefits of fire-hardened homes: Fifty-one percent of homes that were built to code after 2008 survived; only 18 percent of older homes escaped serious damage. "Those numbers are stunning. Building codes really do work," says Robert Raymer, an engineer with the California Building Industry Association in Sacramento.

Adhering to fire codes does not add significant costs to building, according to a 2018 report by the nonprofit research group Headwaters Economics. Upgrading a roof with fire-resistant asphalt shingles tends to increase costs by about 27 percent, but using fire-resistant materials for the exterior, such as stucco or cement siding, can reduce costs by about 25 percent. Fire-resistant materials also tend to require less maintenance and have longer life spans than wood or plastic.

California has no requirements for retrofitting older homes for fire resistance. "Building codes don't take into account the millions of homes that were built in fire-prone areas before 2008," says Steve Hawks, Cal Fire's deputy chief of wildland fire prevention engineering. In January, California Governor Gavin Newsom announced a $100 million pilot program to help people finance fire safety features for older homes.

Making fire-hardening improvements may lower insurance costs. Unlike flood insurance, fire insurance has traditionally been part of homeowners insurance. But with insured losses from the 2017 and 2018 fires totaling over $24 billion, insurers are scrambling to figure out how to stay in business.

Some insurance companies have responded by drastically raising premiums or dropping high-risk customers. In December 2019, the state insurance commissioner imposed a one-year moratorium on policy nonrenewals. And the California Fair Access to Insurance Requirements Plan expanded to provide fire insurance to homeowners when all other insurance options have failed.

Ready for fire

In a wildfire, most houses are ignited not by walls of flames but by embers — small sparks that can travel far from the main fire, Hawks says. House fires can start when one or a few of these sparks land on combustible material, such as dry leaves in a gutter, or if embers find their way inside the house through a roof vent or open window.

For homes built before 2008, Cal Fire suggests some low-cost retrofitting strategies, including sealing any gaps with caulk, weather stripping or fine metal mesh screens; removing dead or dry vegetation from around the house and regularly cleaning leaves and other flammable material from gutters and under decks. More expensive investments include replacing roofs and decks with fire-resistant materials and upgrading windows to multipaned tempered glass that can withstand high temperatures.

One of the most important strategies, required by law in some fire-prone states, is a 100-foot (30.5-meter) radius of defensible space around the home that is kept free of dead or dry plant matter. At least five to 20 meters of cleared space

around a structure can slow or stop the spread of a wildfire and protect a home from catching fire from direct flame contact or radiant heat, according to a 2014 study in the *International Journal of Wildland Fire*. "I don't stop at 100 feet. I clear everything around my ranch out to 500 feet. Defensible space is the most effective tactic I've seen for protecting property," says retired Kern County firefighter Carrie Shreffler, a resident of Posey, Calif.

Every property is unique in terms of fire risk. "If you really want to assess a home's vulnerability, you also have to look at weather, topography and fire history for the given area," Hawks says. "What is the home made out of? How is it constructed? Does it have defensible space? Is there water available for fighting a fire? How close together are the neighboring homes?"

In densely built areas, the houses themselves can fuel fires. "You've probably seen aftermath photos where a fire has swept through a town and all the homes have burned, but there are still trees standing and green vegetation," Moritz says. "That's what happens when the homes themselves are the fuel. It's not a land management problem where you should have cleared more brush. You can't thin the fuels because the homes were the fuel."

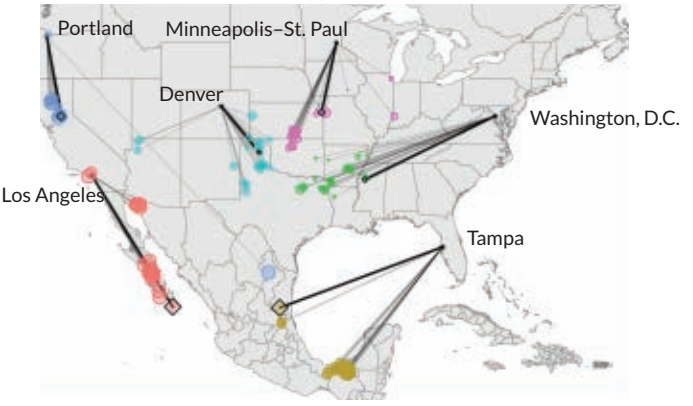
As more homes are built in fire-prone areas across the United States, community-level fire safety approaches will be needed, Moritz says. "A whole suite of risk-reduction measures can be applied at the community scale," he says. "We need to pay attention to how we lay out communities, with buffer zones between houses and between the community and the surrounding landscape."

In a report published in April by the University of California Division of Agriculture and Natural Resources, Moritz and colleagues also recommend burying power lines, creating water storage facilities for fighting fires, hardening emergency facilities and creating community refuges where people can take shelter.

Some communities are already taking steps to prepare for emergencies. In Sequoia National Forest, the Posey Area Fire Auxiliary has been meeting every month for over two decades to educate residents about fire prevention. In 2016, the Cedar Fire burned right to the edge of the mountain community, located within the national forest, but no lives were lost and of about 300 homes, only three abandoned cabins burned, in part due to the community's diligence. "We all learned a long time ago that we need to be our own first line of defense," Shreffler says.

After the Cedar Fire, Posey and other surrounding communities were struck by several rain-triggered floods. Flooding after a wildfire is common, Moritz says, because the charred ground cannot absorb water as readily as it once did. These flood events can sometimes evolve into highly destructive debris flows, a thick slurry created when ash mixes with floodwater.

Homeowners living in fire-prone regions near creeks or drainages should consider the possibility of needing to fire- and flood-proof their homes, Moritz says. "The vision is that someday, we will build such hardened and sustainable homes that natural hazards will just be something that happens outside," Moritz says. "We'll [be able to] watch fires go by like violent rainstorms."



By the 2080s, climates of major U.S. cities are expected to warm to match locations hundreds of kilometers south, as shown above. For example, Washington, D.C., will feel more like northern Mississippi, and Los Angeles could feel as warm as Mexico's Baja Peninsula.

M. FITZPATRICK *ET AL*/*NATURE COMMUNICATIONS* 2018

Old-fashioned self-sufficiency

Adapting to climate change may seem daunting, but for many in the United States, the impacts won't come in the form of devastating floods or fires. Instead the seasons will gradually get hotter. For those not facing catastrophe, many of the most effective climate resiliency tactics are rooted in common sense and self-sufficiency, says Alexandra von Meier, an electrical engineer at the University of California, Berkeley.

"A small amount of preparation can go a long way to making any situation more livable," von Meier says. For example, a solar power array and battery bank, or an emergency generator or portable solar setup, "can make a big difference" in maintaining basic home systems and lines of communication. Installing rainwater collection barrels can help see your garden through a dry season and help you keep water on hand in emergencies. And making upgrades for a better insulated, more energy-efficient home will help lower home operating costs, as well as your carbon footprint (see Page 34), Raymer says.

That preparation is key, von Meier says. "Whether people will be able to stay in their own homes in the aftermath of a natural disaster or a long-term power outage will ultimately depend on their level of preparedness. Do you have enough food and water on hand? Do you have a plan for when the lights don't work or water stops coming out of the faucet? Do you have ways to communicate with the outside world? These are very basic needs that people should know how to meet." ■

Explore more

■ Oliver E.J. Wing *et al*. "Estimates of present and future flood risk in the conterminous United States." *Environmental Research Letters*. February 28, 2018.

Mary Caperton Morton is a freelance science and travel writer living in the fire-prone foothills of California's Sierra Nevada.

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Reducing Your Emissions

Individuals can have influences big and small

By Christie Aschwanden

Three years ago, Kim Cobb was feeling "completely overwhelmed" by the problem of climate change. Cobb spends her days studying climate change as director of the Global Change Program at Georgia Tech in Atlanta, but she felt paralyzed over how to be part of the solution in her personal life. The barriers felt immense.

She decided to start small. On January 1, 2017, she made a personal climate resolution: She would walk her kids to school and bicycle to work two days a week. That change didn't represent a lot in terms of carbon emissions, she says, "but it was a huge lesson in daily engagement."

In the beginning, her modest goal seemed daunting, but she quickly discovered that the two simple activities nourished her physical and mental well-being. She wanted to do them every day. "It's no longer for the carbon — it's for the fact that I genuinely love riding my bike and walking my kids to school," she says. And that made her wonder: What other steps was she thinking of as sacrifices that might actually enrich her life?

A November 2019 survey by the Yale Program on Climate Change Communication suggests that Cobb isn't alone in her worries about climate change. Fifty-eight percent of the U.S. residents surveyed were "alarmed" or "concerned" about global warming. Cobb has turned her concern into action. It's not too late to reduce the damage caused by global warming, but it will take drastic reductions in greenhouse gas emissions, says Jonathan Foley, executive director of Project Drawdown, a San Francisco–based nonprofit research organization that identifies ways to reduce carbon emissions.

To keep global temperatures from rising too quickly, we need to re-engineer our society away from fossil fuels. A 2015 study calculated that to rein in warming, about 80 percent of global reserves of coal, 50 percent of natural gas reserves and 33 percent of the world's oil must be left unused.

We can't get to drawdown, the point at which levels of greenhouse gases in the atmosphere start to steadily decline, with one easy fix, Foley says. Action is required on multiple levels — government, industry and individuals — and across multiple systems, including energy, transportation, housing and food. We need to do *all* of the things, says Foley, whose organization has identified more than 80 climate "solutions" available now. These range from renewable energy technologies to plant-based diets to mass transit. "To get to drawdown, we need them all," Foley says.

When it comes to the changes that individuals can make, "the most effective thing that you can do depends on your specific circumstances," says Christopher Jones, director of the CoolClimate Network at the University of California, Berkeley. His group has produced maps that estimate a household's carbon footprint based on ZIP code and lifestyle. The graphics on the following pages, based on CoolClimate Network calculations, will help you find your biggest levers for cutting emissions, which for U.S. households are, on average, the equivalent of 48 metric tons of carbon dioxide per year.

> "The most effective thing that you can do depends on your specific circumstances."
> CHRISTOPHER JONES

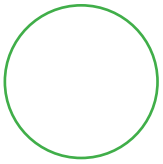
Transportation

How you get where you're going is one of the biggest sources of greenhouse gas emissions, and the size of your transportation emissions usually depends on where you live, Jones says. City dwellers have more access to public transportation, while people in the suburbs tend to drive a lot more. For people who drive long distances, getting the most fuel-efficient car, a hybrid or an electric, may be the best way to curb emissions. Carpooling when possible, combining trips and leaving the car home once a week also help.

If you fly, there's a good chance that aviation emissions are your biggest lever. Once people can travel again, consider vacationing closer to home and look for alternatives to business travel, such as videoconferencing. Take ground transportation instead of flying whenever possible. When flying can't be avoided, take the advice of Dan Rutherford, shipping and aviation director at the International Council on Clean Transportation: Fly like a NERD. Choose a New(er) aircraft; book Economy class; take a Regular, medium-sized plane instead of a less-efficient small regional or jumbo jet; and select a Direct flight.

Shelter

The average U.S. home uses three to four times the electricity of a European one, Foley says. That's mostly due to inefficient appliances and lighting and insufficient insulation. Those are all things that homeowners can address. Installing solar panels takes a big chunk out of your emissions. But if panels are too costly or just not feasible, purchasing renewable energy from a clean energy provider can offer the same emissions savings.



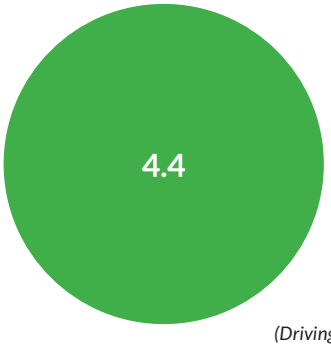
= 1.0 ton of CO_2 equivalent saved per year
(Relevant assumptions shown in parentheses)

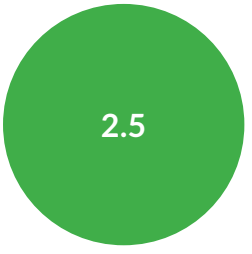
Replace 25 mpg car with

Electric car

Hybrid car (55 mpg)

Fuel-efficient car (40 mpg)





(Driving 12,000 miles per year)

Replace 25 miles of driving a week with

Bicycling

Taking the bus

(Current car gets 25 mpg; bus is diesel engine)

Change air filters regularly and keep tires properly inflated

(These two actions raise efficiency by 3 percent each)

Transportation

How you travel plays a big role in your carbon emissions. Think about your main means of transportation and trim from there. If you're in the car a lot, go for a higher-efficiency model. If you're a frequent flier, look for ways to cut back on the number of flights you take.

Eliminate one round-trip cross-country flight per year

(Based on approximate round trip from New York to San Francisco)

Alternate commuting alone in a car with

Carpooling two days/week

Telecommuting five days/month

(Car gets 25 mpg, commute is 25 miles round trip; carpool with one other person)

Practice ecodriving: Reduce rapid acceleration and braking and slow top cruising highway speed from 70 to 65 mph

(Driving 12,000 miles per year, fuel economy 25 mpg)

Shelter

What you can do to cut the carbon emissions from your home depends on whether you own or rent. Some of these options, like installing solar panels, are only available to people who own their home. But there are plenty of other things that both renters and owners can do.

Turn the thermostat...

- down 5° F in winter — 0.3
- up 5° F in summer — 0.3

(Home is about 1,850 square feet, heated with electricity)

Change your source of electricity

Purchase green energy from a clean energy provider — 6.3

Install solar panels at your home — 6.3

(Household uses 10,700 kilowatt-hours of electricity per year and 100 percent of electricity comes from a clean energy provider or from solar panels)

Line dry two loads of laundry per week

0.2

(Machine-drying four loads of laundry uses 690 kilowatt-hours of electricity)

Replace 10 incandescent lightbulbs with LEDs

0.7

(Lights are on five hours per day)

Reduce your trash output by 20 percent

0.3

(Household throws out 0.5 cubic yards of trash a week)

Turn off the lights when not in use

0.2

(Shut five lights at 40 watts each for four hours per day)

Put desktop computer in sleep mode nights and weekends and turn off monitor during those times

0.2

(Remember to do this 50 percent of the time)

Plant five trees in your yard

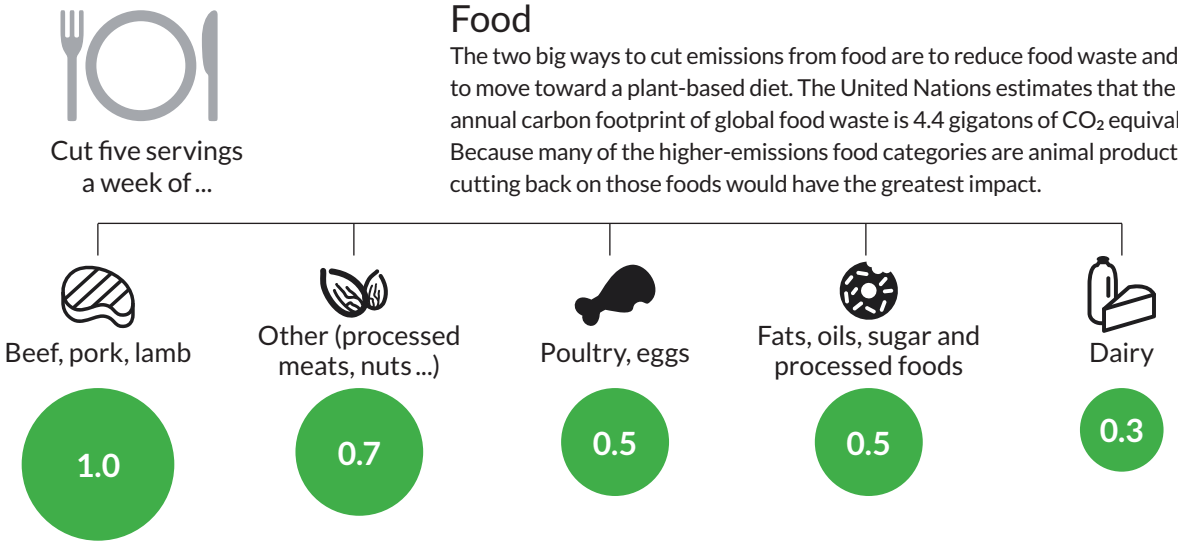
0.3

(Some of the savings comes from reduced AC use as the result of shade from the trees)

Install low-flow showerheads

0.2

(Household takes two showers per day for eight minutes each; savings come from heating water)



If home improvements are in your budget, go for optimized insulation, weather stripping and energy-efficient windows and appliances. Install thermostats that adjust the temperature based on when you're home and awake. And, of course, bigger houses take more energy to heat, cool and light, plus more space means more stuff. "The majority of emissions regarding shelter come from the stuff you buy," Jones says. If downsizing is an option for you, it's worth considering.

Food

The biggest lever to cut food emissions is to stop producing more food than we need. Americans waste about 25 percent of the food we buy. According to Project Drawdown, adopting a vegetarian diet can also cut emissions, by about 63 percent, while going vegan can reduce them by as much as 70 percent. Agriculture is a major source of greenhouse gas emissions, and meat and dairy production are the big contributors. Even cutting back on animal products can make a difference.

Do individual choices matter?

When Cobb looked at her carbon footprint, she found that flying represented about 85 percent of her emissions. So she joined a community of people on Twitter who resolved to fly less, and she committed to cutting her business and personal flights by 30 percent. With the group's support, she dropped another 30 percent the next year, but it wasn't always easy. Her pledge didn't make her many friends within the academic community initially. But the goal of flying less has become more mainstream, at least among her colleagues, as she's shown it can be done.

"It started as an individual action," she says, but her decision to forgo certain work travel created new opportunities for virtual conferences and other flying alternatives for her colleagues, too. "It has transformed into a collective-scale action to shift cultural norms," Cobb says.

Social influence can drive change, says Diana Ivanova, a research fellow at the School of Earth and Environment at University of Leeds in England who reviewed emissions reduction options in April in *Environmental Research Letters*. If you see other people taking steps to shrink their carbon footprints, "you may feel more empowered to enact changes yourself."

Researchers call this transmission of ideas and behaviors through a population "behavioral contagion." That's where individual action can be a potent force for change, says Robert Frank, a Cornell University economist. "Installing solar panels, buying an electric vehicle or adopting a more climate-friendly diet don't just increase the likelihood of others taking similar steps, it also deepens one's sense of identity as a climate advocate," Frank writes in his 2020 book, *Under the Influence: Putting Peer Pressure to Work*. Those actions can also encourage other meaningful actions, like supporting candidates who favor climate-protecting legislation.

Some of the most significant action is happening at state and local levels. Your mayor and city council have a lot of power to reduce the community's carbon footprint, says Cobb, who found herself getting more involved with each success. She was elected traffic chair of her neighborhood board in 2017 and is now working on improving biking infrastructure to make cycling safer for everyone.

Individual actions can create ripple effects, says ecological economist Julia Steinberger of University of Leeds. Teenage climate activist Greta Thunberg helped spread awareness about aviation emissions, and now overnight train lines between European cities are reopening. "It wasn't a big industry-wide decision or government regulation. It was a bunch of people deciding, we don't want to fly any more," Steinberger says. ■

Explore more

- UC Berkeley's CoolClimate Network carbon footprint calculator: coolclimate.berkeley.edu/calculator
- Project Drawdown: drawdown.org

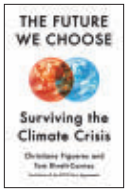
Christie Aschwanden is a journalist based in Colorado.

BOOKSHELF

New books offer different takes on climate change

Climate change is increasingly becoming part of everyday conversations. For those who want to join the discussions, there is no shortage of books that give detailed background and context on the subject. The question is, which to read?

Science News staff members have reviewed several books published this year to guide you to which ones you might like. Many of these offerings address perhaps the most pressing question: With limited time to act, what's the best way to reduce greenhouse gas emissions to avert the most dire impacts of climate change?



The Future We Choose
Christiana Figueres and Tom Rivett-Carnac
Knopf, $23

WHO SHOULD READ?
Those who are afraid it's too late to curb climate change

In this call to arms, two architects of the Paris Agreement paint side-by-side visions of the world in 2050: a pollution-choked hellscape rife with water wars and nationalist paranoia, and a hopeful, forested world of energy efficiency and community-based agriculture. It's not too late for that second future, the authors argue, but it requires a mind-set shift away from pessimism and the idea of resource availability as a zero-sum game. The book offers 10 actions for readers to take, from avoiding fossil fuels to engaging in politics.

The Future Earth
Eric Holthaus
HarperOne, $22.99

WHO SHOULD READ?
Readers looking for solutions to the problem

In this imagined history of the next 30 years, a meteorologist plots a path toward zero carbon emissions. We won't get there with solar panels and electric vehicles alone, he says, criticizing those as market-based mechanisms that reinforce the status quo. Instead, a political and economic revolution is required. The book envisions economies driven by need rather than want, global systems for climate migration and natural disasters as catalysts for collective action. Such a vision is politically feasible, he argues, because not taking action will be much more costly in the long run.

The 100% Solution
Solomon Goldstein-Rose
Melville House, $17.99

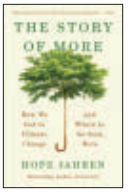
WHO SHOULD READ?
People who want to hear a lawmaker's perspective

A former Massachusetts state legislator presents a concise and, he claims, realistic five-pillar framework for reaching negative carbon emissions by 2050. Because most new emissions come from rapidly developing countries, solutions must be economically viable for everyone. He argues that a "World War II–scale mobilization" of technology development can get us there. Central to his plans are scaling up nuclear power, improving battery storage and rolling out "greener" industrial processes.

A Field Guide to Climate Anxiety
Sarah Jaquette Ray
Univ. of California, $16.95

WHO SHOULD READ?
Anyone who feels worried, depressed or guilty about climate change

Drawing on the author's expertise as an environmental humanities scholar, this book outlines how environmentally conscious citizens can cultivate a healthy mind-set and strong interpersonal relationships for taking climate action. To deal with fear and sadness associated with climate change, the author suggests mindfulness practices. To avoid burnout, she advocates setting attainable goals, like reducing personal emissions or collaborating on environmental projects with local community members. The book also offers practical tips for interacting with skeptics.



The Story of More
Hope Jahren
Vintage, $15

WHO SHOULD READ?
Those who want to get up to speed on climate change's underlying causes

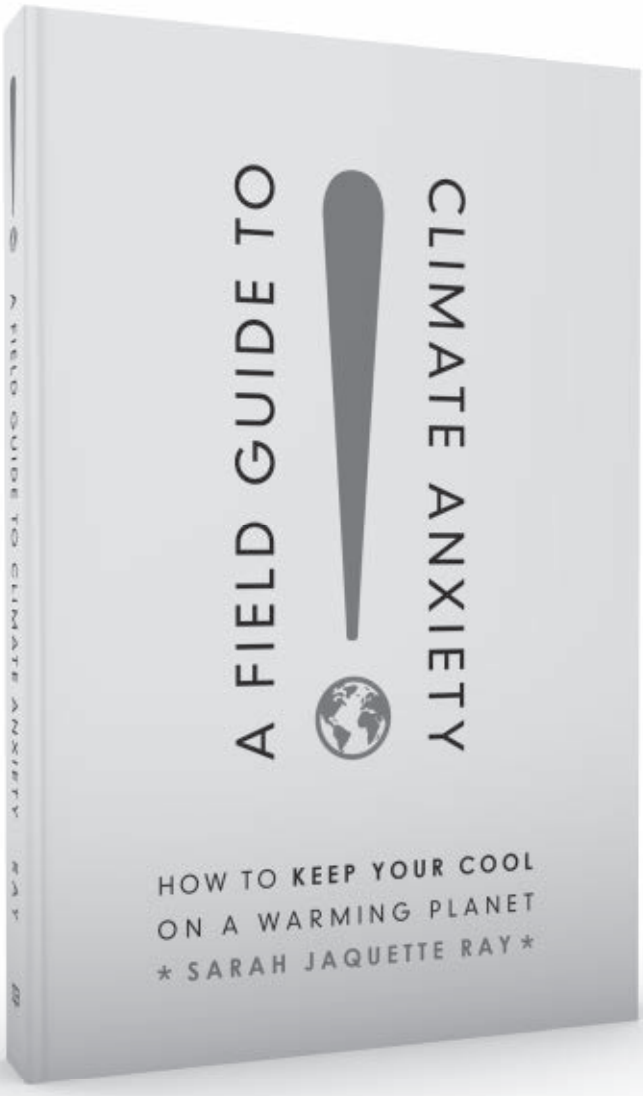
A paleobiologist's succinct examination of "how we got to climate change" is both sweeping and straightforward. Ranging across human history, and everywhere from Mesopotamia to Minnesota, this book explores how the same ingenuity and industrious spark that has allowed us to squeeze ever more food and energy from the Earth also set the stage for the current climate crisis. The book ends with practical actions individuals can take to solve the crisis that all fall under the umbrella of using less and sharing more.

Beyond Global Warming
Syukuro Manabe and Anthony J. Broccoli
Princeton Univ., $35

WHO SHOULD READ?
Serious science buffs

In 1894, a Swedish scientist made a startling announcement: His calculations suggested that pumping enough carbon dioxide into the atmosphere could raise global temperatures. Scientists have since devised increasingly complex models to understand our impacts on climate, weaving together observations and equations to simulate changes on land, in the ocean and in the atmosphere. This book describes the evolution of these models. Packed with data and graphs, it's not a light read, but it gives an in-depth, science-rich understanding of this crucial field.

NEW FROM UC PRESS



Paperback, 216 pages, $16.95

Gen Z's first "existential toolkit" for combating eco-guilt and burnout while advocating for climate justice.

"It would be foolish not to freak out over climate change. But it would be sad if that despair kept you from working hard on this crisis, not to mention enjoying life on what is still a beautiful planet. This book has some wise strategies for finding a useful balance."

—Bill McKibben, author of *Falter: Has the Human Game Begun to Play Itself Out?*

"Bold and beautiful, this hands-on companion is essential reading for wrestling with the most important issue of our time."

—Kari Marie Norgaard, author of *Living in Denial: Climate Change, Emotions, and Everyday Life*

"Essential reading for anyone despairing over our current climate emergency and future of turbulent change."

—Leslie Davenport, author of *Emotional Resiliency in the Era of Climate Change*

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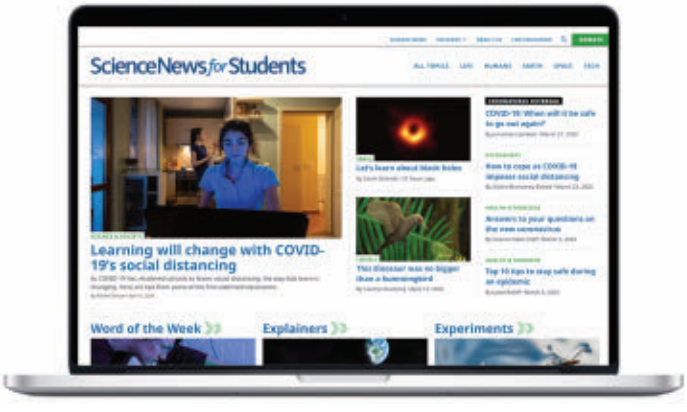
Expanding access to kid-friendly science journalism and learning resources

Science News for Students and *Science News* in High Schools offer free STEM resources for fifth through 12th grades

With schools closed worldwide and learning disrupted by the COVID-19 pandemic, *Science News* wants to ensure that students, parents and educators have what they need for continued learning outside the classroom. *Science News for Students* and the *Science News* in High Schools Digital Library offer a variety of free, age-appropriate STEM resources for students from fifth through 12th grades, suitable for learning from home.

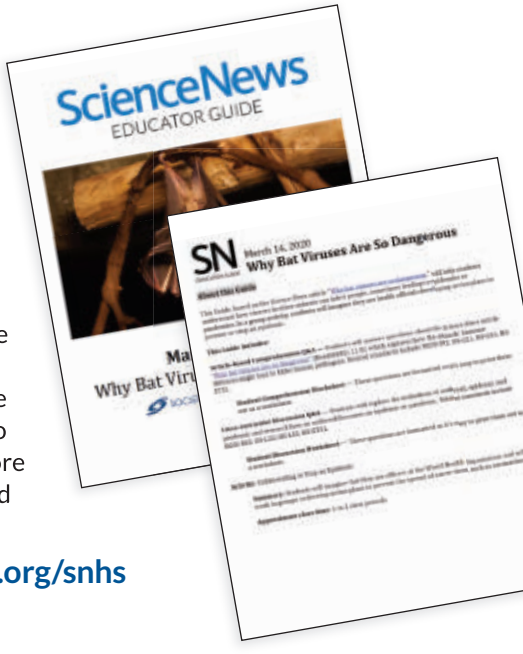
Science News for Students' free resources include coverage of science topics written for younger readers, experiments to do at home and a brand-new series that mixes STEM learning and fun called "Let's learn about."

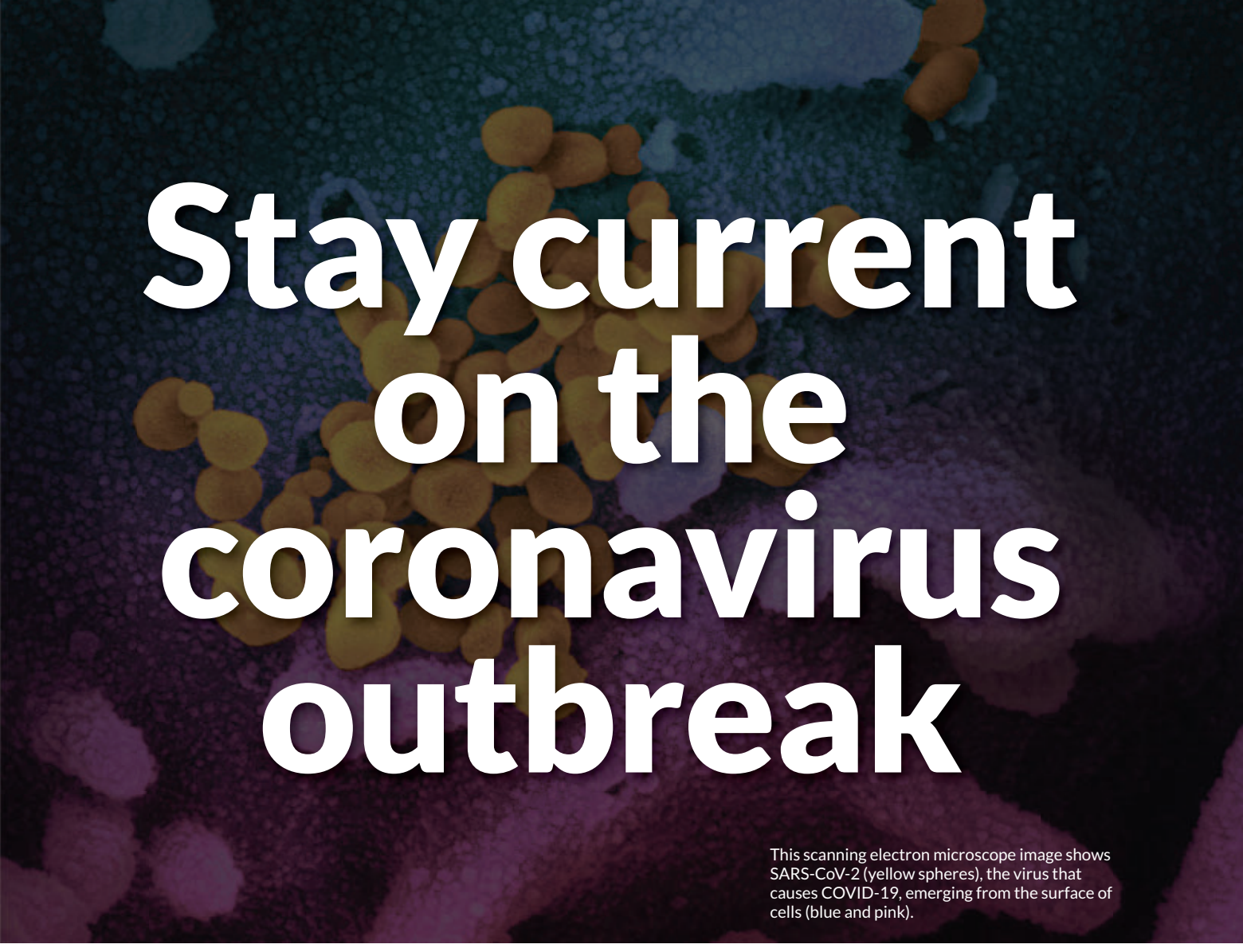
www.sciencenewsforstudents.org



The *Science News* in High Schools Digital Library has more than 200 original STEM-related exercises connected to *Science News* articles covering STEM subjects, from public health and climate change to astronomy and neuroscience. These resources can be used to engage students with core high school concepts and to build virtual lessons.

www.sciencenews.org/snhs





Stay current on the coronavirus outbreak

This scanning electron microscope image shows SARS-CoV-2 (yellow spheres), the virus that causes COVID-19, emerging from the surface of cells (blue and pink).

RML/NIAID (CC BY 2.0)

ScienceNews

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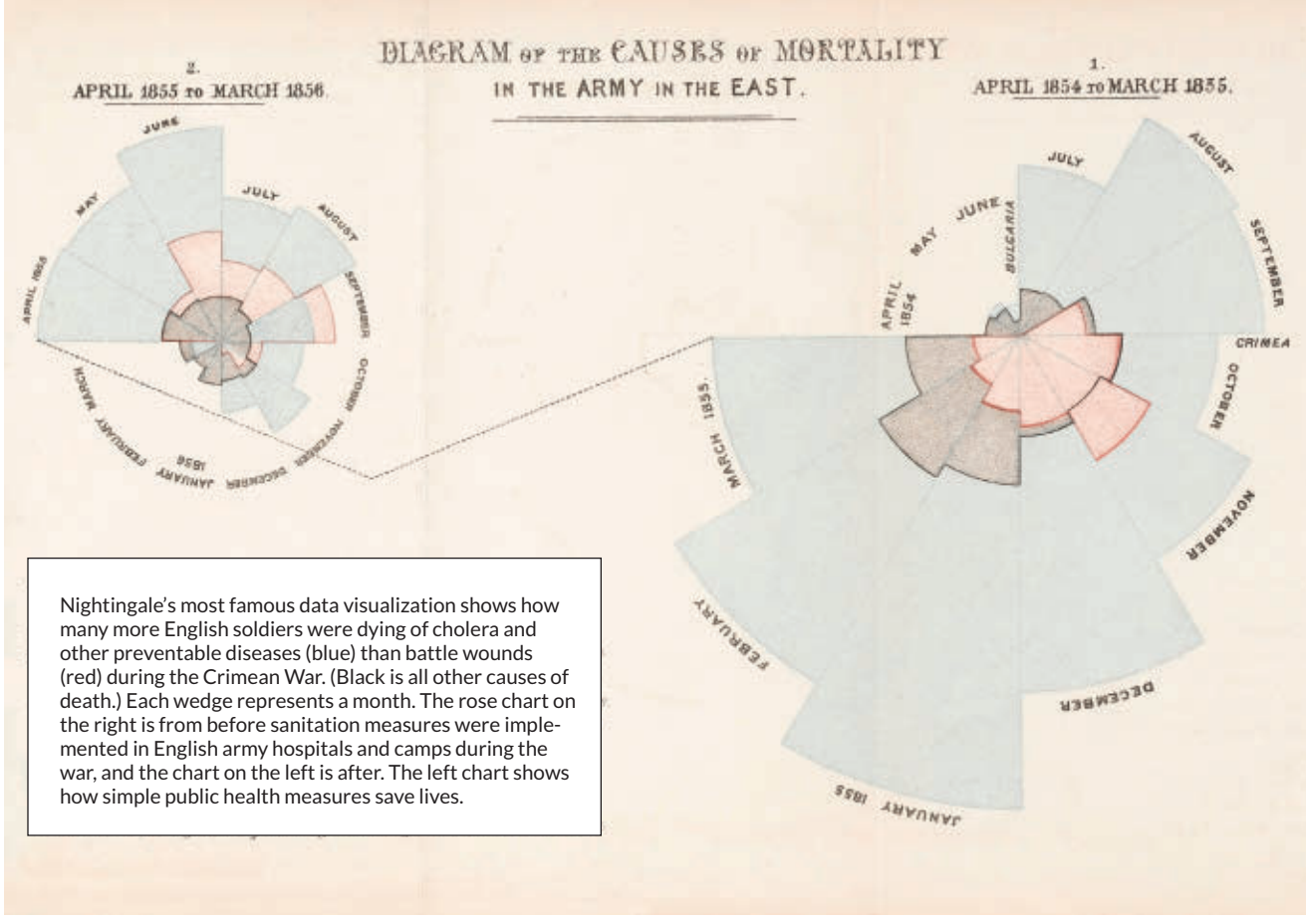
Florence Nightingale saved lives through data

Victorian icon Florence Nightingale, who would have celebrated her 200th birthday on May 12, is best known as the founder of modern nursing. But Nightingale (left) was also a statistics and data visualization pioneer who sought to illustrate that simple sanitation techniques, such as handwashing, could stop the spread of infectious diseases. While that's a particularly timely message given the ongoing coronavirus pandemic, it wasn't one widely known, or even believed, in the mid-1800s.

Nightingale's best-known diagram (below) is a variation of a pie chart known as a rose, or polar area, chart. In that diagram, she showed that poor sanitation, not battle wounds, lay behind most English soldiers' deaths during the Crimean War in the 1850s and that such deaths were avoidable, says statistics historian Eileen Magnello of University College London. It "provided unequivocal evidential data that preventable contagious diseases could be eliminated."

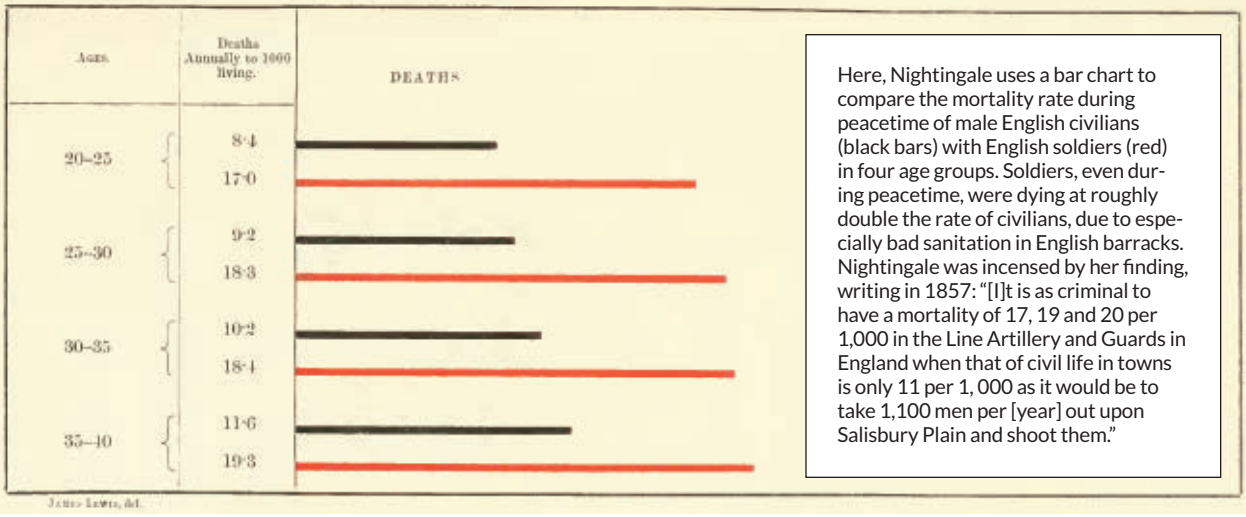
To make the graph, Nightingale used data she and medical staff collected while caring for English soldiers in army hospitals and camps. She observed the soldiers' horrific living conditions — dirty linens, clothes infested with lice and fleas, and rats hiding under the beds. Far more soldiers, she realized, were dying of diseases, such as cholera, typhus and dysentery, than battle wounds.

That graph wasn't Nightingale's only attempt at data visualization: She made a series of other charts (two shown at right) to help convince the general public that sanitation saves lives. Her ideas began to permeate public consciousness. Patients at hospitals, for example, started receiving access to fresh air, bedpans and clean utensils, bed linens and towels. — *Sujata Gupta*

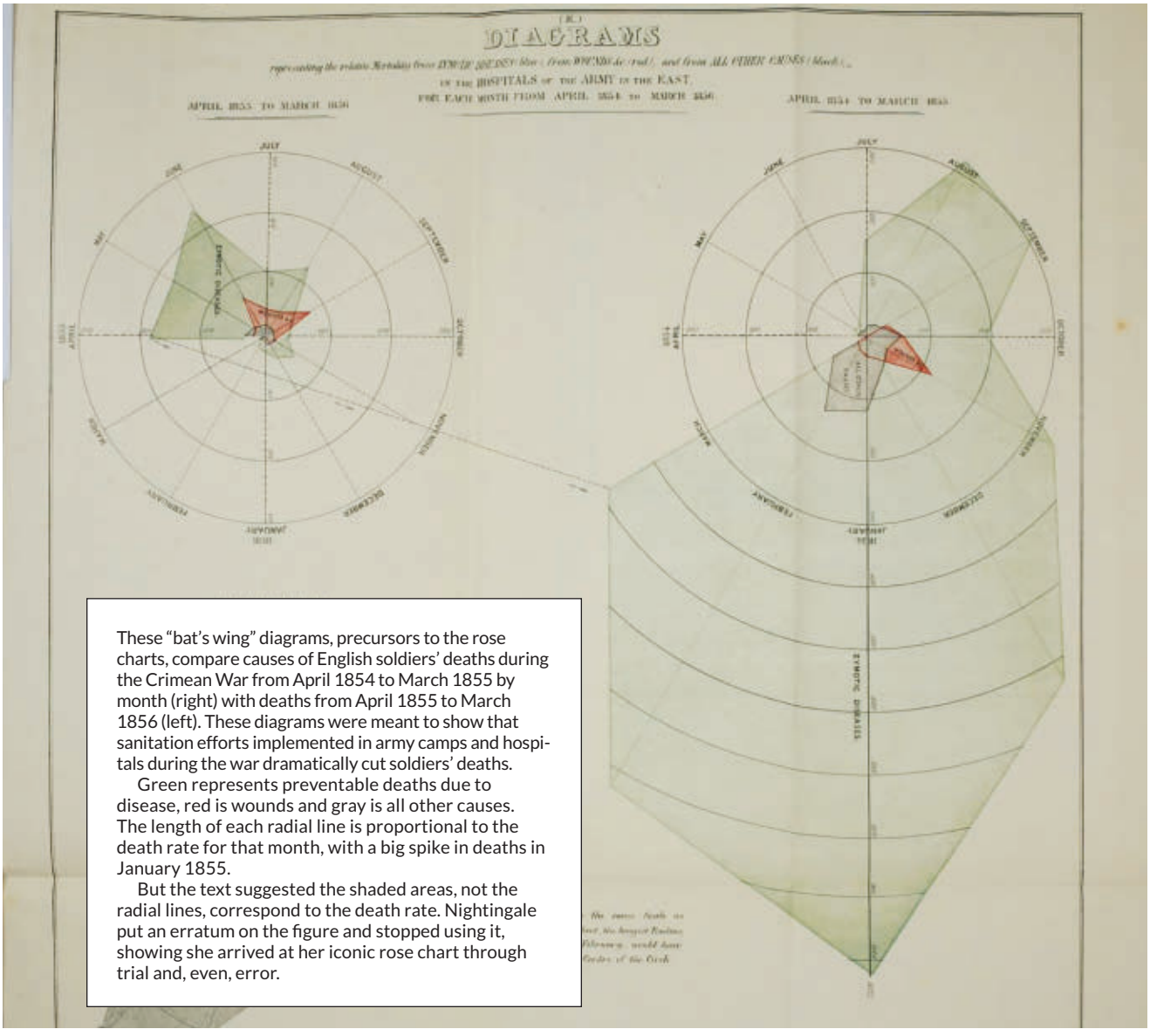


Nightingale's most famous data visualization shows how many more English soldiers were dying of cholera and other preventable diseases (blue) than battle wounds (red) during the Crimean War. (Black is all other causes of death.) Each wedge represents a month. The rose chart on the right is from before sanitation measures were implemented in English army hospitals and camps during the war, and the chart on the left is after. The left chart shows how simple public health measures save lives.

FROM TOP: INCAMERASTOCK/ALAMY STOCK PHOTO; WELLCOME COLLECTION (CC BY 4.0)



Here, Nightingale uses a bar chart to compare the mortality rate during peacetime of male English civilians (black bars) with English soldiers (red) in four age groups. Soldiers, even during peacetime, were dying at roughly double the rate of civilians, due to especially bad sanitation in English barracks. Nightingale was incensed by her finding, writing in 1857: "[I]t is as criminal to have a mortality of 17, 19 and 20 per 1,000 in the Line Artillery and Guards in England when that of civil life in towns is only 11 per 1, 000 as it would be to take 1,100 men per [year] out upon Salisbury Plain and shoot them."

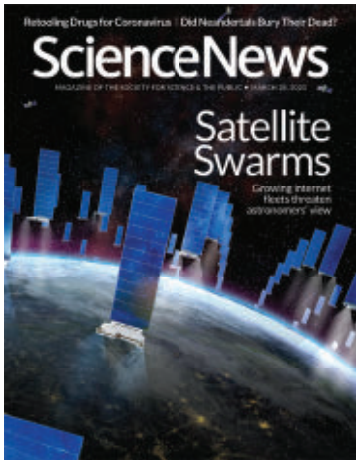


These "bat's wing" diagrams, precursors to the rose charts, compare causes of English soldiers' deaths during the Crimean War from April 1854 to March 1855 by month (right) with deaths from April 1855 to March 1856 (left). These diagrams were meant to show that sanitation efforts implemented in army camps and hospitals during the war dramatically cut soldiers' deaths.

Green represents preventable deaths due to disease, red is wounds and gray is all other causes. The length of each radial line is proportional to the death rate for that month, with a big spike in deaths in January 1855.

But the text suggested the shaded areas, not the radial lines, correspond to the death rate. Nightingale put an erratum on the figure and stopped using it, showing she arrived at her iconic rose chart through trial and, even, error.

BOTH: ELMER BELT FLORENCE NIGHTINGALE COLLECTION/UNIV. OF CALIFORNIA LIBRARIES/ARCHIVE.ORG



MARCH 28, 2020

Space jam

Fleets of satellites launched to expand global internet access are interfering with telescopes and astronomy research, ***Christopher Crockett*** *reported in "An obstructed view"* (SN: 3/28/20, p. 24). Reader **Michael Brostek** asked if researchers could use small satellites to build telescopes that orbit above the obstructing satellites. "With the proliferation of small satellites, could 'huge' [telescopes] be built ... that would be better than the best ground scopes?" **Brostek** asked.

Launching telescopes above the offending satellites is certainly an option, but it is more of a plan B at this point, **Crockett** says. As for launching many small satellites to act as a big telescope, "plans come and go, but never seem to get off the ground," he says. The feat would require building an interferometer in space, where two or more telescopes line up their incoming light waves to act as one telescope. "That's hard enough to do on the ground, and no one has done it in space yet," he says.

If the astronomy community decides to go that route, a lot of incredible science could be done. "You could build optical and infrared telescopes with a resolution equal to a telescope the size of Earth or bigger!" **Crockett** says.

COVID-19 Q&A

Science News *reporters* ***Tina Hesman Saey***, ***Aimee Cunningham***, ***Jonathan Lambert*** *and* ***Erin Garcia de Jesus*** *are following the latest research to keep you up to date on the coronavirus pandemic. The team is answering reader questions about COVID-19.*

Blood plasma from people who have recovered from COVID-19 contains antibodies that may help treat patients infected with the virus (*SN: 4/25/20, p. 6*). A reader who wished to remain anonymous asked how many people could be treated by the plasma from one recovered COVID-19 patient.

The plasma donated from one person who has recovered from COVID-19 can treat around two to four people. That's why officials are working to ramp up the plasma donation process.

On April 3, the U.S. Food and Drug Administration announced an expanded access program to coordinate the collection and distribution of plasma around the country. Patients who are hospitalized and have severe illness, or are at high risk of developing life-threatening symptoms, are eligible to receive plasma through this program and must be enrolled by their doctors.

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