SN
SCIENCE NEWS MAGAZINE
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AUGUST 18, 2018 & SEPTEMBER 1, 2018

Wildfires Erase Clean Air Gains

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SPECIAL REPORT

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Special Report

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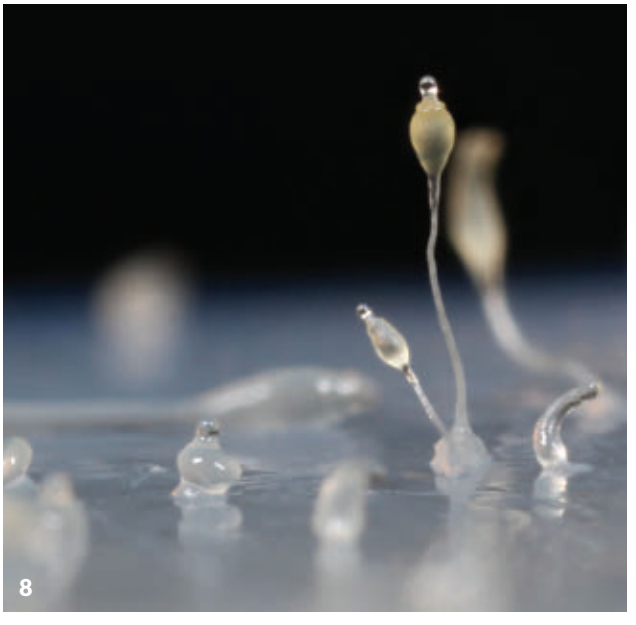

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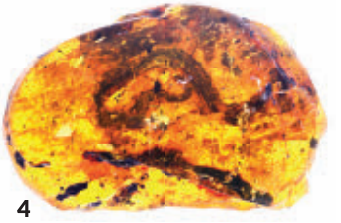

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COVER People wait in a flooded area of Dhaka, Bangladesh, on June 17, 2017, to get drinking water. *Mehedi Hasan/NurPhoto/Getty Images*

The trouble with water, be it too much or too little

A year ago, while news reports focused on the inundation of Houston by Hurricane Harvey, much of the Indian city of Mumbai was also underwater. Both coastal cities, more than 14,000 kilometers apart, had been swamped by extreme rainfall. Deputy news editor Katy Daigle, who had reported from India for seven years for the Associated Press before joining *Science News*, knew that flooding was already a chronic problem for Mumbai. Flood risks for this city of 21.4 million and many other coastal megacities in Asia are only getting worse, as climate change raises sea levels and is likely to increase rainfall in the region. Despite the obvious dangers, there's no obvious way to respond. "There isn't a one-size-fits-all solution for cities to follow," Daigle says. "Coping with a watery future is going to require tough decisions that only local communities can make."

This special issue on the future of water looks at how the increased scarcity of potable water and sea level rise, as well as the potential for more rain, will pose challenges worldwide. Contributing correspondent Alexandra Witze looked at the complex factors driving water shortages (Page 14), and Daigle collaborated with freelancer Maanvi Singh to report on urban flooding (Page 24). Earth and climate writer Carolyn Gramling traveled to the Florida Everglades, where scientists are trying to figure out if the vast ecosystem can be saved from the double whammy of freshwater diversion and saltwater intrusion (Page 18).

Work on a special report like this starts months before a magazine goes to press, when we decide on a topic to explore. In this case, we started with "climate change." A staff-wide brainstorming session followed, with dozens of ideas proposed and much whiteboard scribbling. Then those ideas had to be checked out, with editors asking more questions, reporters digging into more research and visuals editors weighing in on ways we might show rather than tell. After much debate, we decided that focusing on the future of water was the best way to provide fresh insight into this enormous topic.

All that work goes on while we're also covering the news of the day, and the demands of the 24/7 news cycle make it hard for reporters to get out in the field. Still, we think that on-the-scene reporting is crucial for explaining how science is done and how climate change is affecting people and ecosystems worldwide. "From Day One, I felt like we couldn't do this story justice without local reporting," Daigle says of her feature. She reported from our headquarters in Washington, D.C., while Singh reported from Mumbai.

Thanks to Singh, I now know how Saif, the owner of a soda shop on the beach in Mumbai, contends with flooding that had repeatedly threatened his livelihood. And from Gramling, who trekked out to research plots in the midst of the swamp, I know that the mosquitoes may be more of an occupational hazard than the alligators.

We have big ambitions for our coverage of climate change including more reports from the field, as we continue to cover this extraordinary time in the history of Earth and humans. — *Nancy Shute, Editor in Chief*

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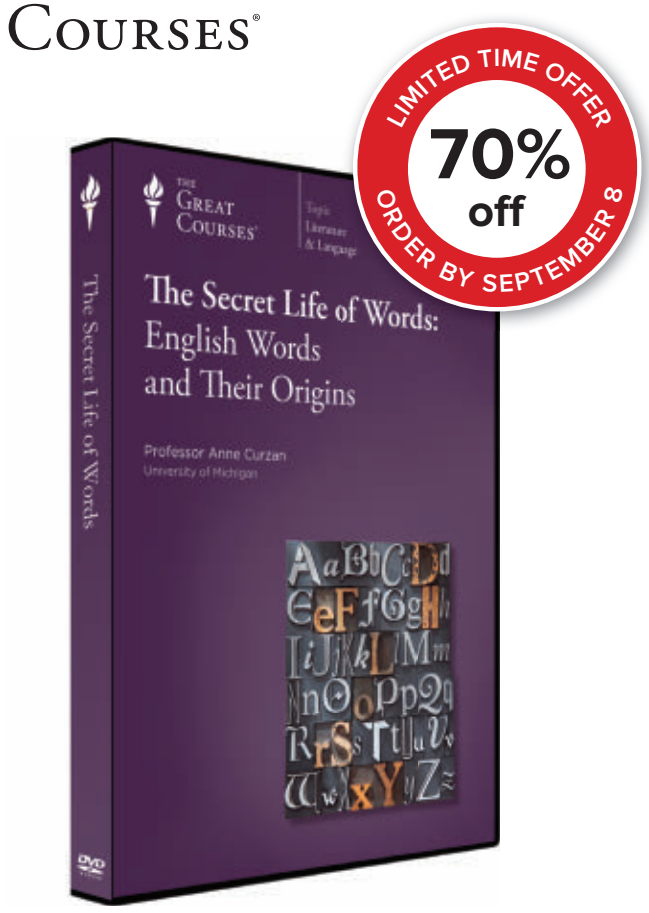

Uncover the Secret Life of Words

If it seems as if English is changing all around you, you're right. It's evident in newer words such as "bling" and "email," and from the loss of old forms such as "shall." But does this mean our language is in decay—or is change just the natural order of things? **The Secret Life of Words** answers this question by presenting the fascinating history behind the everyday words in our lexicon.

Award-winning Professor Anne Curzan of the University of Michigan—a member of the American Dialect Society and the *American Heritage Dictionary*'s usage panel—approaches the subject like an archaeologist, digging deep below the surface to unearth the remarkable story of English, from its Germanic origins to the rise of globalization and cyber-communications. Packed with surprising insights, these 36 delightful lectures reveal how culture has evolved over the centuries and why there is no such thing as a boring word.

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15. Foot and Pedestrian—Word Cousins
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17. Analogous Prologues—Greek Roots
18. The Tough Stuff of English Spelling
19. The *b* in *Debt*—Meddling in Spelling
20. Of Mice, Men, and Y'All
21. I'm Good ... Or Am I Well?
22. How *Snuck* Sneaked In
23. Um, Well, Like, You Know
24. Wicked Cool—The Irreverence of Slang
25. Boy Toys and Bad Eggs—Slangy Wordplay
26. Spinster, Bachelor, Guy, Dude
27. Firefighters and Freshpersons
28. A Slam Dunk—The Language of Sports
29. Fooling Around—The Language of Love
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Excerpt from the August 17, 1968 issue of *Science News*

50 YEARS AGO

Stormfury: Calming the Eyewall

Since man cannot muster anything approaching the energy of a hurricane, and so has no hope of overcoming the storm by force, Stormfury attempts to use the giant's own energy against it.... Last week, Project Stormfury began its 1968 season.

UPDATE: The goal of the U.S. government's Project Stormfury, which began in the 1960s, was to knock the wind out of tropical cyclones. By injecting clouds with particles of ice-forming silver iodide, researchers hoped they could disrupt the destructive eye wall of such storms. Meteorologists tested only a few hurricanes with this cloud-seeding approach because of strict rules and fickle hurricane seasons. The project shut down in 1983. Although it failed to meet its goal, Stormfury helped scientists improve hurricane forecasting (*SN Online: 9/21/17*). Researchers have proposed other hurricane-busting methods, such as dispersing sulfate aerosols into the stratosphere to try to cool the planet and reduce the number of hurricanes.

The details of a baby snake skeleton, without a skull, became clearer when high-energy X-rays revealed what was hidden inside murky amber.

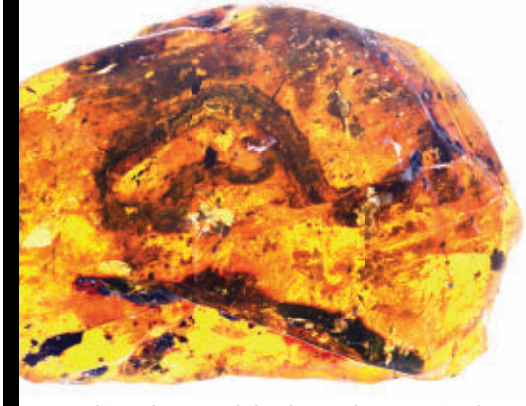
FIRST

Baby snake preserved in Myanmar amber

The first known fossil remains of a baby snake have turned up in a hunk of amber found in Myanmar. The critter, a new species named *Xiaophis myanmarensis*, met its untimely demise about 99 million years ago during the Cretaceous Period, an international team of researchers reports July 18 in *Science Advances*.

The fossil is tiny, the first hint that it was a baby snake. The skeleton, which is missing its skull, is about 5 centimeters long. In total, the snake was probably less than 8 centimeters long. Its incomplete bone formation matches what's seen today in neonatal snakes.

This find is exciting because the fossil record for snakes has been notoriously sparse until about the last 20 years, says paleontologist Michael Caldwell of the University of Alberta in Edmonton, Canada, an author of the study. Snakes don't preserve well in general. And this baby is especially delicate, with 97 wafer-thin vertebrae packed into just 4.75 centimeters of skeleton.



This walnut-sized chunk of amber contains the first known baby snake fossil.

"Even if something that small was preserved in the fossil record, in normal fossil preservation styles, you'd never find it," Caldwell says. Sedimentary rock would crush the fragile remains and separate vertebrae, which individually would be nearly impossible to identify. It's only because this snake had the misfortune to get caught up in sticky tree resin that its skeleton has been so exceptionally preserved in 3-D.

This fossil along with preserved skin from a larger snake of a different species offer the first evidence that some Cretaceous snakes lived in forests. That's not necessarily a surprise, Caldwell says. By 99 million years ago, snakes were distributed broadly around the world. But other snake fossils don't always provide enough clues for scientists to ID the animals' habitats. Because resin oozes from a tree, anything preserved inside it must have lived nearby. — *Laurel Hamers*

FROM TOP: L. XING *ET AL*/*SCIENCE ADVANCES* 2018; MING BAI/CHINESE ACADEMY OF SCIENCES

HOW BIZARRE

Macaques snack on plantation rats

Behavioral ecologist Anna Holzner recalls the first time she saw a southern pig-tailed macaque munching on a headless rat. These monkeys were known to mainly eat fruits, insects and even dirt, but nobody had reported them eating rats. "It was funny," Holzner says, "and disgusting."

This unexpected act occurred dozens of times from March to August 2016 as Holzner, of Leipzig University in Germany, and colleagues recorded what the macaques ate on oil palm plantations in northwest Peninsular Malaysia. To planters there, the macaques are pests.

Holzner did the work as part of a project led by primate ecologist Nadine Ruppert of Universiti Sains Malaysia in Penang. Holzner presented the results July 2 in Kuching, Malaysia, at the annual meeting of the Association for Tropical Biology and Conservation.

While pig-tailed macaques (*Macaca nemestrina*) spend most of their time in the forest, they visit nearby plantations daily to forage, Ruppert, Holzner and others reported in a related study in the April *International Journal of Primatology*.

Holzner's new study shows that in the plantations, pig-tailed macaques ate mostly oil palm fruits, spending only 1 percent of their meal times on rats. The researchers estimate, however, that a group of 30 macaques might eat as many as 2,080 rats in a year. Holzner and colleagues counted fewer rats on plantations wherever they located macaques.

The study has local plantation owners reconsidering the monkeys, which may be agents of rat control rather than pests, Holzner says. Still, as macaques adapt to the encroaching plantations and their numbers grow, they prey on and compete with birds and other creatures living in adjacent forests, warns ecologist Matthew Luskin of the Nanyang Technological University in Singapore. — *Yao-Hua Law*

Southern pig-tailed macaques peel back bark on oil palm trees, pouncing when a rat falls out.

MONKEY: A. HOLZNER/MACACA NEMESTRINA PROJECT; NEPTUNES: ESO, P. WEILBACHER/AIP, NASA, ESA, M.H. WONG AND J. TOLLEFSON/UC BERKELEY

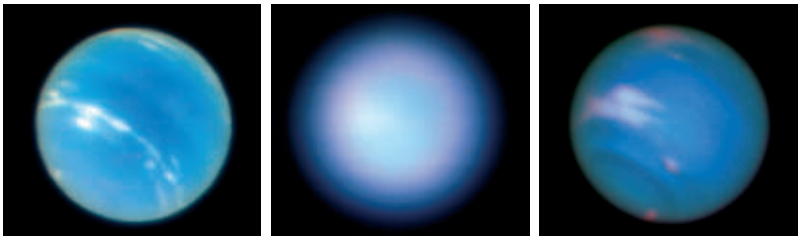
PICTURE THIS

Telescope offers clearer view of Neptune

A telescope on Earth has snapped pictures of Neptune at least as clear as those from the Hubble Space Telescope. The trick? Taking the twinkle out of stars.

Released by the European Southern Observatory on July 18, the images come from a new observing system on the Very Large Telescope in Chile. Four lasers cancel out blurring caused by Earth's atmosphere — the same effect that makes it look like stars are twinkling — at different altitudes.

The system is an updated version of adaptive optics (*SN: 6/14/03, p. 373*), a technique long used to focus telescopes. Lasers create artificial "stars" whose size and brightness are precisely known. That gives scientists a way to measure how the atmosphere is distorting their view of real, faraway stars at any given moment. The shape of the telescope's mirror changes in real time to correct for that distortion and see the sky as it really is. The resulting images from the Chilean telescope are as sharp and clear as those taken from space. That's good news, as Hubble won't last forever, and its main successor, the James Webb Space Telescope, won't take images in the visible part of the light spectrum (*SN: 3/17/18, p. 4*). With adaptive optics, telescopes on the ground can pick up where Hubble leaves off. — *Lisa Grossman*



With improved focusing, the ground-based Very Large Telescope in Chile took better pictures of Neptune (left) than it used to (middle). The shots were as good as Hubble's (right).

SAY WHAT?

Meghalayan \mehg-uh-LAY-an\ n.

The current geologic age that started over 4,200 years ago

Welcome to the Meghalayan, our geologic here and now. It's one of three newly named ages that divvy up the Holocene Epoch, a geologic time period kicked off 11,700 years ago by the end of the Ice Age.

First came a warming period, now dubbed the Greenlandian Age. Then, about 8,300 years ago, the Northgrippian Age began with a 4,100-year-long big chill. Finally, the Meghalayan started over 4,200 years ago with a 200-year worldwide megadrought.

"It marked a quite serious collapse of human agricultural civilizations," says Phil Gibbard of the International Union of Geological Sciences, which released an updated geologic time scale July 13. The megadrought triggered human crises and migrations ranging from China to the Middle East to India. A stalagmite from a cave in the northeast Indian state of Meghalaya is the official time stamp marker for the start of the age. The drought is also recorded in other geologic sediments and at archaeological sites around the world. — *Beth Geiger*

Radar observations (rainbow colors) have revealed what may be a 20-kilometer-wide lake (blue triangle) hidden beneath ice near Mars' south pole, not far from the most visible part of the southern ice cap.

ATOM & COSMOS

Lake of liquid water detected on Mars

Purported reservoir is buried beneath 1.5 kilometers of polar ice

BY LISA GROSSMAN

A Mars orbiter has detected a wide lake of liquid water hidden below the planet's southern ice sheets. There have been much-debated hints of tiny, ephemeral amounts of water on Mars before. But if confirmed, the lake is the first discovery of a long-lasting cache of the liquid.

"This is potentially a really big deal," says planetary scientist Briony Horgan of Purdue University in West Lafayette, Ind. "It's another type of habitat in which life could be living on Mars today."

The lake is about 20 kilometers across, planetary scientist Roberto Orosei of the National Institute of Astrophysics in Bologna, Italy, and colleagues report online July 25 in *Science*. But the water is buried beneath 1.5 kilometers of ice.

Orosei and colleagues spotted the lake using the European Space Agency's Mars Express. The spacecraft aimed radar at the planet to probe beneath the surface. As radio waves passed through the ice, they bounced off different materials embedded in the ice. The brightness of the reflection tells scientists about the material doing the reflecting; liquid water makes a brighter echo than ice or rock.

Combining 29 radar observations taken from May 2012 to December 2015, Mars Express revealed a bright spot surrounded by much less reflective areas in the ice layers near Mars' south pole. Orosei and colleagues considered other explanations, such as radio waves bouncing off a hypothetical layer of carbon dioxide ice at the top of the sheet, but those options either wouldn't produce the same radar signal or were too contrived to be likely.

That left one option: a lake of liquid water. Subglacial lakes on Earth have been discovered in the same way.

The lake is probably not pure water. Temperatures at the bottom of the ice are about –68° Celsius, and pure water would freeze there, even under the pressure of the ice. But salt in the water could lower the freezing point. Sodium, magnesium and calcium salts have been found elsewhere on Mars (*SN: 4/11/09, p. 12*). The pool could also be more mud than water, but that could still be habitable, Horgan says.

> "It's another type of habitat in which life could be living on Mars today."
>
> **BRIONY HORGAN**

Previously, scientists have discovered extensive solid water ice sheets under the Martian dirt (*SN Online: 1/11/18*). There were also hints that liquid water flowed down cliff walls on Mars (*SN: 10/31/15, p. 17*), but those may instead be dry avalanches. The Phoenix lander saw what looked like frozen water droplets near the north pole in 2008, but that water may have been melted by the lander itself.

"If this [lake] is confirmed, it's a substantial change in our understanding of the present-day habitability of Mars," says Lisa Pratt, NASA's planetary protection officer.

Though the lake's depth is unclear, the volume dwarfs any previous signs of liquid water on Mars, Orosei says. The lake has to be at least several tens of centimeters deep for Mars Express to have noticed it. That means it could contain at least 10 billion liters of water. "When we've talked about water in other places, it's in dribs and drabs," Horgan says.

Mars Express began orbiting the Red Planet in 2003. It took researchers more than a decade to collect enough data to convince themselves the lake was real.

For the mission's first several years, limitations in the spacecraft's computer forced the team to average hundreds of radar pulses together before sending the data back to Earth. That strategy sometimes canceled out the lake's reflections, Orosei says. On some orbits, the bright spot was visible; on others, it wasn't.

In the 2010s, the scientists switched to a technique that let the team store the data and send it back more slowly. Then in 2015, months before the end of the observing campaign, the experiment's principal investigator, Giovanni Picardi of Sapienza University of Rome, died unexpectedly. "It was incredibly sad," Orosei says. "We had all the data, but we had no leadership. The team was in disarray."

Discovering the lake is "a testament to perseverance," says planetary scientist Isaac Smith of the Planetary Science Institute, who is based in Lakewood, Colo.

But there is room for doubt, Smith says. NASA's Mars Reconnaissance Orbiter has seen no sign of the lake, even in CT scan–like 3-D views of the poles. It could be that the NASA probe's radar is scattering off the ice in a different way, or that the wavelengths it uses don't penetrate as deeply. Smith and other members of the Mars Reconnaissance team will look again and try to create a 3-D view from the Mars Express data.

"I expect there will be debate," Smith says. "This paper is well earned. But we should do some more follow-up." ■

USGS ASTROGEOLOGY SCIENCE CENTER, ARIZONA STATE UNIV., INAF

BODY & BRAIN

Lower blood pressure may aid memory

Preliminary results show the benefits of aggressive treatment

BY AIMEE CUNNINGHAM

Keeping a tight lid on blood pressure isn't just good for the heart. It may also help the brain.

People given intensive drug treatment for high blood pressure were less likely to develop an early form of memory loss, according to preliminary results from a clinical trial called SPRINT-MIND. This approach reduced the rate of new cases of mild cognitive impairment by around 19 percent, compared with people who received less aggressive treatment.

And the intensely treated group developed fewer white matter lesions over time, researchers reported July 25 at the Alzheimer's Association International Conference in Chicago. White matter lesions, which are associated with dementia, are thought to be caused by blood vessel injuries in white matter, the part of the brain that contains nerve fibers.

The brain research is part of SPRINT, the Systolic Blood Pressure Intervention Trial involving more than 9,300 participants. Some received intensive treatment aimed at lowering their systolic blood pressure — the pressure on artery walls when the heart beats — below 120 millimeters of mercury; others got standard treatment to bring it below 140.

The trial had already reported that people who received the intensive treatment dropped their risk of heart attacks and other cardiovascular problems by 25 percent, compared with the standard group. The results were the basis for more stringent blood pressure guidelines released last year (*SN: 12/9/17, p. 13*).

Observational studies have shown that people with lower blood pressure have a lower risk of dementia, says geriatrician Jeff Williamson of Wake Forest School of Medicine in Winston-Salem, N.C. SPRINT-MIND set out to test that claim.

Using memory tests, researchers assessed the trial participants for probable dementia (unable to perform daily activities independently), early memory loss (some difficulty functioning, but still independent) or no impairment. By June 2018, more than 8,600 of the people, with an average age of 68, had completed an assessment.

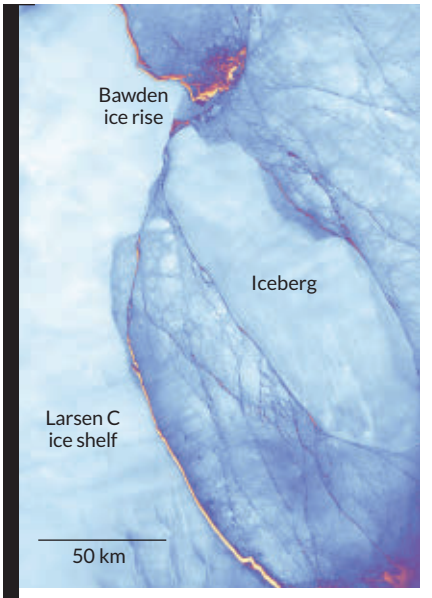
Fewer people in the intensely treated group had early memory loss, which is often a precursor to dementia, says Williamson. The trial was ended early, in 2015, due to the compelling cardiovascular benefits, so participants' blood pressure was medically managed for only two to three years. "That's an encouraging message," Williamson says. "It doesn't take but just a few years to see this effect."

The trial also looked at white matter lesions. These injuries in the brain are a consequence of aging, but are also associated with hypertension, says Ilya Nasrallah, a neuroradiologist at the University of Pennsylvania. Previous work has found that white matter lesions increase risk for dementia in people 60 and older.

About 450 participants had MRI brain scans at the start of the trial and about four years later. The volume of white matter lesions increased by 0.28 cubic centimeters over that time in the intensive treatment group and 0.92 cubic centimeters in the standard group.

But there is evidence that the relationship between blood pressure and brain health may change with advancing age, says Zoe Arvanitakis, a cognitive neurologist at Rush University Medical Center in Chicago who was not involved with the trial.

In adults 75 and older, past work has found that low diastolic blood pressure — the pressure on arteries when the heart rests between beats — increases the risk of dementia. The age at which people are at high risk for dementia is older than the average age of those in the SPRINT-MIND trial, Arvanitakis says. "We really need to study this question in older persons as well." ■



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EARTH & ENVIRONMENT

Massive iceberg gets stuck in Antarctica

About a year ago, an iceberg about the size of Delaware broke off the Larsen C ice shelf in Antarctica (*SN: 8/5/17, p. 6*). And the ice chunk hasn't moved much since. The iceberg traveled about 45 kilometers northeast before getting stuck behind an elevated ice promontory called the Bawden ice rise (as shown above in an infrared satellite image taken July 1).

Scientists monitoring the iceberg say it has been battering the Bawden ice rise as winds and ocean currents push against the iceberg. Bawden helps stabilize Larsen C. If Bawden were destabilized, that could lead to the collapse of the rest of the ice shelf, which could have implications for sea level rise, says Earth observation researcher Anna Hogg of the University of Leeds in England.

The iceberg may still escape if it can twist around the tip of Bawden. Currents and winds often carry Antarctic icebergs toward South Georgia Island in the southern Atlantic Ocean, where many icebergs thin out and melt away, says glaciologist Ted Scambos of the National Snow and Ice Data Center in Boulder, Colo. — *Leah Rosenbaum*

LIFE & EVOLUTION

How social amoebas feed their kids

Proteins help slime molds store food for the next generation

BY SUSAN MILIUS

In the final frenzy of reproduction and death, social amoebas secrete proteins that help preserve a starter kit of food for offspring.

Dictyostelium discoideum, a slime mold in soil, eats bacteria. Some forms of this species farm the microbes, passing them along in spore cases that give the next generation of amoebas the beginnings of a patch of prey. Tests find that the trick to keeping the parental immune system from killing this starter crop of bacteria is a surge of proteins called lectins, researchers say in the July 27 *Science*.

Lectins create a different way for the amoebas to treat bacteria: as actual symbionts inside cells, instead of as prey or infections, says study coauthor Adam Kuspa, a molecular cell biologist at Baylor College of Medicine in Houston. In a lab test of this ability, coating other bacteria with lectin derived from a plant allowed bacteria to slip inside cells from mice and survive as symbiotic residents.

Some stealthy proteins let social amoebas save live food in the ball-shaped spore cases atop their slender stalks for the next generation.

The findings mark another chapter in a story that has been upending decades of what people thought they knew about social amoebas. The basic, almost alien, scenario is still true: *D. discoideum* amoebas, nicknamed Dicty, start life as single cells. When food dwindles, cells come together into a multicellular slug-shaped creature with eight to 10 types of cells and the power to crawl. It then develops into something more like a fungus with a stalk holding up a case of spores, which start the next generation of amoebas.

Scientists once believed those casings held only spores. "For 70 years, we all thought that *Dictyostelium* development was sterile," Kuspa says. Then in 2011, researchers discovered that some Dicty strains are "farmers," routinely packing live bacteria into spore cases and jump-starting new bacterial livestock with each generation (*SN: 2/12/11, p. 11*).

Researchers also discovered that the Dicty animal-like slug phase forms an immune system that kills bacteria, even as evidence grew that some bacteria had uses beyond food, such as providing defense chemistry. How the slug avoided killing its helpful bacteria was a mystery.

Comparing secretions of Dicty strains carrying bacteria versus strains that don't showed a "dead-obvious" difference, Kuspa says: more lectins called discoidin A and discoidin C in the carrier forms. A series of tests supplying and withholding the proteins showed big effects on the fates of bacteria. Lectins raise the chances that bacteria can slip inside an amoeba cell and live hidden from immune system sentinels. That gives the bacteria a chance to end up in the spore case.

Lectins' powers help make sense of how the discovery of bacterial farming fits with the revelation of the bacteria-killing immune system. "Outstanding" work, says Debra Brock of Washington University in St. Louis, who studies both phenomena. "I love mechanisms." ■

MATH & TECHNOLOGY

Turning electronic chips into a spray

Aerosol of sensors could track environmental, health hazards

BY MARIA TEMMING

Talk about cloud-connected devices.

Using 2-D materials, researchers have built microscopic chemical sensors that can be sprayed in an aerosol mist. Spritzes of such electronic chips, described online July 23 in *Nature Nanotechnology*, could one day help monitor environmental pollution or help diagnose diseases.

Each sensor comprises a polymer chip about 1 micrometer thick and 100 micrometers across (about as wide as a human hair) overlaid with a circuit made with atomically thin semiconducting materials. This circuit includes a photodiode, which converts ambient light into an electric current, and a chemical detector. The chemical detector is composed of a 2-D material that conducts electric current more easily if the material binds with a specific chemical in the environment.

Researchers can choose from a vast menu of 2-D materials to fashion detectors that are sensitive to different chemicals, says MIT chemical engineer Volodymyr Koman. In lab tests, Koman and colleagues made a sensor spray that detected ammonia vapor inside a sealed section of piping and a spray that ID'd soot particles sprinkled across a surface.

Right now, researchers can determine whether the sensors have come in contact with certain particles only after the fact — by collecting the chips and hooking them up to electrodes. These electrodes test how easily electric current flows through a chip's chemical detector, which reveals whether it touched a particular chemical. But future sensors could emit light signals when in contact with a target, says study coauthor Michael Strano, a chemical engineer at MIT.

The team is also investigating ways to power the circuits without ambient light and to integrate multiple chemical detectors onto a single chip.

"It's very exciting," says Kourosh Kalantar-Zadeh, an electrical and chemical engineer at the University of New South Wales in Sydney. Sprayable sensors could someday detect gas leaks, power plant pollution and other contaminants.

Similar devices could also be injected into the bloodstream, or inhaled or swallowed, for medical monitoring. ■

EARTH & ENVIRONMENT

Wildfires threaten clean air gains

Extreme pollution is worsening in the western United States

BY LAUREL HAMERS

The western United States has become an air pollution hot spot.

Air quality in states from Nevada to Montana is worse than it was 30 years ago on the days with the most extreme air pollution. Bigger and more frequent wildfires that spew plumes of fine particulate matter into the sky are largely to blame, researchers report online July 16 in the *Proceedings of the National Academy of Sciences*.

By contrast, the rest of the country has seen decreasing trends in similar smog and haze over the last three decades. Legislation such as the Clean Air Act, which mandates air quality standards and the regulation of vehicle and factory emissions of particulate matter, is making a difference, says study coauthor Daniel Jaffe, an atmospheric scientist at the University of Washington in Bothell.

But the increase in lung-clogging particulate matter from wildfires shows how the effects of climate change — which may be helping to increase forest fire activity in the American West — can counteract those gains, Jaffe says.

Wildfire smoke is filled with fine particulates, which are minuscule solids or droplets that can be inhaled into the lungs and exacerbate breathing problems. Children, the elderly and people with asthma are most at risk, but communities near wildfires can temporarily experience levels of pollutants so high that it's unsafe for anyone to be outside for very long. "When we start to think about people's health, episodic events matter a lot," says Gannet Hallar, an atmospheric scientist at the University of Utah in Salt Lake City who wasn't part of the study.

> "When we start to think about people's health, episodic events matter a lot."
>
> GANNET HALLAR

Regular exposure to elevated levels of these fine airborne pollutants (less than 2.5 micrometers wide, or about 3 percent of the width of a human hair) has also been linked to an increased risk of chronic health conditions such as heart disease (*SN: 9/30/17, p. 18*).

Tracking the broader influence of wildfires on air pollution can be tricky because the fires are intermittent and patchy, says Jaffe, who carried out the study with University of Washington colleague Crystal McClure, also an atmospheric scientist. "Most of the year, wildfires aren't impacting air quality, but on some of the worst days they are." And the blazes can hit one community hard, but leave neighboring towns relatively unaffected.

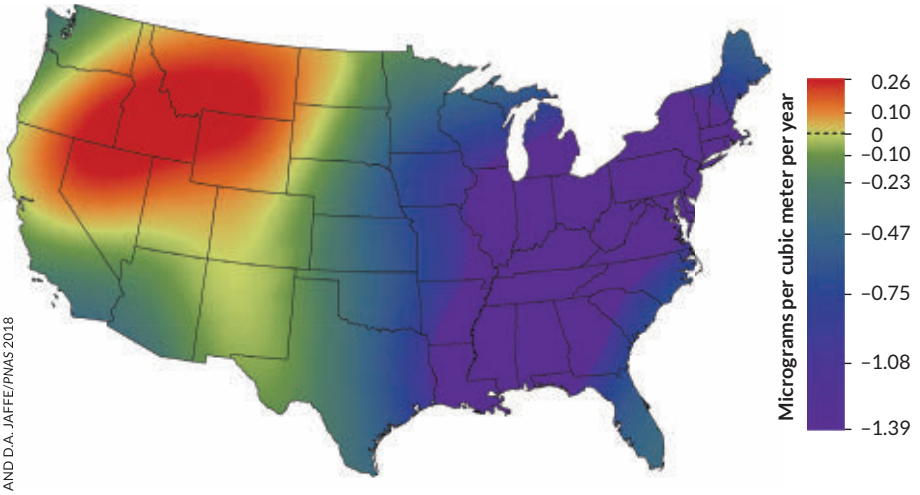
Jaffe and McClure looked at daily measurements of fine particulate matter at more than 100 rural monitoring sites around the country from 1988 to 2016. In most areas, the data showed a success story of cleaner air over time, but not in a stretch of the western United States that suffers from wildfires every summer.

The researchers made similar calculations for levels of a few specific pollutants — particulate carbon, a hallmark of fire emissions, and sulfate, a by-product of burning fossil fuels. Particulate carbon levels had increased over time from Nevada to Montana, but sulfate levels didn't, supporting the conclusion that rather than industrial activity, wildfires are mainly driving the air pollution trend in the western United States.

Most of the time, air quality is fine in the affected states — wildfires might disturb a given community for only a few days or weeks out of a year. But the air quality on the bad days, when air pollutants are especially high, is getting worse over time, the analysis showed. Those particularly bad days tended to be in the summer, when wildfires are at their peak. From Nevada to Montana, levels of fine particulates on the handful of days with the worst air quality each year have increased at an average rate of 0.21 micrograms per cubic meter per year, though there's substantial local variability in that number.

As the overall air quality picture in the country has improved, we now have harder work to do, says Jenny Hand, an atmospheric scientist at Colorado State University in Fort Collins. Those challenges include figuring out how to prevent and mitigate these more uncontrollable sources of air pollution that can't be regulated like emissions from human sources can, she says. ■

Change in microscopic particulate matter on extreme air pollution days (1988–2016)



C. D. MCCLURE AND D. A. JAFFE/*PNAS* 2018

Hazy outlook From 1988 to 2016, levels of fine particulate matter on the days with the worst air pollution decreased across most of the United States (cooler colors on the map), thanks to air quality regulations. But in one region of the western United States, wildfires are making bad air quality days worse than they used to be (warmer colors).

ATOM & COSMOS

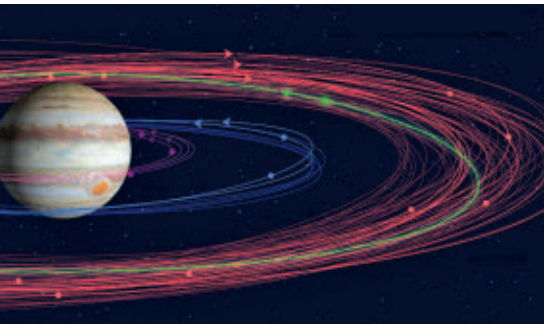
Jupiter's moon tally grows by 12

One renegade satellite could collide with its neighbors

BY LISA GROSSMAN

Astronomers have found 12 more moons around Jupiter, and one is really weird. While 11 orbit in the same direction as their neighbors, one doesn't, potentially putting it on a fatal collision course.

"It's driving down the highway on the wrong side of the road," says Scott Sheppard, a planetary scientist at the Carnegie Institution for Science in Washington, D.C.



Of 12 recently found Jovian moons (illustrated in red, blue and green), one (green) orbits in the opposite direction of its neighbors (arrows show orbit direction). The orbits of four moons discovered by Galileo are also shown (purple).

Sheppard and colleagues found the moons while looking for a putative planet that may exist beyond Neptune, known colloquially as Planet Nine (*SN: 7/23/16, p. 7*). During a 2017 survey of the most distant objects in the solar system using the Victor M. Blanco 4-meter telescope in Chile, Jupiter was visible in the same area of sky that the team was searching. "Might as well kill two birds with one stone," Sheppard thought at the time.

The researchers found a dozen objects moving around the sun at the same rate as Jupiter. Follow-up observations confirmed the moons' existence and orbits: two inner moons that orbit in the same direction that Jupiter spins, nine outer moons that orbit the planet in the opposite direction and one oddball traveler. The team announced two of the moons in 2017 and the remaining 10 on July 16.

The motions of all but the oddball are normal for Jovian moons, which now number 79. Scientists think that's because the inner moons formed from a disk of gas and dust that orbited the giant planet in the solar system's early days, similar to how the planets formed around the sun (*SN: 5/12/18, p. 28*). The outer moons were probably free-floating space rocks captured when they came too close, and their opposite orbit was set by the direction that they approached Jupiter from.

But one moon broke the mold. Informally dubbed Valetudo for the Roman goddess of health and hygiene, the moon is tiny, about a kilometer across. It orbits in the same direction as Jupiter's spin, but alongside the farther-out retrograde moons. Valetudo will probably collide with one or more of the other moons sometime between 100 million and a billion years from now, the team calculates.

Valetudo may be the remnant of a bigger object that has withstood several collisions, or of a family of moons that has since been smashed to smithereens. "It's probably the largest surviving member, if not the only one," Sheppard says.

Such nonconformist satellites are not rare, notes UCLA planetary scientist David Jewitt. "But they are very interesting, because we know that they have been captured by their host planets, but we don't know how, or from where." Figuring out what oddballs like Valetudo are made of could help nail down those details. ■

MATH & TECHNOLOGY

New robot gently grabs sea critters

Device could unlock secrets of fragile, soft-bodied marine life

BY MARIA TEMMING

Like a submarine Poké Ball, a new robotic device gently captures and releases deep-sea creatures without a scratch. This critter catcher could be decked out with cameras and other sensors to give scientists an unprecedented view of life in one of Earth's most mysterious environments.

The contraption, designed to be mounted on a remotely operated underwater vehicle, folds into a 12-sided box about 21 centimeters across. Using a joystick, an operator on board a nearby ship can carefully close this box around soft-bodied creatures such as jellies and cephalopods that might be hurt or killed by other specimen-collection tools. Temporarily detaining creatures inside the enclosure, described online July 18 in *Science Robotics*, would create rare opportunities for closeup inspections of otherwise elusive deep-sea creatures.

Deep-sea free-floaters, including some jellyfish and their gelatinous ilk, are "sometimes considered the forgotten fauna," says study coauthor and marine biologist David Gruber of Baruch College, City University of New York. While many biologists survey the hustle and bustle of the seafloor, homing in on small creatures in open water is much more difficult, he says, so our understanding of these animals is "almost a blank slate."

Researchers have a few tools in their arsenals for capturing open-water animals and bringing them to the surface for examination. But nets or suction devices well suited for nabbing sturdy deep-sea dwellers, such as fish and crustaceans, can shred fragile life-forms like comb jellies and siphonophores (*SN: 7/16/05, p. 46*). The new creature-catching gadget offers "a really cool" way to handle the deep sea's most delicate residents more gently, says Kelly Robinson, a biological oceanographer at the University of Louisiana at Lafayette who was not involved in the work.

Zhi Ern Teoh, a mechanical engineer at Cooper Perkins Inc., an engineering firm based in Lexington, Mass., and colleagues tested the device in an underwater canyon in Monterey Bay off the

ROBERTO MOLAR CANDANOSA/CARNEGIE INSTITUTION FOR SCIENCE

BODY & BRAIN

Gut microbes relieve autism symptoms

Impact on behavior lasts at least 2 years after fecal transplants

BY TINA HESMAN SAEY

MADISON, WIS. — Giving children with autism a healthier mix of gut bacteria as a way to improve behavioral symptoms continued to work even two years after treatment ended.

The finding may solidify the connection between tummy troubles and autism, and provide more evidence that the gut microbiome — the collection of bacteria and other microbes that live in the intestines — can influence behavior.

"It's a long way from saying there's a cure for autism," says Michael Hylin, a neuroscientist at Southern Illinois University in Carbondale who was not involved in the work. "But I think it's a promising approach."

Children with autism spectrum disorders often have gastrointestinal problems. In previous studies, environmental engineer Rosa Krajmalnik-Brown of Arizona State University in Tempe and colleagues discovered that children with autism had fewer types of bacteria living in their guts than typically developing children did. And many of the kids were missing *Prevotella* bacteria, which may help regulate immune system actions. The researchers wondered whether altering the children's cocktail of gut microbes to get a more diverse and healthier mix might help fix both the digestive issues and the behavioral symptoms associated with autism.

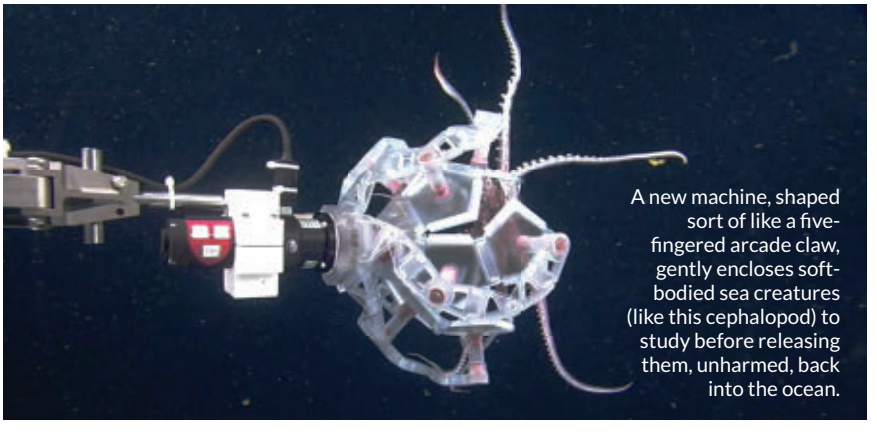
In a small study of 18 children and teenagers with autism, the scientists gave kids fecal transplants from healthy donors over eight weeks. During treatment and two months afterward, the kids had fewer gastrointestinal problems, including diarrhea, constipation, abdominal pain and indigestion, than before the therapy. Autism symptoms, such as hyperactivity, repetitive actions and irritability, also improved and seemed to be getting even better at the end of the trial than immediately after treatment ended, the team reported last year in *Microbiome*. But no one knew whether the improvements would last.

Krajmalnik-Brown announced the results of a two-year follow-up study July 10 at the Beneficial Microbes Conference. The children had kept many of the *Prevotella* and other beneficial bacteria gained during treatment. And the diversity of bacteria in the children's guts was even greater two years later than it was two months after the therapy ended, Krajmalnik-Brown said.

Some of the children's stomach troubles had worsened slightly. But on average, scores on a gastrointestinal-symptoms scale were still more than 60 percent better than before kids received the transplants. The real surprise was that the children's autism symptoms continued to lessen two years after the therapy ended. Still, the study was small. "Don't try this at home," Krajmalnik-Brown cautioned.

The children were ages 7 to 16 when the study started. Ideally, treatment would begin at younger ages, said Krajmalnik-Brown, but the researchers have not gotten approval to conduct the research in younger children.

Next, the scientists need to make sure that the improved behavioral symptoms are really due to fecal transplants. The team will put the idea to the test in a study of the therapy in adults with autism. ■



A new machine, shaped sort of like a five-fingered arcade claw, gently encloses soft-bodied sea creatures (like this cephalopod) to study before releasing them, unharmed, back into the ocean.

Z.E. TEOH *ET AL*/*SCIENCE ROBOTICS* 2018

coast of California. The researchers trapped and released jellyfish and squid up to 700 meters below the surface, but the machine is designed to work as deep as 11 kilometers.

Encasing animals inside this robotic box "is really the first step among many," Gruber says. He and his colleagues now hope to rig the machine with 3-D cameras, DNA-swabbing technology and other sensors to gather information on specimens' physiology. The chamber could also be equipped with instruments to tag animals before they're released back into the ocean.

Using this technology to inspect deep-sea life on its home turf would be far less stressful for animals than bringing them up to the surface. At sea level, "you've got pressure changes, temperature changes, light changes and people staring at them," says George Matsumoto, a marine biologist at the Monterey Bay Aquarium Research Institute in Moss Landing, Calif., where Gruber, Teoh and colleagues tested the device.

Observations of sea creatures in their element may reveal more about what they eat, where they travel and how they are reacting to climate change, as well as uncover new species. Given that scientists know "virtually nothing" about the deep sea, "almost anything we come up with is going to be useful information," Matsumoto says. ■

Watch a robot collect squishy deep-sea life at **bit.ly/SN_JellyCatcher**

ATOM & COSMOS

Once again, Einstein is proved right

General relativity is confirmed near a supermassive black hole

BY EMILY CONOVER

A single star, careening around the monster black hole in the center of the Milky Way, has provided new proof that Albert Einstein was right about gravity.

More than 100 years ago, Einstein's general theory of relativity suggested that gravity is the result of matter curving the fabric of spacetime (*SN: 10/17/15, p. 16*). Now, in a paper in the July *Astronomy & Astrophysics*, researchers report the observation of a hallmark of general relativity known as gravitational redshift. The measurement is the first time general relativity has been confirmed in the region near a supermassive black hole.

As light escapes a region with a strong gravitational field, its waves get stretched out, making the light redder, in a process known as gravitational redshift. A research team called the GRAVITY collaboration used the Very Large Telescope array in Chile to demonstrate that the star's light was redshifted by just the amount predicted by general relativity.

Scientists have observed gravitational redshift before but never in the vicinity of a supermassive black hole. "That's completely new, and I think that's what makes it exciting," says Clifford Will, a physicist at the University of Florida in Gainesville who was not involved with the study.

Einstein's theory of gravity was upheld in measurements of a star that passed by a supermassive black hole. The star's recent trajectory is shown in this artist's conception.

The supermassive black hole at the heart of the Milky Way has a mass about 4 million times that of the sun. Many stars swirl around this black hole. The researchers zeroed in on one star, S2, which completes an elliptical orbit around the black hole every 16 years.

In May 2018, the star made its closest approach to the black hole, zipping by at 3 percent of the speed of light — extremely fast for a star. At that point, the star was just 20 billion kilometers from the black hole. That may sound far away, but it's only about four times the distance between the sun and Neptune.

Measuring the effects of general relativity in the black hole's neighborhood is challenging because the region is packed with stars, says UCLA astrophysicist Tuan Do, who studies S2 but was not involved with this work. If attempting to observe this region with a run-of-the-mill telescope, "you'll just see this big blur."

To obtain precise measurements and pinpoint individual stars, the scientists used adaptive optics (see Page 5), which can counteract the distortions caused by the Earth's atmosphere, and combined information from four telescopes in the Very Large Telescope's array.

GRAVITY scientists hope to test other aspects of general relativity, including the theory's prediction that S2's orbit should rotate over time. A similar rotation was previously seen in Mercury's orbit around the sun, which puzzled astronomers until Einstein's theory explained the effect.

The team might find other stars that orbit even closer to the black hole, allowing the researchers to better understand the black hole and further scrutinize general relativity. If that happens, Will says, "they'll really start to explore this black hole up close and personal, and it'll be a very cool new set of tests of Einstein's theory." ■

GENES & CELLS

Why cuts in the mouth heal so fast

Scientists ID gene regulators that lessen oral inflammation

BY TINA HESMAN SAEY

Mouth wounds heal faster than injuries to other parts of the skin, and now scientists are learning how the mouth performs its speedy repairs.

Some master regulators of gene activity work overtime in the mouth to heal wounds without scarring, researchers report in the July 25 *Science Translational Medicine*. Those regulators — the proteins SOX2, PITX1, PITX2 and PAX9 — are active in skin cells called keratinocytes in the mouth, but not in keratinocytes from the arm. The regulators hold down inflammation that can lead to scarring, and they turn on molecular programs involved in wound closure, say scientists from the University of California, San Diego and the National Institutes of Health in Bethesda, Md.

Knowing how the mouth performs its healing feats may eventually lead to therapies that fix skin sores without forming scars. Because the regulators are involved in many biological processes, including guiding an organism's development, scientists need to discover which of these processes is important for wound healing, says Luis Garza, a skin researcher and dermatologist at the Johns Hopkins University School of Medicine. The study may provide some clues.

Researchers made small circular wounds in the mouths and the inner upper arms of 30 volunteers. The mouth wounds healed about three times as fast as the arm wounds — on average at a rate of about 0.3 millimeters a day compared with less than 0.1 millimeters a day. Reducing amounts of PITX1 and SOX2 in mouth keratinocytes grown in lab dishes altered the activity of genes involved in cell movement needed for wound closure. Boosting SOX2 levels in the skin of mice shortened healing time, from about nine days to about three. ■

M. KORNMESSER/ESO

ATOM & COSMOS

Neutrinos travel as fast as light

An intergalactic race between light and a bizarre subatomic particle called a neutrino has ended in a draw.

The tie suggests that high-energy neutrinos, which are so lightweight that they behave as if they're massless, adhere to a basic rule of physics: Massless particles travel at the speed of light.

Comparing the arrival times of a neutrino and an associated blaze of light emitted from a bright, flaring galaxy (*SN: 8/4/18, p. 6*) showed that the neutrino and light differed in speed by less than a billionth of a percent, physicists report online July 13 at arXiv.org.

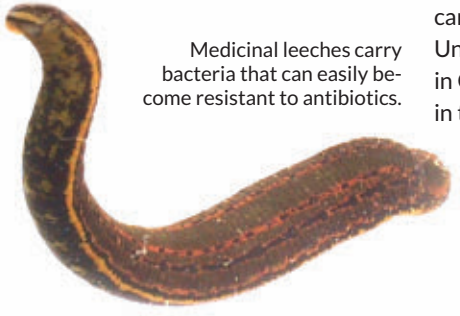
Some theories propose that a "spacetime foam" might slow particles of very high energies. Spacetime on extremely small scales is not smooth, but foamy, the idea goes. As a result, high-energy particles could get bogged down, as if moving through molasses. That effect could have caused a significant difference between the speeds of the neutrino and the associated light, which would build up into a delay over the 4-billion-light-year trip from the neutrino's home galaxy to Earth. But since the flare of light was spotted around the same time as the neutrino, there's no evidence for such a discrepancy. — *Emily Conover*

GENES & CELLS

What leeches' gut bacteria reveal about antibiotic resistance

Drug resistance in leeches really sucks.

A bacterium found in leeches' guts needs exposure to only 0.01 micrograms per milliliter of ciprofloxacin to become resistant to the antibiotic. Scientists thought the bacterium would need exposure to 400 times that amount to develop drug resistance, Joerg Graf, a biologist at the University of Connecticut in Storrs, and colleagues report July 24 in *mBio*.



KARL RAGNAR GJERTSEN/WIKIMEDIA COMMONS (CC BY 2.5)

Medicinal leeches carry bacteria that can easily become resistant to antibiotics.

In the United States, doctors can use certain leeches to help patients heal from reconstructive surgery. The creatures suck up blood and secrete anticoagulants, aiding tissue growth.

In the 2000s, researchers noticed an uptick in drug-resistant infections in these patients caused by the *Aeromonas* bacteria found in *Hirudo verbana*, a medicinal leech. Now, scientists have analyzed the contents of leeches' stomachs and found drug-resistant bacteria and low levels of ciprofloxacin and enrofloxacin, an antibiotic used on poultry farms. The leeches may have been exposed to the drugs through poultry blood used as leech food.

Graf suggests that leech farmers eliminate antibiotics from their operations. But *Aeromonas* is also found in freshwater settings. "It is concerning because similarly low amounts [of antibiotics] have been detected in the environment," he says.

For now, it's unclear if other kinds of bacteria can also become drug-resistant at such a low threshold. If so, that could complicate global efforts to prevent drug-resistant infections. — *Leah Rosenbaum*

BODY & BRAIN

Tick bite linked to heart disease

It sounds bonkers that a tick bite can make meat eaters allergic to steak, but it's true. Now research adds a potential twist: The source of this tick-related sensitivity to red meat may also be linked to coronary artery disease.

A bite from *Amblyomma americanum*, the lone star tick, can trigger antibodies to a sugar called alpha-gal, found in many mammals but not humans. For some people, that produces an allergic reaction to alpha-gal in red meats. In a new study, heart patients with the antibodies had more plaque buildup in their artery walls, cardiologist Coleen McNamara of the University of Virginia School of Medicine in Charlottesville and colleagues report in the July *Arteriosclerosis, Thrombosis and Vascular Biology*. Of 118 people ages 30 to 80, 31 who tested positive for the antibodies had about 25 percent more plaque than those who lacked the antibodies.

The link was strongest in those 65 and younger. For the antibody-positive people in that group, the plaques were of the sort more likely to rupture and cause a heart attack.

The study shows only an association. To search for a possible mechanism, the team plans to study alpha-gal and artery inflammation in mice; inflammatory cells released via the immune system contribute to plaques. — *Aimee Cunningham*

MATTER & ENERGY

Physicists find a new quasiparticle

There's a new clique among quantum particles in a semiconductor.

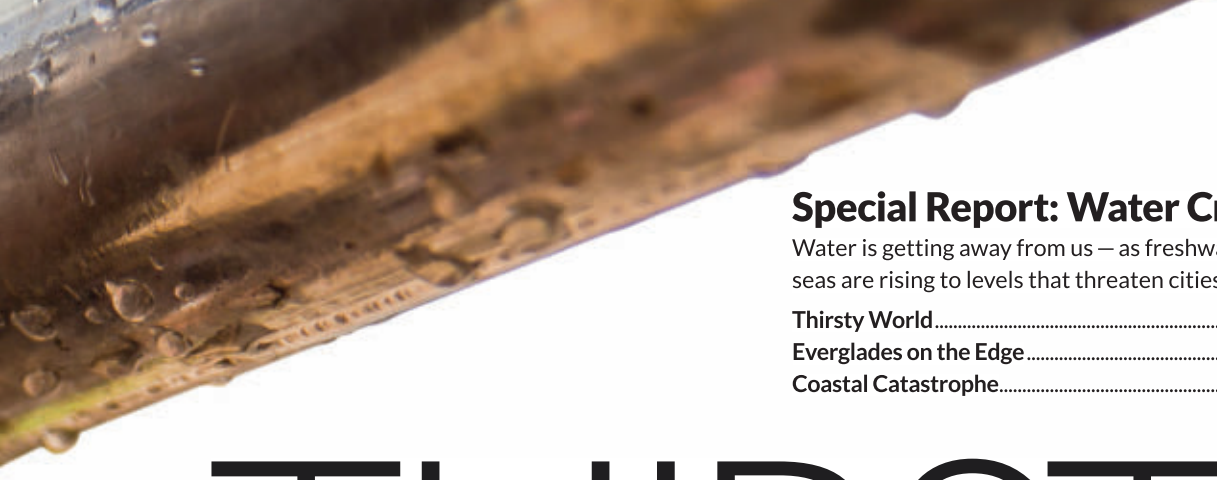
Electrons and positively charged holes in the material's atomic lattice band together to create a tight-knit posse dubbed a collexon, researchers report July 26 in *Communications Physics*. This new class of quasiparticle — a quantum clan that acts like a single subatomic particle — could help researchers better understand semiconductors, which are essential to most modern electronics.

The collexon is similar to a quasiparticle called an exciton, a pairing of an electron and a hole (*SN: 5/17/14, p. 5*). While these pairs go it alone in excitons, electron-hole duos in collexons join forces with the surrounding sea of electrons.

Researchers made the discovery when they inserted germanium atoms into a gallium nitride semiconductor, and zapped the material with a laser to see how it emits light. In similar experiments, emissions from excitons fade as the number of impurities, such as germanium atoms, increase. But this time, at high concentrations of the introduced atoms, light shone at different wavelengths than seen with excitons. The team deduced that large numbers of wandering electrons, introduced by the germanium, helped stabilize excitons to form the new quasiparticle.

It's too early to predict applications, says study coauthor Gordon Callsen of the École Polytechnique Fédérale de Lausanne in Switzerland. But the discovery suggests that scientists underestimate interactions among ensembles of particles in semiconductors. — *Christopher Crockett*

A child drinks water at a well in South Sudan, a country in which only half the population has ready access to clean drinking water.



Special Report: Water Crisis

Water is getting away from us — as freshwater becomes scarce, seas are rising to levels that threaten cities and ecosystems.

Thirsty World 14
Everglades on the Edge 18
Coastal Catastrophe 24

THIRSTY WORLD

Globally, more than 2 billion people lack access to clean water

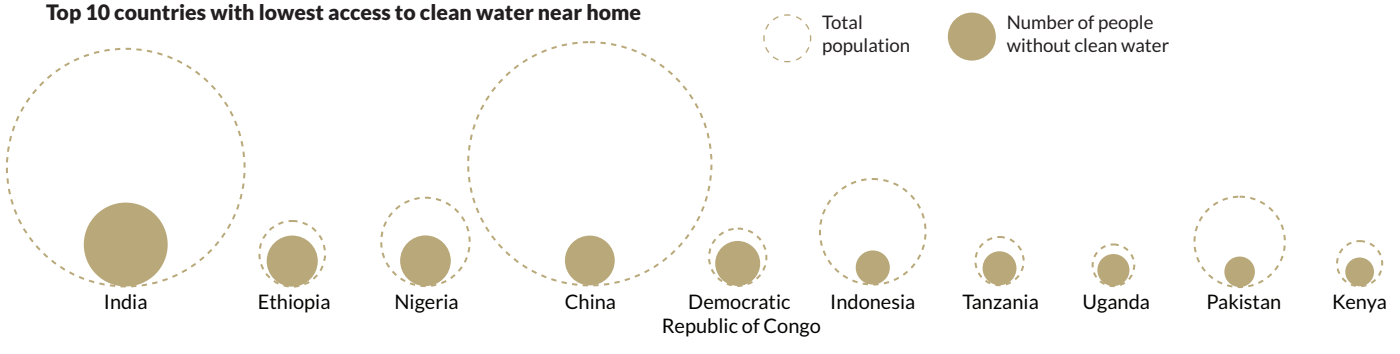
By Alexandra Witze

Freshwater is crucial for drinking, washing, growing food, producing energy and just about every other aspect of modern life. Yet more than 2 billion of Earth's 7.6 billion inhabitants lack clean drinking water at home, available on demand.

A major United Nations report, released in June, shows that the world is not on track to meet a U.N. goal: to bring safe water and sanitation to everyone by 2030. And by 2050, half the world's population may no longer have safe water. Other stories in this special *Science News* report explore rising sea levels closing in on coastal cities, such as Mumbai, India, and efforts to overhaul water management to save Florida's Everglades. Here, we focus on freshwater, asking: Will people have enough water to live?

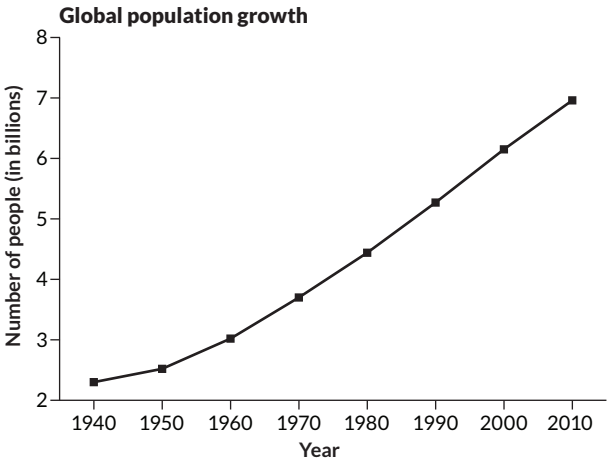
Two main factors are pushing the planet toward a thirstier future: population growth and climate change. For the first,

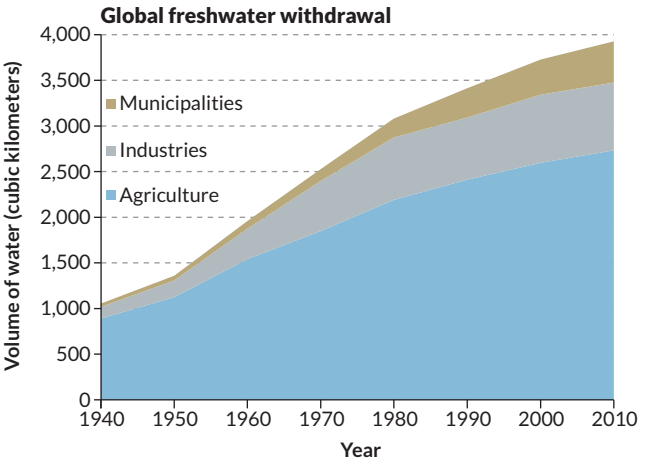
Water woes The United Nations wants the world's population (currently 7.6 billion people) to have access to safe water and sanitation by 2030, but there's a long way to go. India has improved water access in rural areas, but remains at the top of the list for sheer number of people (163 million) lacking water services. Ethiopia, second on the list with 61 million people lacking clean water, has improved substantially since the last measurement in 2000, but still has a high percentage of total residents without access. SOURCES: "THE WATER GAP: STATE OF THE WORLD'S WATER 2018"/WATERAID; THE WORLD BANK



OPPOSITE PAGE: STEFANIE GLINSKI/AFP/GETTY IMAGES; ALL GRAPHS: E. OTWELL

Water withdrawal is outpacing population growth Most of the world's freshwater goes to agriculture, mainly to irrigating crops but also to raising livestock and farming aquatic organisms, such as fish and plants. As the global population rises (below, left), agricultural production rises to meet demand for more varied diets. In recent decades, the increase in water withdrawal from the ground or lakes and rivers has slowed (below, right), but it still outpaced the rate of population growth since 1940. SOURCES: AQUASTAT/FAO; I.A. SHIKLOMANOV/*WATER INTERNATIONAL* 2000





the question is how to balance more people against the finite amount of water available. Short of any major but unlikely breakthroughs, such as new techniques to desalinate immense amounts of seawater (*SN: 8/20/16, p. 22*), humankind will have to make do with whatever freshwater already exists. Most goes to agriculture, with smaller amounts for industry and domestic use. For decades, the rate of water withdrawals for all of these sectors has outpaced the rise in global population.

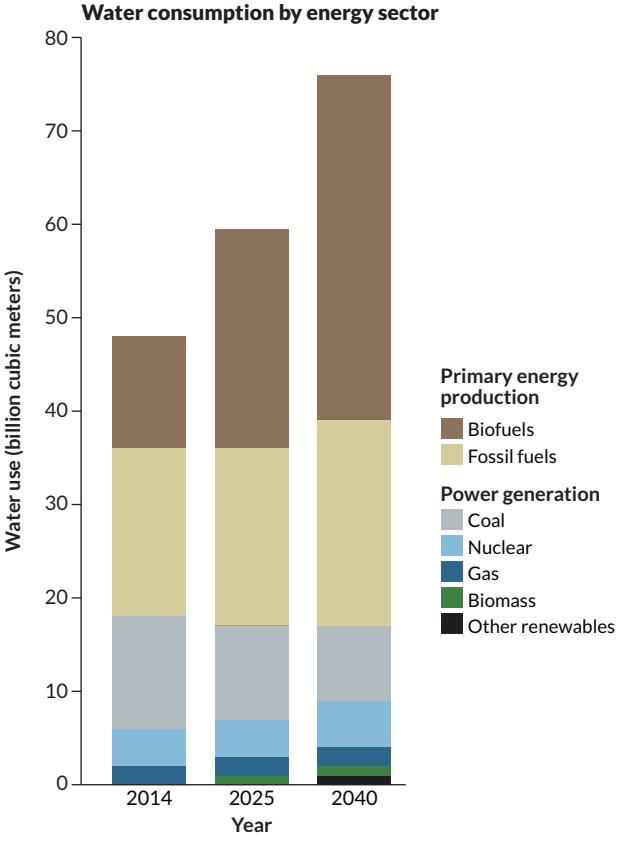
That means every drop is increasingly precious — and tough choices must be made. Plant your fields with sugarcane to make ethanol for fuel, and you can't raise crops to feed your family. Dam a river to produce electricity, and people downstream can no longer fish. Pump groundwater out for yourself, and your neighbor might just want to fight over it. Researchers call this the food-water-energy nexus and say it is one of the biggest challenges facing our increasingly industrialized, globalized and thirsty world.

"There just isn't enough water to meet all our needs," says Paolo D'Odorico, an environmental scientist at the University of California, Berkeley whose team analyzed the food-water-energy nexus in a paper published online April 20 in *Reviews of Geophysics*. And sometimes what sounds like a good idea — such as switching to renewable energy sources to reduce carbon emissions — might help in one area but hurt in another. For example, it can take more water to grow biofuel crops than to consume fossil fuels.

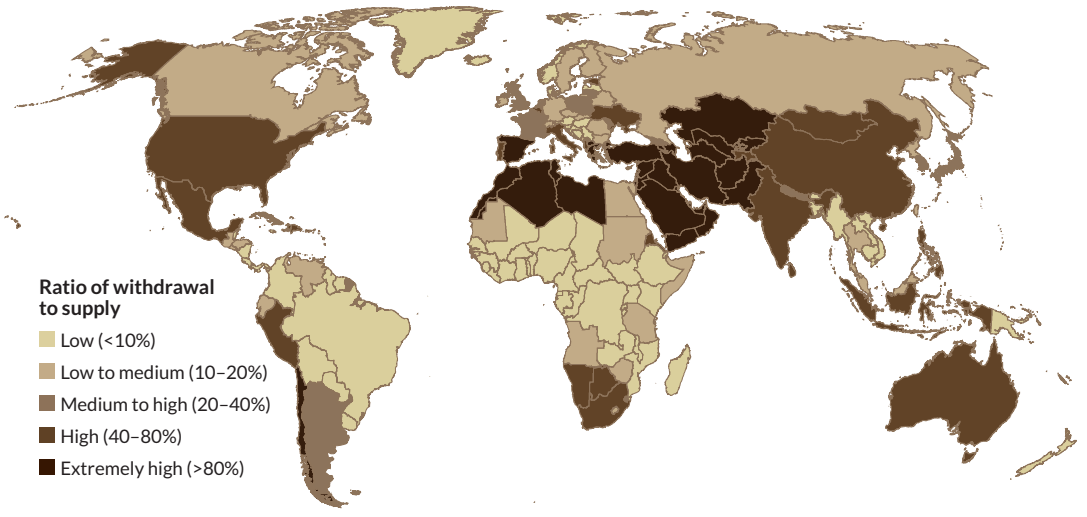
Then there's climate change. Rising global temperatures alter weather patterns and change how water cycles between the ground and the atmosphere. Freshwater stores can shrink. Extreme events, such as flooding and drought, are becoming more common on our warming planet (*SN: 1/20/18, p. 6*). That means more water in places where people don't need it, and less water where they do.

Cities will bear the brunt of future water shortages. Early this

Water for energy production In one example of changing priorities, the energy sector is expected to consume more and more water in decades to come. Shifting energy away from fossil fuels toward lower-carbon sources such as biofuels can require more water. Below, water consumption is defined as water that is used and not returned to its source, such as when growing corn or sugarcane to make ethanol. These projections are based on nations' stated commitments to phase out fossil fuel subsidies and reduce emissions of greenhouse gases. SOURCE: "WORLD ENERGY OUTLOOK 2016 SPECIAL REPORT: WATER-ENERGY NEXUS"/IEA



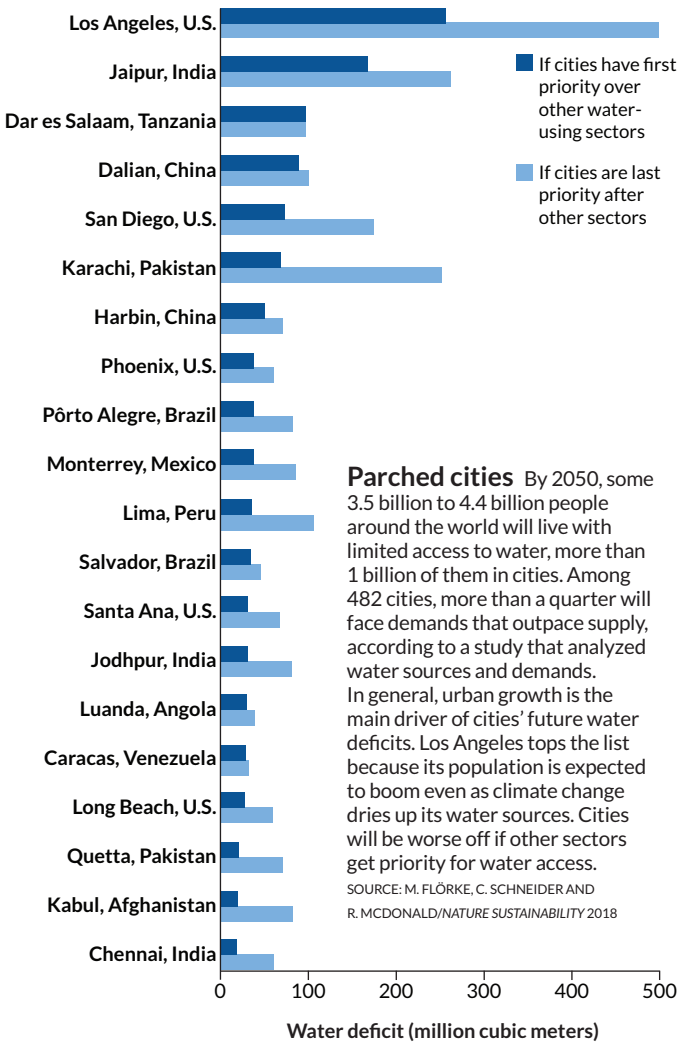
Water stress by country in 2040



Climate effects

As greenhouse gases build up in Earth's atmosphere, trapping heat and altering the planet's weather and climate, water will become more precious. This map shows how water stress — the ratio of water use to water supply — is expected to look by the year 2040. It assumes a "business-as-usual" scenario in which carbon emissions rise steadily. The highest stress is expected in areas where water supply is vulnerable because of already arid climates and growing populations.

Top 20 cities with largest urban water deficits in 2050



Parched cities By 2050, some 3.5 billion to 4.4 billion people around the world will live with limited access to water, more than 1 billion of them in cities. Among 482 cities, more than a quarter will face demands that outpace supply, according to a study that analyzed water sources and demands. In general, urban growth is the main driver of cities' future water deficits. Los Angeles tops the list because its population is expected to boom even as climate change dries up its water sources. Cities will be worse off if other sectors get priority for water access.

SOURCE: M. FLÖRKE, C. SCHNEIDER AND R. MCDONALD/*NATURE SUSTAINABILITY* 2018

MAP: AQUEDUCT WATER STRESS PROJECTIONS/WORLD RESOURCES INSTITUTE

year, it looked as if the more than 4 million people living in Cape Town, South Africa, were going to run out of water. Officials calculated a "Day Zero" in April when the taps would run dry. Only through belated and desperate conservation measures, such as slashing the amount of water for irrigating crops, did city residents eke through until the rainy season began in May. That Cape Town crisis is almost certainly the first of many.

In the face of such inexorable changes, it's easy to despair. But science offers hope, in the form of alternative paths forward. Computer modelers at MIT, for example, find that policies to fight climate change, such as the 2015 Paris agreement that the United States announced its intention to pull out of last year (*SN Online: 6/1/17*), can reduce the severity of future water shortages. If nations follow commitments similar to those in the agreement, 60 million people across Asia could avoid dire water scarcity by 2050, the team wrote in June in *Environmental Research Letters*.

But the Paris agreement is not enough. As research increasingly makes clear, there are trade-offs and decisions to be made. Cape Town's experience shows how governments need to better prepare for the competing demands on water supplies. Municipalities may need to raise the cost of water to the point where people value it enough to conserve it.

"We can address the problem by thinking about technological solutions, but we also have to think about changing our behavior," says Martina Flörke, a hydrologist and environmental scientist at the University of Kassel in Germany. "If we can make clear ... that water has value, that it's an ecosystem service that we use and have to take care of — then we are really thinking about how to adapt." ■

Explore more

- United Nations. "SDG 6 Synthesis Report 2018 on Water and Sanitation." bit.ly/UNwater2018

EVERGLADES

Scientists wrestle with how to fight the effects of sea level rise

By Carolyn Gramling

The boardwalk at Pa-hay-okee Overlook is a brief, winding path into a dreamworld in Everglades National Park. Beyond the wooden slats, an expanse of gently waving saw grass stretches to the horizon, where it meets an iron-gray sky. Hardwood tree islands — patches of higher, drier ground called hammocks — rise up from the prairie like surfacing swimmers. The rhythmic singing of cricket frogs is occasionally punctuated by the sharp call of an anhinga or a great egret.

And through this ecosystem, a vast sheet of water flows slowly southward toward the ocean.

The Everglades, nicknamed the river of grass, has endured its share of threats. Decades of human tinkering to make South Florida an oasis for residents and a profitable place for farmers and businesses has redirected water away from the wetlands. Runoff from agricultural fields bordering the national park causes perennial toxic algal blooms in Florida's coastal estuaries.

But now, the Everglades — home to alligators and crocodiles, deer, bobcats and the Florida panther, plus a dizzying array of more than 300 bird species — is facing a far more relentless foe: rising seas.

South Florida is ground zero when it comes to sea level rise in the United States. By 2100, waters near Key West are projected to be as much as two meters above current mean sea level. Daily high tides are expected to flood many of Miami's streets. The steady encroachment of saltwater is already changing the landscape, killing off saw grass and exposing the land to erosion.

Rising seas and sinking soil could turn this iconic wetland ecosystem into open water.

Against this looming threat, Everglades ecologists and hydrogeologists are racing to find ways to mitigate the damage before the land is reclaimed by the ocean, irrevocably lost.

Sea level rise is a global problem (see Page 24), but coastal water management in South Florida faces some particular challenges, as a 2014 National Climate Assessment report noted. Growing urban centers need access to freshwater, flat topography encourages ponds of water to linger, and porous limestone aquifers are particularly vulnerable to encroaching saltwater. Storm surges occasionally drive seawater far inland, compounding the problem.

"We can't ignore it anymore," says Shimelis Dessu, a hydrogeologist at Florida International University in Miami. When it comes to water management needs in South Florida, ecological conservation has tended to be low on the list, compared with human and agricultural needs, Dessu says. Now, sea level rise is forcing people to think differently. "The ocean is no longer an external thing," he says. "It's already in the house."

Draining the swamp

Florida's tug-of-war over water has a long history.

In the 1800s, settlers first began draining the land to make way for agriculture and communities. Water management in the state began in earnest in 1948, when the U.S. Congress authorized the Central and Southern Florida Project for Flood Control and Other Purposes.

KEITH LADZINSKI/GETTY IMAGES

ON THE EDGE

That project was meant to control flooding along the Kissimmee River and Lake Okeechobee, in the south-central part of the state. During the rainy months in summer and fall, the river and the broad, shallow lake often overflowed, flooding surrounding areas. The spillage would travel slowly southward across southern Florida in a broad sheet and eventually drain into Florida Bay, an open water body between the mainland and the Florida Keys. During the journey, some of the water would seep into the ground, replenishing the Biscayne Aquifer, a limestone layer that underlies much of the southeastern part of the state.

But the recurrent flooding made the land uninhabitable and farming impossible. So with Congress' 1948 authorization, the U.S. Army Corps of Engineers built a complex system of levees, canals and reservoirs to control the floods and channel water away from farmlands south of Lake Okeechobee and from growing population centers. Three large "water conservation areas" were constructed to collect and store water during high rainfall events and release it in times of drought. The remaining wetlands — encompassing about half of their original area — were enclosed into two protected areas, Everglades National Park and Big Cypress National Preserve.

> "The ocean is no longer an external thing. It's already in the house"
>
> **SHIMELIS DESSU**

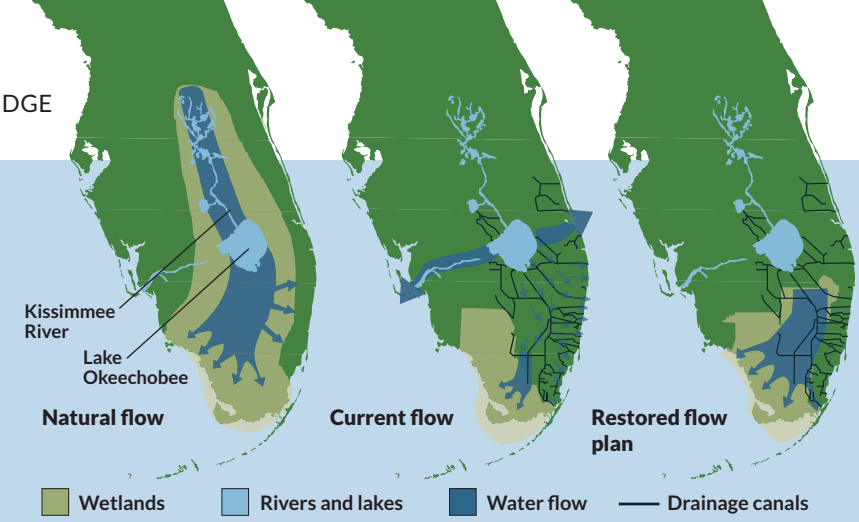
Such an intensive overhaul of South Florida's water cycle led, perhaps inevitably, to new problems. Reducing the amount of freshwater that naturally heads south into the Everglades proved destructive to the habitats of plants and animals. Wading bird populations, for example, shrank by 90 percent over the last century. Diverting the water away from its natural overland course also meant less water was available to replenish the Biscayne Aquifer, which provides drinking water to 3 million people.

Agriculture is big business in Florida; the state's exports total more than $4 billion each year. But fertilizer from the agricultural regions pollutes waterways feeding into Lake Okeechobee, causing algal blooms in the lake. Regulated discharges from the lake to control flooding shunt polluted water to the east, west and south, causing periodic algal blooms on the coasts and in Florida Bay.

Hoping to undo some of the damage, Congress approved a 35-year, $10.5 billion project in 2000 to send more freshwater south into the river of grass. That project, the Comprehensive Everglades Restoration Plan, or CERP, remains the largest hydrologic restoration project ever undertaken in the United States.

CERP has shown signs of success. The National Academies of Sciences, Engineering and Medicine, which evaluates the progress of Everglades restoration every two years, reported in 2016 that freshwater flow through the Everglades has indeed increased since the project began. And in some areas, groundwater levels and vegetation are beginning to return to how they looked before the extensive water management began.

But the academy's 2016 report also pointed to a glaring problem. Researchers know a lot more about the effects of climate change now than they did in 2000. Without accounting for these effects, particularly rising sea levels, the restoration plan will not be able to meet its intended goals: restoring the wetlands and buffering inhabited areas against Florida's intensely fluctuating hydrologic cycle.



Managed water Water flow in the Everglades begins with the Kissimmee River and other rivers, which pour into Lake Okeechobee. Left to its natural course (left), the water periodically spilled over the lake's banks and flowed southward in a broad, shallow sheet (dark blue). But decades of heavy management (center) have channeled the water away from the wetlands to make way for South Florida's cities and agriculture. The Comprehensive Everglades Restoration Plan (right) aims to restore some of the natural flow while still managing the water. SOURCE: U.S. ARMY CORPS OF ENGINEERS, JACKSONVILLE DISTRICT

Losing ground

Over the last half-century, the freshwater-saltwater transition zone in the Everglades has moved inland by at least a kilometer, due both to rising sea levels and to the reduction of freshwater flow through the Everglades. Some scientists call this inland shift of saltwater the Anthropocene Marine Transgression, a nod to the fact that humans are ultimately responsible for the rising seas and freshwater management.

In part, it's a simple problem of water pressure. Freshwater flowing down off the land, or in belowground aquifers, pushes toward the sea. If that tap is slowed to a trickle and freshwater pressure is reduced, the seawater meets less resistance and can drive farther inland. It's a problem many coastal communities around the world have faced when overdrawing from coastal aquifer wells: Removing too much freshwater at once allowed seawater to sneak in and poison the well. Add rising sea levels to the mix, and the low-lying Everglades face a double hit of saltwater intrusion above ground and below.

Because it is underground, the saltwater intrusion zone is not visible on a map. "But you can see the legacy effect ... above ground," says wetland ecologist Stephen Davis of the Everglades Foundation, a nonprofit group based in Palmetto Bay, Fla. "The salinity periodically knocks back the plant community."

Hardest hit is the ubiquitous saw grass. Saw grass is hardy stuff; it is resistant to wildfires and thrives even in nutrient-poor soil. But saltwater is another matter. In 2000, a team of scientists surveyed the southernmost portion of the Everglades from the air. The researchers noted odd pockmarks dotting the land — bare patches where the saw grass had died. "Some of these landscapes look like Swiss cheese," Davis says.

Thick, organic peat soil is the building block of many wetlands, including the Everglades, says Fred Sklar, director of the South Florida Water Management District's Everglades division, based in West Palm Beach. But peat soil is fragile: Too little freshwater and it dries up. And worse, the combination of dwindling freshwater and increasing saltwater inundation is a one-two punch, "a kind of turbo boost, allowing the soil to break down," Davis says. Chemical or biological changes within the peat soil — scientists aren't sure exactly what — then trigger a sudden collapse. Soil elevation drops rapidly, exposing the roots of the saw grass, which eventually die.

The bare patches of ground are the most visible scars of saltwater intrusion, but the extent of the damage is probably much greater than is visually apparent, Davis says. Storm surges from hurricanes such as 2017's Irma, along with king tide events, the highest high tides of the year, can push saltwater several kilometers inland. As a result, many regions that look fine to the eye are destabilizing beneath the surface, on the verge of collapse, he says.

Widespread peat collapse could be devastating to the Everglades on two fronts. Maintaining the elevation of the soil is a bulkhead against seawater intrusion; the collapsed areas become zones of open water. And peat-filled wetlands represent a vast carbon sink — a region where far more carbon dioxide is absorbed through photosynthesis than is released through respiration. Losing the soil effectively changes the region from a place that stores carbon to one that adds carbon dioxide to the atmosphere, fueling climate change.

Researchers don't yet know how quickly land is subsiding in the Everglades. But research suggests that even slightly salty waters could cause the soil to sink at a "potentially staggering" rate, Davis says, dramatically increasing how quickly rising seas will be able to reclaim land. Biologist Sean Charles of Florida International University infused plots of saw grass–bearing peat soil with brackish water (still much less salty than seawater). In just one year, soil elevation in the salty plots sank by almost three centimeters, while the soil in the freshwater plots held its elevation or increased slightly.

A tale of two field sites

There's a second boardwalk at Pa-hay-okee, which gets its name from a Native American word for "grassy waters." Unlike the visitors' overlook, getting to this platform requires a short, gutsy slog across a few meters of open wetland, possibly under the watchful gaze of an alligator.

That expanse is an intentional deterrent, says Benjamin Wilson, a wetland ecologist at Florida International University. This boardwalk isn't meant for visitors; it's for scientists, who built it as part of a long-term research study to try to understand what, exactly, causes peat soil collapse.

About a 20-minute drive to the south, a sister field site near West Lake is hidden behind a forest screen of salt-tolerant

T. TIBBITTS

mangroves, their roots entangled and exposed, their branches creaking eerily. The two sites sit on either side of the saltwater intrusion zone: Pa-hay-okee is still largely fresh, but West Lake is brackish.

The first phase of the project, led by wetland ecologist Tiffany Troxler of Florida International University, was to figure out where the peat is most vulnerable to sea level rise, now and in the future, using existing well data, geologic maps and computer simulations of sea level rise. The second step — and the reason for studying the paired sites — examined how salinity changes might affect the peat soil and saw grass. "And then we should have a better idea of where saw grass is going to be, and where peat collapse may occur in the future," Troxler says.

Alongside the boardwalk, the team embedded a dozen Plexiglas tubes right into the marsh. The chambers, each about half a meter in diameter, are open at the bottom and top, but can be twisted open or closed to allow the water to flow freely through them, or to temporarily sequester the chambers from the rest of the wetland.

Many factors can alter soil chemistry. Reduced freshwater flow can dry out the soil briefly, exposing it to oxygen. And seawater seeping up from the phosphorus-rich limestone aquifer below the wetlands brings in an extra supply of the nutrient, which is otherwise in short supply in the Everglades.

Once a month for four years — during wet and dry seasons — team members visited the chambers at both sites, closing them and dosing them with cocktails composed of different amounts of saltwater and nutrients.

"It was fun," Wilson says cheerfully. Despite the muddy slog, team members chose not to wear full-body waders. "We're lucky to be in South Florida, where the water never really gets cold." Then, he pauses. "Well, it can get really miserable," he acknowledges after a few seconds. Although they didn't wear waders, the researchers covered up in long-sleeved shirts and pants, even in the summertime, and shielded their faces, despite the stifling heat. "Do you want 100 mosquitoes in your face, or do you want to be sitting in 95-degree humidity, not being able to breathe with these masks on?" he asks rhetorically.

This sometimes grueling work yielded results, as the team tracked how different factors might affect the saw grass ecosystem and peat collapse. Specifically, the researchers assessed changes in how much carbon dioxide the soil released into the atmosphere as a result of added salt and phosphorus, and also tracked changes in saw grass root growth.

A change in microbe activity was another possible culprit in soil collapse. So microbial biologist Shelby Servais of Florida International University examined whether the saltwater increased microbial growth, which could in turn speed breakdown of organic material. It didn't happen. "What we found is that, in general, salt exposure suppresses activity of the microbial community."

Even saltwater inundation — by itself — may not be causing the soil breakdown, Wilson says. What really seemed to matter was how dry the soil was to begin with, before saltwater was added. When the soil was already wet, adding more salt had no effect on how much carbon dioxide the soil released to the atmosphere, the team found. But when the researchers added salt to dry soil, carbon dioxide spiked. The team also noticed that saw grass plants grew fewer roots.

A third phase of the peat soil project is now getting under way. The researchers will precisely track where soil elevation has dropped, and by how much. The team will plunge a rod into the ground all the way to the bedrock and use pins attached to the rod to measure elevation changes over time. From that, Troxler says, "you can get an idea of whether [soil creation in] the wetlands is keeping up with sea level rise."

Race against the rise

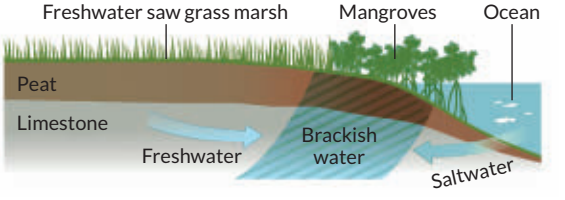
What should planners do if, as some simulations suggest, sea level rise is already outpacing the efforts by state and federal authorities to restore freshwater flow through the Everglades?

Dessu and colleagues took a close look at freshwater management efforts side by side with projections of sea level rise. "We have some control over the freshwater management. The other side, the sea level rise, we don't have any control over," he says.

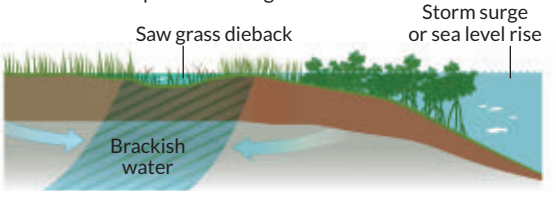
The researchers had about 16 years' worth of data on changing ecology in the wetlands, including information about

Soil slump Beneath the land surface, saltwater and freshwater struggle for dominance in the Everglades. Saltwater is gaining the upper hand, as sea levels rise and drive the brackish zone farther inland. The saltier water causes peat soil to collapse and saw grass to die, leaving a pockmark pattern of brackish pools of water in the wetlands.

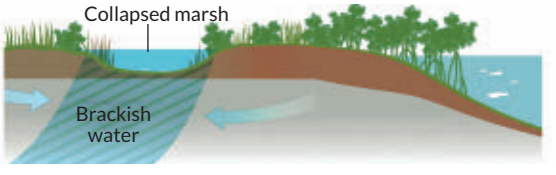
1. Saw grass grows in the freshwater zone. Mangrove trees thrive in the coastal brackish water.



2. Rising sea levels or hurricane-driven waters push saltwater farther inland. Soil collapses and saw grass dies.



3. More soil collapses around the dead saw grass, leaving a pool of brackish water.



S. DAVIS

The Everglades is home to more than 300 species of birds, including 16 wading bird species, such as the great blue heron.

The good and bad of South Florida's watery world

Sugar dominates the crops in the Everglades Agricultural Area, a 280,000-hectare region south of Lake Okeechobee that was drained to make way for farming.

Rising sea levels have led to annual flooding of low-lying streets in parts of Miami.

A broad, shallow sheet of freshwater flows south through the saw grass near Pa-hay-okee Overlook in Everglades National Park.

Decreased freshwater flow and rising seas are causing peat soil to collapse, exposing the roots of saw grass plants once buried in the soil, until the landscape resembles Swiss cheese (Everglades' Cape Sable shown here).

Mangrove trees (shown at Everglades' West Lake) help protect the coastline from erosion and mark regions of increasing saltiness.

the transitions of freshwater saw grass to salt-tolerant mangroves, loss of tree islands and proliferations of water- and nutrient-loving cattail plants. The team analyzed these changes, as well as changes in salinity and nutrients measured in wells in the region, to observe which areas had become saltier over time.

Then, Dessu says, the researchers examined freshwater management practices. Since 1985, South Florida water managers have been gauging how much freshwater to release from the water conservation areas based on the amount of rainfall that fell 10 weeks earlier. In the dry season, that delay is a problem, the team reported in April in the *Journal of Environmental Management*.

"By the time the flow is delivered, it's two months too late," Dessu says. The study concluded that the state's water managers should consider not just how much water to send down into the Everglades, but when, exactly, would be the best time to do it. "That actually was kind of a surprise," says Florida International University hydrogeologist René Price, a study coauthor.

Managers can use the difference between measured freshwater level and seawater level to decide when best to deliver a plug of freshwater to maintain enough water pressure to help push seawater back, Dessu says. It's a kind of Band-Aid fix — one that won't solve the long-term problem of saltwater encroachment into the wetlands, but may at least ameliorate its immediate effects, he adds.

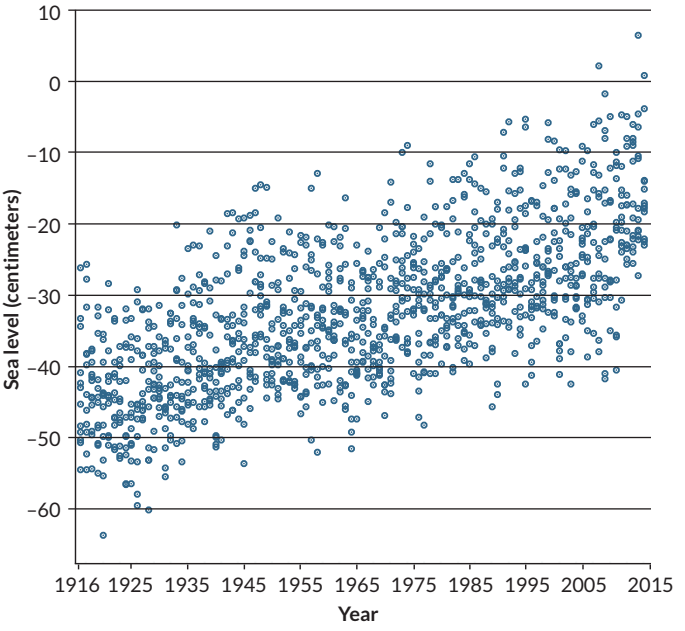
The future of the Everglades

Such fixes are, perhaps, the story of Everglades restoration. In fact, restoration is a misnomer, Sklar notes. "It's not really possible to bring back the past."

Rehabilitation is more to the point. In March, Sklar and other South Florida water managers proposed an ambitious plan that could increase the overall flow of freshwater to the Everglades. The plan centers around the construction of a vast new water reservoir that would collect much of the fertilizer-polluted water from Lake Okeechobee to keep it from running to the coasts where it stimulates algal blooms. Within the reservoir, the water would be scrubbed, then sent to the wetlands. If the U.S. Army Corps of Engineers approves the project, it will become part of legislation headed to Congress in the fall for approval, Sklar says.

The Everglades water managers are walking a tightrope, juggling the needs of residents, farmers and business leaders who want a say about where the water goes. Conservationists in Florida understand this all too well. "If we made it all about climate change and sea level rise, there are those that wouldn't be receptive," Davis says. "So we talk about ... issues like water supply and making the system more drought resilient."

"Let's face it," he adds. "Science is incredibly important in shaping Everglades restoration projects, but it's politics that gets the projects authorized and ultimately built." But he notes that researchers still have many questions about how best to save the Everglades. For example, Davis says, scientists are just beginning to examine whether increasing freshwater flow can even save the saw grass.



Higher tides A tidal gauge station at Key West, Fla., shows that sea level was an average of 30 centimeters lower 100 years ago. Each blue dot is a monthly reading. Some values are negative because sea level is reported relative to a reference point on dry land. SOURCE: S. DESSU

Too much freshwater might, in fact, be a cure that's worse than the disease. "There are models out there that show if we continue to release more freshwater to stem the tide of saltwater, it will end up just flooding the Everglades," Price says, pointing to the push and pull. "We want to save the freshwater system, but how much flooding can it stand?"

In fact, the best hope for Everglades rehabilitation may be the mangroves. The gnarled, salt-tolerant trees are a visible sign of how the ecosystem is already changing, as they steadily march into regions vacated by freshwater saw grass.

Mangroves colonize new areas as their seeds wash inland. When the seeds settle into a spot, the plants can begin to grow, rapidly producing an abundance of fine roots — the primary component of peat soil. The trees can't prevent all inundation or save the freshwater plants, but they may, at least, be able to keep the soil in place.

But as with so much in the Everglades, it's a question of timing, Price says. Mangroves can't move in if the soil is already completely gone. The trees need enough sediment to establish a foothold. Once established, however, mangroves can build up soil quickly, perhaps even at a pace that matches sea level rise.

"If they don't, the peat collapse will take over," Price says. "And it'll just turn to open water." ■

Explore more

- Shimelis B. Dessu *et al*. "Effects of sea-level rise and freshwater management on long-term water levels and water quality in the Florida Coastal Everglades." *Journal of Environmental Management*. April 1, 2018.
- National Academies of Sciences, Engineering and Medicine. *Progress Toward Restoring the Everglades: The Sixth Biennial Review*. National Academies Press, 2016.

COASTAL CATASTROPHE

Mumbai and a growing number of megacities face rising waters

By Katy Daigle and Maanvi Singh

Each year when the monsoon rain sheets down and the tides swell over coastal Mumbai, Saif shutters his soda shop on Juhu Beach and takes shelter up in the rafters. Still, the water invades through the roof and over the concrete floors, sometimes reaching as high as the freezers full of ice cream.

For 36-year-old Saif, the coastal megacity's chronic flooding is stressful. "What would happen if too much water comes?" asks Saif, who, like many in India, goes by one name. "I could get swept up with it." Last year's torrential floods killed at least 14 people in Mumbai. And in July 2005, when a meter of rain fell in a single day, flooding cost the city about $1.7 billion in damages.

Rebuilding his uninsured shop after the 2005 floods cost Saif about $57,000. He was lucky. When those floodwaters receded after two days, more than 1,000 people had died from drowning, landslides or other flood-related accidents in Mumbai and surrounding areas. "What can we do?" Saif asks. "Who can win against nature?"

Such questions are becoming more urgent in coastal cities at mounting risk of climate-driven flooding. Climate change is raising sea levels, while also making storms more severe and bringing heavier rains to some places. For densely populated cities like Mumbai — the financial heart of India, which is the world's fastest-growing major economy — those risks threaten to throw personal incomes and national economies into chaos.

"The challenge is getting people to prepare for a risk they can't yet see," says Stéphane Hallegatte, lead economist at the World Bank's Global Facility for Disaster Reduction and Recovery in Washington, D.C. "A very tiny change in sea level can have an enormous impact on risk levels," he adds.

By 2005, coastal city flooding cost the world an average of $6 billion a year, according to calculations by Hallegatte and colleagues. Even if humankind manages to limit the release of carbon dioxide enough to keep global warming to an average 2 degrees Celsius above preindustrial levels — which is highly unlikely — seas will still rise by a global average of about 20 centimeters by 2050, if not more. That's enough to more than double the frequency of flooding in the tropics, where Mumbai is located, according to a 2017 paper in *Scientific Reports*.

Global losses from coastal flooding may surpass $1 trillion annually by 2050 unless coastal cities prepare, Hallegatte's team says. That projection is actually conservative, because it doesn't include damage from other climate-related flood risks such as heavier rains and stronger storms (*SN: 6/27/15, p. 9*). Last year, Hurricane Harvey's extreme rainfall, probably fueled by climate change, caused $125 billion in flood losses in Houston (*SN: 1/20/18, p. 6*). And in Puerto Rico and the U.S. Virgin Islands, Hurricane Maria caused $90 billion in damages, mostly from winds.

If cities invest enough to just hold steady at their current level of flood risk, future losses would drop drastically, to about $60 billion per year, Hallegatte says. Mumbai's share would be about $6.4 billion — making it the second-most economically vulnerable city after China's Guangzhou.

Many of Asia's fast-growing coastal megacities, with populations of 10 million or more, are vulnerable to multiple flood threats. Mumbai, the Bangladeshi capital of Dhaka and Manila in the Philippines, among others, face a future of heavier rainfall and higher storm surges. Manila and

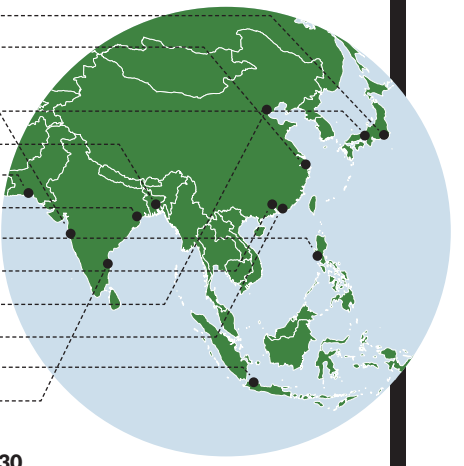
Opposite page: A woman poses for a photograph as a wave at high tide crashes over Mumbai's seaside promenade in July during a pause in the seasonal monsoon rains.

Going mega

Mumbai and other fast-growing coastal megacities in Asia are particularly vulnerable to climate-related flooding. Twenty-one of the world's 31 megacities hug a coastline, 13 of which are in Asia. These cities of 10 million or more often drive their national economies and are home to both rich and poor. As the world's population balloons, two more Asian coastal cities will be pushed into the mega zone by 2030: Bangkok and Vietnam's Ho Chi Minh City, according to United Nations estimates. In addition to flooding, these megalopolises could face water supply disruptions (see Page 14), dangerous heat waves (*SN: 4/14/18, p. 18*), increased food insecurity and more disease outbreaks.

Asian coastal megacity population estimates: 2016 and 2030 (in millions)

Tokyo JAPAN 38.1 → 37.2
Shanghai CHINA 24.5 → 30.8
Mumbai INDIA 21.4 → 27.8
Osaka JAPAN 20.3 → 20.0
Dhaka BANGLADESH 18.2 → 27.4
Karachi PAKISTAN 17.1 → 24.8
Kolkata INDIA 15.0 → 19.1
Manila PHILIPPINES 13.1 → 16.8
Guangzhou CHINA 13.1 → 17.6
Tianjin CHINA 11.6 → 14.7
Shenzhen CHINA 10.8 → 12.7
Jakarta INDONESIA 10.5 → 13.8
Chennai INDIA 10.2 → 13.9



Will reach megacity status in 2030

Bangkok THAILAND 11.5
Ho Chi Minh City VIETNAM 10.2

SOURCE: U.N. 2016 WORLD CITIES REPORT

OPPOSITE PAGE: JANAK RATHOD; THIS PAGE: C. CHANG

others, like Indonesia's Jakarta, are also sinking fast. Some spots in Jakarta are sinking at a rate of 20 to 28 centimeters a year.

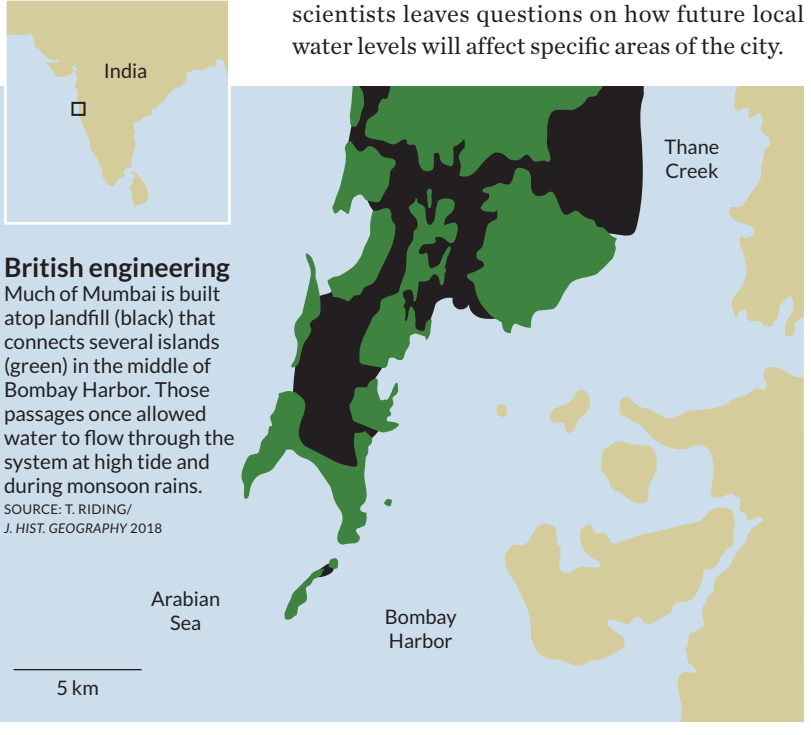
"For an individual, it doesn't matter if the water is coming from sea rise or a storm surge or the clouds, a flood is a flood," Hallegatte says. "Cities should be looking ... at one-meter sea level rise, at least. Because the cost of failure is so big, you need to have a plan for the worst-case scenario."

An ambiguous picture

On a Sunday evening in June, the promenade along Mumbai's iconic Marine Drive is packed. Families stroll eating ice cream, children chase street vendors peddling cotton candy, and friends squeeze together for selfies framed against the blue-gray waters of the Arabian Sea. Dark, roiling monsoon clouds loom over the horizon, as waves crash a meter away against the concrete barricade.

The promenade was built a century ago when India was part of the colonial British Empire. The walkway's days may be numbered. Mumbai's coastal waters rose at least nine centimeters during the 20th century, according to tide gauge data. Today, seawater regularly spills over the promenade during high tide.

It's not clear how much farther seas will rise around Mumbai. A variety of factors, including tides, gravity and Earth's rotation, influence local area sea rise in complex ways. And a lack of detailed data on Mumbai's coastal geography available to scientists leaves questions on how future local water levels will affect specific areas of the city.



British engineering
Much of Mumbai is built atop landfill (black) that connects several islands (green) in the middle of Bombay Harbor. Those passages once allowed water to flow through the system at high tide and during monsoon rains.
SOURCE: T. RIDING/ *J. HIST. GEOGRAPHY* 2018

The state of Maharashtra, where Mumbai is located, acknowledged this data deficit in its 2014 climate change plan. Nevertheless, the state has so far ignored a 2017 Indian Supreme Court order to release maps demarcating future flood lines.

Maharashtra's environment secretary, Anil Diggikar, told *Science News* that the mapping is being done, though he did not say when the maps might be made public. But the state does recommend that rainfall and sea level trends be considered in new construction projects and public infrastructure. "This is especially important for [the] economic hub of Mumbai and surrounding districts," he says, while also touting plans for restoring coastal stands of protective mangrove trees.

Marine scientist Mani Murali of the National Institute of Oceanography in Goa, India, has tried to work out Mumbai's future flood risk using low-resolution 2011 topographic data from NASA. That work, under peer review, doesn't tell the detailed story he knows the city needs. "But I thought something is better than nothing."

He may have a point, with the rate of global sea rise fast accelerating — from a yearly average of 1.8 millimeters in the last century to about 3.0 millimeters per year today, according to a report in the Feb. 27 *Proceedings of the National Academy of Sciences*.

And while global sea level projections up to 2050 are considered reliable, the situation beyond midcentury is less clear. Much depends on whether humankind can limit global emissions of carbon dioxide and other heat-trapping atmospheric gases. Princeton University climatologist Michael Oppenheimer is not optimistic.

"This is a battle that we are currently losing," says Oppenheimer, a coordinating lead author of the Intergovernmental Panel on Climate Change's special report on oceans, cryosphere and climate change, due out in September 2019. "Sea level rise and the flood heights are only going to increase ... for the foreseeable future."

The annual monsoon, the seasonal shift in winds that brings flooding rains to Mumbai, adds an extra layer of uncertainty to projecting how much flooding will accompany sea rise, he says. The future of this South Asian weather system has been difficult to predict, thanks in part to the mysterious influence of the Indo-Pacific Warm Pool. It's Earth's largest region of warm surface seawaters spanning the midocean region between the western Pacific and the eastern Indian oceans. That warmth partly fuels monsoon storm clouds.

C. CHANG

Still, most studies suggest that the monsoon rains will increase. "Uncertainty is not an excuse [for inaction] at this point," Oppenheimer says. "People need to get moving."

Land where it shouldn't be

Lakshmi Murali lives with her husband and son in a quiet, gated community, lush with jackfruit trees and flowering hibiscus in Mumbai's flood-prone neighborhood of Andheri. Every June, as the rain starts falling, she unplugs the electronics in their ground floor apartment and moves her silk saris out from under the bed.

Across the city, the rains rage against the glass windows of luxury high-rises. Public transportation and street commerce come to a halt. Water pounds the tin roofs of slum shanties where about half of Mumbai's 21.4 million people live. A sewage-tainted slurry burbles out of the city's outdated and often-clogged drainage system, backing up into rivers and creeks that then overflow into homes and businesses.

Last year was particularly bad: In 24 hours, about 33 centimeters of rain fell. "You had to see it to believe it," says Murali, a 54-year-old lawyer who is not related to the marine researcher of the same name. Her building's plumbing system failed, and the toilets overflowed. Residents turned off their power for fear of getting electrocuted. As water rose inside their homes, Murali and a few neighbors used an iron rod to smash a hole through the wall surrounding their backyard to let the water flow out.

"Today, we are young, and we say, 'Yeah, it's OK,'" Murali says. Even as such flooding worsens, she has what some might call misplaced faith that things will work out. "The state will work on building enough infrastructure to keep the city alive and will not allow the city to drown. Man will work against what nature is proposing to do."

Mumbai's current predicament is partly due to the power of engineering over nature. Large parts of the city are built on land that, 300 years ago, was mostly underwater. When the Portuguese settled the region in the 16th century, they maintained Mumbai as a sleepy collection of coastal islands. But the British, who took over in 1661, reimagined Mumbai as a contiguous landmass and created a peninsula by filling in land gaps to connect the islands even in the wet season.

"So many of these megacities are built on land that is only artificially higher than sea level, in places where landfilling took place," says Washington D.C.–based Susmita Dasgupta, the lead environmental economist for the World Bank's Development Research Group.

As monsoon rains pounded Mumbai in July, water poured down the steps onto the beach in front of Saif's soda shop.

M. SINGH

Dasgupta was involved in the World Bank's first report in 2007 on how sea level rise might affect national economies. The aim was to trigger discussion and preparation for a possible future economic catastrophe. She and her team offered guarded impact estimates based on hypothetical scenarios of between one and five meters of global sea level rise, using satellite images of coastal outlines and local elevations.

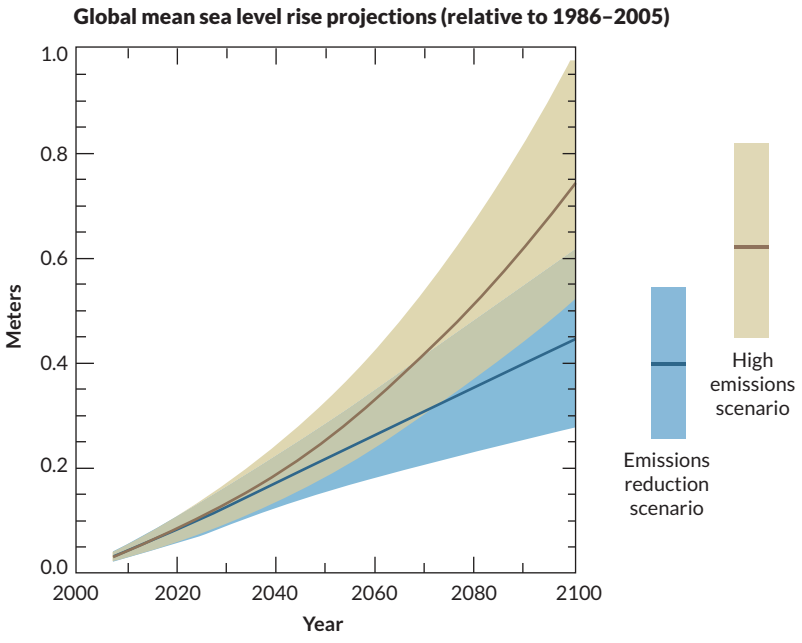
In estimating potential economic losses, the team considered an affected area's population multiplied by the country's gross domestic product per capita, but not infrastructure or property assets. That report projected that one meter of sea rise would cost the world 1.3 percent of the global economy. Applied to the forecast global GDP for 2018, that comes to about $1.3 trillion, not far from the estimates by Hallegatte's team.

"But we wanted to raise the issue," Dasgupta says. She faced a wave of hostility and derision for the effort. "Even bank colleagues were unhappy about it, saying we were being alarmist and that this kind of research was premature." Eleven years later, no one doubts the sea is rising.

Juggling the numbers

Amid the confusing tumble of scientific studies on how climate change might raise flood risks, some scientists have built online visual apps to help the public understand what's at stake.

One tool, by the U.S. National Oceanic and Atmospheric Administration, shows past global sea level trends based on tide gauges. But the app does not give projections. And it relies on sometimes patchy data. For example, there are no read-



Sea rise scenarios
Global sea level rise could be kept to a lower projection range (blue) if humankind curbs greenhouse gas emissions. Today, the world is on track for a much higher level of rise (tan). SOURCE: IPCC 2014

ings for Mumbai's water levels from 1994 to 2005 or after 2010. The Maharashtra government says local sea levels are rising 1.2 millimeters a year, based on those incomplete data.

In 2017, a team from NASA's Jet Propulsion Laboratory, or JPL, launched an app to demonstrate how melting ice sheets would affect 293 major port cities across the globe. The scientists measured the melt using NASA's GRACE satellites, which detect gravity changes from the ice loss. To boost accuracy, the team recently added a component to the app that accounts for the fact that water expands as it warms.

Still, true sea level rise projections involve complex computer modeling of overlapping systems. The JPL app doesn't do that. "So it's risky" to put too much stock in the numbers it spits out, says JPL sea level and ice supervisor Eric Larour. "But the real risk is that people underestimate that this is going to get worse."

For Mumbai, the JPL app foresees at least another 2.9-centimeter rise in coastal water in 10 years — and 14.4 centimeters in the next 50 years.

Those estimates could soon be revised upward. Larour's team plans one more update to include research published in the June 13 *Nature* showing that Antarctic ice sheets are melting three times as fast as they were 25 years ago (*SN: 6/7/18, p. 6*). That much melting, Larour says, is "a big, big deal."

The JPL team hopes to have a single, detailed modeling app for the world within two years, using NASA's high-resolution satellite images of water levels and of land gradients, "so that people can use it in active mitigation policy," Larour says. "A lot of areas at risk in South Asia — India, Bangladesh, Sri Lanka — and across Asia don't have the information to do this."

Economic gains lost

It's not easy to find a coastal megacity taking decisive and effective action against future flood risks. Bangladesh has long built coastal sea walls of stacked mud, which may help prevent ocean storm surges from cascading inland to Dhaka. Fast-sinking Jakarta is working on its own giant sea wall as well. But walls won't help Mumbai; they would prevent rain-driven freshwater floods from draining out after the monsoon.

Massive structural engineering is not the answer. Many scientists suggest that cities lighten their burden on the land by maintaining natural coastlines, protecting sand dunes and preserving forests or even growing more of them. At the least, cities should refrain from making development decisions that will make things worse, such as paving over water-absorbent soils or building on natural floodplains. Governments can also improve storm drains, offer voluntary relocation packages or even consider introducing ferries rather than trying to raise or maintain existing roads.

"We need to evolve to a situation where we're more congruent with nature, rather than fighting it," says urban planning expert Amrita Daniere of the University of Toronto, codirector of the Urban Climate Resilience in South East Asia Partnership. The group is aiding flood-preparation efforts in so-called second-tier cities, each still home to millions of people. "It's too difficult to influence policy and practice in a megacity," she says.

There are cities like Bangkok, the capital of Thailand, that may be just too vulnerable. Built atop an estuary feeding into the Gulf of Thailand, the city — also sinking — is on track to go mega by 2030. "It wouldn't shock me if they had to move the capital in 20 years," Daniere says.

Cities that don't own up to their vulnerability risk squandering economic gains made in the last few decades, economists say. Some cities could face a financial reckoning even before flooding worsens. The mere notion of increasing risk is enough to spook investors.

"That could have a domino effect on other cities, with bigger consequences for the global financial system," says Gregory Unruh, an expert in sustainable business strategy at George Mason

C. CHANG

University in Fairfax, Va. Yet modeling economic consequences is daunting, he says. These trends "tend to be based more on perceptions, on understanding bubbles and behavioral economics."

Pressure is mounting for cities to disclose climate risks. Credit rating agencies including Moody's and Standard & Poor's have begun including climate change impacts in their assessments. Last year, the Financial Stability Board of the Group of Twenty international forum urged insurers, banks and institutional investors to release climate-related financial risk disclosures.

Still, "there's not much happening," says Richard Hewston, a climate change analyst at Verisk Maplecroft in Bath, England, which advises on the risks of doing business around the world. "Sea rise is a gradual threat," even though it can worsen events like tropical cyclones, Hewston says. So it's difficult for people to use sea level rise as a reason to spend billions of dollars on infrastructure to prevent disaster.

Mumbai's flood risk makes the city a "high risk" place for climate change vulnerability — the second-most worrying category after "extreme risk," according to Verisk Maplecroft's 2018 hazard index. Among the world's 31 megacities, Mumbai ranks as the ninth riskiest, based on about 50 factors ranging from preparedness to exposure to climate shocks like heat waves, drought, hurricanes and flooding. Mumbai's high population density, high poverty rates and poor sewage and drainage systems "heighten the risk posed by climate-related events like flooding," the company says.

Verisk Maplecroft suggests that Mumbai build better sewage and drainage capacity, halt building on landfill and restore coastal mangrove trees, which keep the land intact with their tangle of roots and act as a natural buffer against the Arabian Sea.

There is little evidence that any of that, beyond mangrove restoration, is being done. Drainage system upgrades have been stalled for years. Limits on building on floodplains are routinely ignored. Mumbai-based environmental economist Archana Patankar worries that these are signs of official neglect.

Mumbai "is an extremely important city in terms of the economic wealth it generates," says Patankar. The city's economy rivals that of some developed nations in Europe. Its stock exchange is valued at around $2.2 trillion — almost twice the entire GDP of Mexico or Australia. Its Hindi-language Bollywood entertainment industry generates billions of dollars in global revenues each year. Not enough work has been done to assess how the city's economy will be impacted, she says.

A father tries to keep his children above water during flooding last February in the sinking megacity of Jakarta, Indonesia.

ARES JONEKSON/SHUTTERSTOCK

Instead, Mumbai appears focused on further developing its fragile coastline. The government is barreling ahead with plans for a 29-kilometer coastal highway, which will require ripping out patches of protective mangrove trees. Construction cranes punctuate the shoreline as new high-rises go up every year.

Property developers are aware of sea level rise, but they're in the business to sell. "No developer in Mumbai does any kind of risk analysis on how sea level and climate change is going to factor into their risks," says Rohitashwa Poddar, managing director of local developer Poddar Housing and Development. Though his company aims to build future-proof homes by placing them on stilts or surrounding them with water-absorbing gardens, few of Poddar's customers ask about flood risk.

"People should know if they're buying property in high-risk areas," adds Stalin Dayanand, director of Vanashakti, the local environmental group that argued in the Indian Supreme Court for the release of the state's forecast maps showing "hazard lines" for where the coast might be located in 100 years.

The state missed the Supreme Court's April deadline. Meanwhile, authorities moved ahead with plans for a $409 million memorial statue of the 17th century Indian ruler Chhatrapati Shivaji to be built on landfill in the middle of Mumbai's bay. If projections are even close to correct, that 200-meter-tall statue could be left towering over a city swamped within decades. ■

> "The real risk is that people underestimate that this is going to get worse."
>
> **ERIC LAROUR**

Explore more

- Sean Vitousek *et al.* "Doubling of coastal flooding frequency within decades due to sea-level rise." *Scientific Reports*. May 18, 2017.

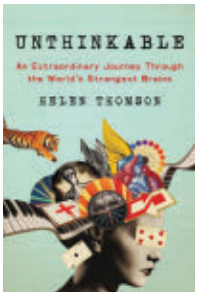
Katy Daigle is deputy news editor. Freelance science writer Maanvi Singh reported this story from Mumbai.

BOOKSHELF

Strange brains offer a glimpse into the mind

To understand the human brain, take note of the rare, the strange and the downright spooky. That's the premise of two new books, *Unthinkable* by science writer Helen Thomson and *The Disordered Mind* by neuroscientist Eric R. Kandel.

Both books describe people with minds that don't work the same way as everyone else's. These are people who are convinced that they are dead, for instance; people whose mental illnesses lead to incredible art; people whose memories have been stolen by dementia; people who don't forget anything. By scrutinizing these cases, the stories offer extreme examples of how the brain creates our realities.



Unthinkable
Helen Thomson
ECCO, $27.99

The Disordered Mind
Eric R. Kandel
FARRAR, STRAUS AND GIROUX, $30

In the tradition of the late neurologist Oliver Sacks, Thomson explores the experiences of nine people with unusual minds. She travels around the world to interview her subjects with compassion and curiosity. In England, she meets a man who, following a bathtub electrocution, became convinced that he was dead. (Every so often, he still feels "a little bit dead," he tells Thomson.) In Los Angeles, she spends time with a 64-year-old man who can remember almost every day of his life in extreme detail. And in a frightening encounter in a hospital in the United Arab Emirates, she interviews a man with schizophrenia who transmogrifies into a growling tiger. By visiting them in their element, Thomson presents these people not as parlor tricks, but as fully rendered human beings.

Kandel chooses the brain disorders themselves as his subjects. He explains the current neuroscientific understanding of autism, depression and schizophrenia, for example, by weaving together the history of the research and human examples. His chapter on dementia and memory is particularly compelling, given his own Nobel Prize–winning role in revealing how brains form memories (*SN: 10/14/00, p. 247*).

With diagrams of key brain regions, Alzheimer's plaques and even chromosomes, Kandel's book reads in some ways as a primer on the basic tenets of biology and neuroscience. Also included are stories of people, such as a woman who describes her bipolar illness in stark terms: "Feelings of ease, intensity, power, well-being, financial omnipotence and euphoria pervade one's marrow." But then, she says, everything changes. "You are irritable, angry, frightened, uncontrollable and enmeshed totally in the blackest caves of the mind. You never knew those caves were there. It will never end, for madness carves its own reality."

Though these cases seem extreme, Thomson and Kandel relate unusual brains to more common forms of thinking. Observing huge emotional swings that come with bipolar disorder can help inform scientists about more mundane changes in our happiness or sorrow. Figuring out why a person thinks he's dead could reveal how we more generally create our sense of self. Understanding why someone might remember everything, or nothing, could help us understand how memories physically change the brain (*SN: 2/3/18, p. 22*).

By connecting these strange brains to everyday mental processes, both books make clear how much we all have in common, and more than that, how all our brains are a little bit unusual.
— Laura Sanders

FILM

Watch scientists become students

When pondering the deepest scientific questions — What is time? What is consciousness? Is there life on other worlds? — it helps to have a knowledgeable guide. But not too knowledgeable.

In *The Most Unknown*, a documentary now available on Netflix, nine scientists perform a research round robin: Each one visits another from an entirely different discipline. Esteemed experts in their own fields, they each know little to nothing about their partner's research. That makes the scientists remarkably good interviewers, asking the naïve but probing questions that lead to fascinating discussions. Drawing on their shared experience as scientists, the researchers quickly grasp their colleagues' work and convey its importance in simple, jargon-free language.

Directed by Ian Cheney, with filmmaker Werner Herzog acting as an adviser, the film weaves together diverse scientific disciplines in sometimes surprising ways. A microbiologist and a particle physicist bond over the different types of dark matter in their two fields. In physics, the term refers to hypothetical particles that interact through gravity but are otherwise mostly inert (*SN: 11/12/16, p. 14*). In microbiology — which pilfered the term from physics — dark matter refers to the oodles of microbial species thought to exist but which scientists have yet

In *The Most Unknown*, an astronomer stows away on board a submersible *Alvin*, which is used to study the deep ocean.

COURTESY OF MOTHERBOARD

Microbiologist Jennifer Macalady of Penn State University (left), who studies cave microbes, takes cognitive psychologist Laurie Santos of Yale University (right) spelunking.

to find and which are expected to vastly outnumber known species (*SN: 9/17/16, p. 18*).

In keeping with the film's title, the researchers find common ground in the search for the unknown. All nine of them are plumbing the dark depths at the limits of current human understanding, including the murky workings of the human brain, life on the deep ocean floor and the cosmic mysteries behind the formation of stars.

The Most Unknown
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It's humanizing to watch the scientists become students: fumbling with unfamiliar concepts and taking part in experiments that put the scientists out of their comfort zones — and that sometimes fail. A physicist learns to shakily control a robotic arm with his brain; a nervous astronomer goes on a deep-sea dive in a submersible; a neuroscientist accustomed to working with humans plies monkeys with grapes.

Pairing up scientists from different fields leads to some delightful insights about how scientific expertise translates — or doesn't — from one field to another. A physicist who built one of the world's most accurate atomic clocks, for example, turns out to be surprisingly bad at telling time when subjected to a neuroscientist's test.

In each partnership, the researchers put their full, wonderful nerdiness on display, expressing reverence for scientific progress of all stripes — and wonder at the mysteries that remain. — *Emily Conover*

COURTESY OF MOTHERBOARD

ART MEETS SCIENCE

Albert Einstein once said, "All religions, arts and sciences are branches of the same tree." It's not surprising to learn that so many Science Talent Search alumni enjoy the connections between art and science.

Neurologist uses poetry as an outlet

Nina Schor (STS 1972) is the deputy director of the National Institute of Neurological Disorders and Stroke in Bethesda, Md. She's also a poet, with several poems published in *Neurology* and a chapbook titled *To the East of Ever After*.

Her research focuses on treating neuroblastoma, a deadly cancer of the peripheral nervous system most commonly detected in children.

Poetry offers Schor an outlet and a way to reflect. "All scientists, and, indeed, all hardworking people, should have an outlet, a pop-off valve," she says.

Nina Schor (center) speaks to Science Talent Search finalists in 2001.

Read more about Schor:
www.societyforscience.org/Nina-Schor

Cindy Wang (second from right) plays viola in a string quartet. Here, the group is performing a Felix Mendelssohn piece.

'STEM Quartet' offers this scientist multiple mind-sets

Cindy Wang (STS 2006) is a pharmaceutical consultant for L.E.K. Consulting in San Francisco. When she isn't working, Wang enjoys artistic endeavors like photography and graphic design. She also plays viola in a quartet of musicians who are all scientists working in health care. They have joked about calling themselves the "STEM Quartet."

Wang has been fortunate to pursue her different interests. "It's that kind of diversity that I like having in my life, using the right and left sides of my brain."

Both art and science involve experimentation, Wang says. "You have to be willing to take risks and try things you've never tried before."

Read more about Wang:
www.societyforscience.org/Cindy-Wang

Playwright finds ways to incorporate science into his works

Jerry Lieblich (STS 2006) has two plays premiering this summer in New York City. One centers on characters who depict the life and work of scientists and the other focuses on chaos theory.

Jerry Lieblich is an award-winning playwright and a published scientist.

Lieblich, an award-winning playwright, has also coauthored a scientific paper. He has held residencies at the Ucross Foundation and the Edward F. Albee Foundation, received an EST/Sloan Foundation Commission and the Himan Brown Creative Writing Award, and is an alumnus of the Soho Rep Writer/Director Lab and Page 73's I-73 Writers Group. Lieblich finds the intersection between art and science conducive to creating plays.

The fusion of science and art offers Lieblich a unique lens through which to view the world. "Whether an artist or scientist, do what it is you want to do," he says. "And value yourself and the work that you make."

Read more about Lieblich:
www.societyforscience.org/Jerry-Lieblich

FROM LEFT: SSP; C. WANG; JOE MARTIN

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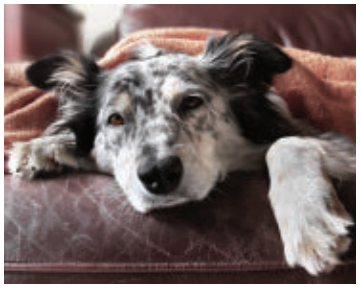
JULY 7, 2018

SOCIAL MEDIA

Ruff life

Pigs and birds remain prime suspects for mixing up the next influenza virus to cause a pandemic in people. But dogs also carry flu viruses that can recombine to make new strains, making the animals worth keeping an eye on, **Tina Hesman Saey** reported in "Dogs harbor a variety of flu viruses" (*SN: 7/7/18, p. 8*). "Welp, time to become a cat person," Reddit user **evolvedtwig** quipped.



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Melt away

*In the last five years, Antarctica has lost ice nearly three times faster on average than it did over the previous 20 years — largely due to climate change, **Laurel Hamers** reported in "Antarctic melting is speeding up" (SN: 7/7/18, p. 6).*

"Isn't there a volcano or multiple volcanoes recently found under Antarctica that might also be contributing to the melting?" asked reader **Leslie Hruby**.

There are nearly 140 volcanoes under West Antarctica alone that we know about, **Hamers** says. The recent analysis calculated the rate of ice loss for the entire continent based on satellite data. Scientists didn't consider the volcanoes' potential contribution.

Whether under-ice volcanoes are contributing to the ice retreat today is unclear. However, the volcanoes could affect future melting in a number of ways, researchers from the University of Edinburgh argued in a 2017 study published in a Geological Society of London special report. Among the possibilities: Multiple eruptions could destabilize the ice and speed up melting. Increased melting could also trigger eruptions: Thinning ice reduces pressure on Earth's mantle, promoting the potential of eruptions, the team proposed.

Choice words

*Greenhouse gas emissions can differ considerably between low-impact and high-impact producers of various types of food, **Susan Milius** reported in "How your food choices affect climate" (SN: 7/7/18, p. 10).*

Although it's important to consider food production's environmental impacts, online reader **Tony Cooley** noted that the researchers did not assess the societal implications of lowering agricultural greenhouse gas emissions.

Scientific research "is an important component of addressing the climate change issue, but is necessarily only one part of the solution," **Cooley** wrote. "And ultimately, getting public acceptance of any such plan will involve discussion of the other components, including the costs of action and the costs of inaction."

Still, **Cooley** thought the research was a good first step. "To make a meaningful response to the climate crisis, as a start it is important to nail down the science and objective factual data so the discussion is not limited to arm waving, wishful thinking and uninformed emotional appeals and manipulation."

Reader **Ron Aryel** didn't see the point of focusing on food choices, as fossil fuels dwarf food animals' contribution to climate change.

Livestock farming alone makes up 14.5 percent of anthropogenic greenhouse gas emissions worldwide, the United Nations Food and Agriculture Organization reported in 2013. That tally includes livestock farming's share of fossil fuel emissions, **Milius** says.

Fusion's dark side

*During the proposed process of dark fusion, dark matter particles could fuse together and give off energy, **Emily Conover** reported in "Fusion may unite dark matter particles" (SN: 7/7/18, p. 9).*

"Could dark fusion be the source of dark energy?" reader **Andrew Benton** asked.

No, says physicist **Sam McDermott** of Fermilab in Batavia, Ill. The amount of energy that would be released during dark fusion is not enough to account for the vast amount of dark energy in the universe. "Even if every single dark matter particle undergoes fusion, which seems unrealistic, we could only extract approximately 0.03 percent of the observed dark energy from dark matter fusion," he estimates.

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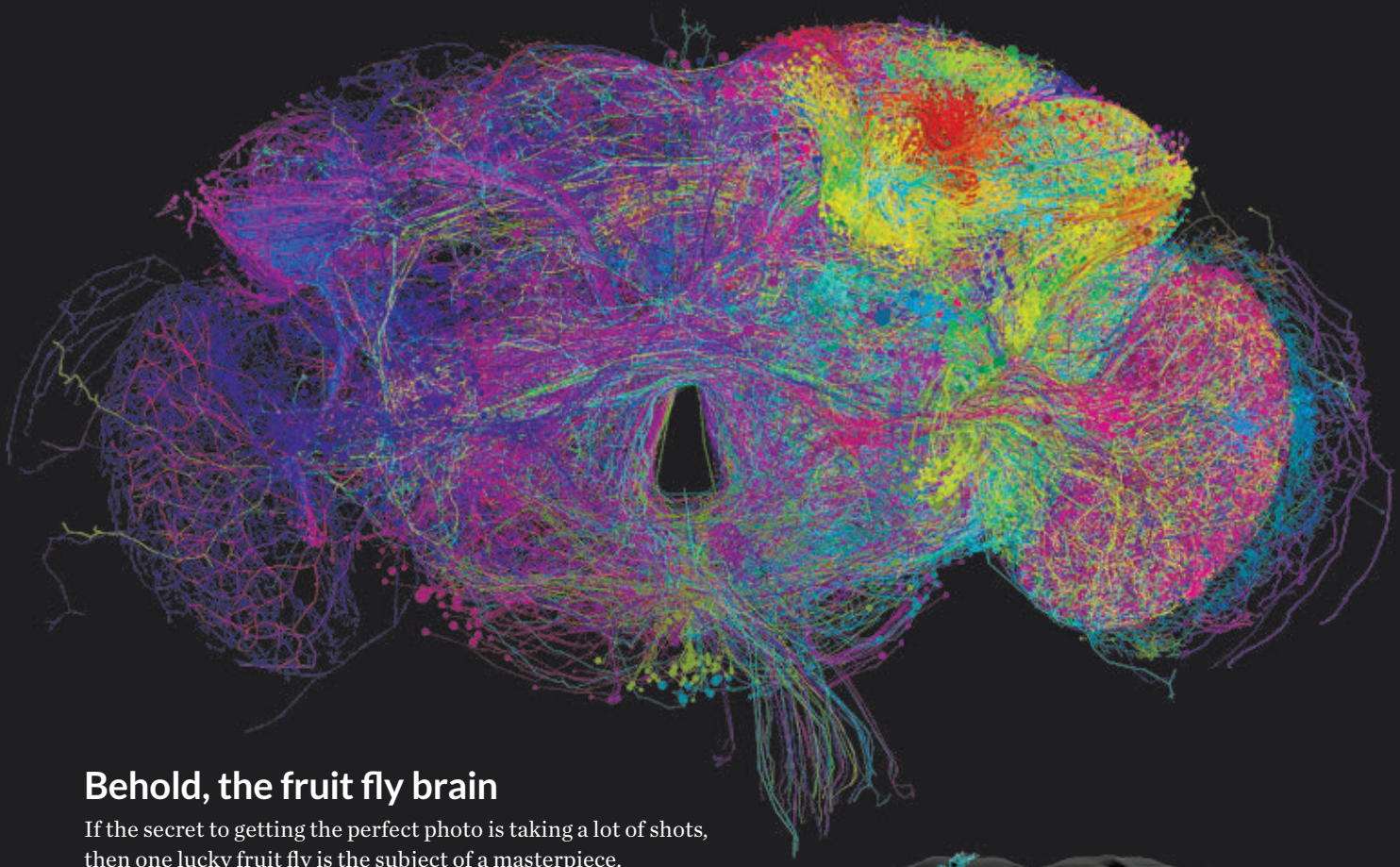


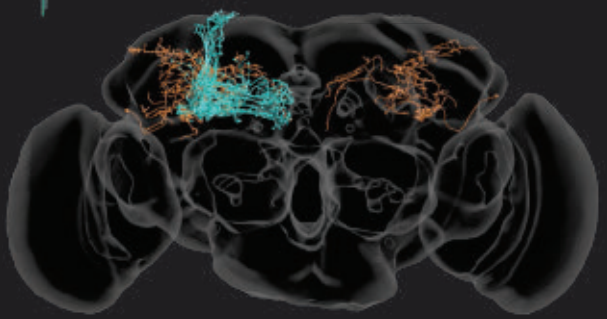
Behold, the fruit fly brain

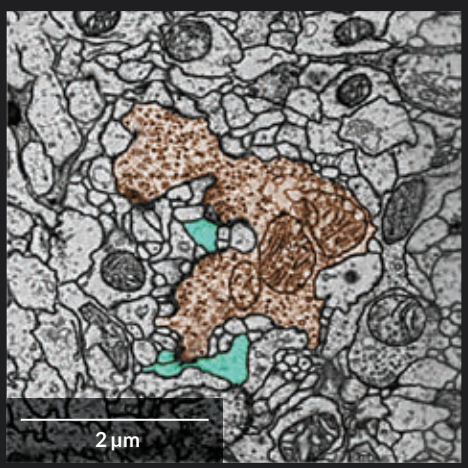
If the secret to getting the perfect photo is taking a lot of shots, then one lucky fruit fly is the subject of a masterpiece.

Using high-speed electron microscopy, scientists snapped 21 million nanoscale-resolution images of the brain of *Drosophila melanogaster*. The dataset captures in minute detail all of the 100,000 nerve cells, or neurons, in the fly's brain, and could help researchers identify the neural circuits that control behaviors such as flying, the team reports online July 19 in *Cell*. (Human brains have roughly 100 billion neurons.)

The 3-D brain model above shows scientists' efforts, so far, at using the dataset to trace neurons' paths, highlighting the complexity of this relatively simple brain. Cells with nuclei close together share the same color, but not necessarily the same function. This color-coding demonstrates how neurons born near each other in the poppy seed–sized brain tend to send their spidery tendrils out in the same direction. Despite the tangle of neural connections, the mapping is far from complete, says study coauthor Davi Bock, a neurobiologist at Howard Hughes Medical Institute's Janelia Research Campus in Ashburn, Va.

The team has already discovered a new type of neuron (orange in the 3-D model at middle and in the electron microscopy cross section at bottom) that talks to another kind of neuron (teal) in the mushroom body, a structure involved in learning and memory. The fly brain has two of these newly described neurons, one on each side. Because of their far-reaching influence, these cells might be involved in integrating different types of sensory information, Bock says. — *Laurel Hamers*





FROM TOP: FULL ADULT FLY TRACING COMMUNITY, P. SCHLEGEL/DROSOPHILA CONNECTOMICS GROUP/UNIV. OF CAMBRIDGE; STEVEN A. CALLE-SCHULER/JANELIA; Z. ZHENG *ET AL*/*CELL* 2018

GEOLOGIC ROAD TRIP OF THE MONTH

CAPE BLANCO, OREGON

Cape Blanco, the westernmost point of the conterminous United States, protrudes 0.5 mile (0.8 km) into the sea as a windswept, nearly treeless plateau, some 200 feet (60 m) above the waves. It ends abruptly as a cliff, flanked by long empty beaches that stretch in either direction. The cape hosts Oregon's oldest and highest continuously operating lighthouse, built in 1870 and now open to the public during spring and summer months.

Aerial view of Cape Blanco toward the north.

Perhaps the most striking thing about Cape Blanco is its apparent flatness, formed from an uplifted marine terrace, called the Cape Blanco terrace. Coastal sand and gravel deposits, which compose the terrace, are well exposed on the beach trail north of the lighthouse parking lot. These deposits are estimated to be 80,000 years old, so the Cape Blanco terrace is probably equivalent to the Whisky Run terrace, which is the lowest terrace at Cape Arago, north of Bandon.

Just inland of the Cape Blanco terrace and at a slightly higher elevation lies the older and much more extensive Pioneer terrace, estimated to be about 105,000 years old. It is also the second-youngest terrace at Cape Arago. Because of its great extent, we can see that it is gently folded into an anticline. At Cape Blanco, the terrace slopes ever so slightly toward the south, joining sea level some 5 miles (8 km) away; to the north, the terrace also reaches sea level in about 5 miles (8 km). Deformation at the subduction zone, less than 50 miles (80 km) to the west, has formed this young fold.

Beneath the terrace lies bedrock, much of which is beautifully exposed in the sea cliffs. You can see these cliffs from the beach along the southwest side of the cape, reached by a road at the far end of the campground. Most of the rocks dip toward the southeast, so they get younger in that direction. The oldest rock, the Jurassic-age Otter Point Formation, consists of dark-colored mudstone and sandstone with scattered blocks of greenstone and even blueschist. The Otter Point is a mélange that formed elsewhere but was accreted to North America sometime at the end of the Mesozoic Era. Rocks of the Eocene-age Umpqua Group, part of a fault slice here, consist of gray shale that was deposited in deep water during and following the accretion. The Miocene-age Sandstone of Floras Lake, named for outcrops near Floras Lake north of Cape Blanco, consists mostly of sandstone and conglomerate, whereas the Miocene-age Empire Formation is largely tan-colored sandstone and siltstone. Needle Rock, the prominent sea stack below the parking lot on the south side of the cape consists of the lower part of the Sandstone of Floras Lake. The Pleistocene-age Port Orford Formation consists mostly of marine-deposited, darker colored sandstone and thin beds of conglomerate that overlies a 30-foot-thick (9 m) base of river-deposited conglomerate and sandstone.

Numerous landslides are eroding the narrow peninsula between the mainland and the lighthouse area. Much of the trail to the beach on the north side winds down through one of these slides. Immediately south of the parking lot, you can see small faults forming in the gravel deposits as they pull away from the terrace edge at the top of one of these slides. Numerous other slides affect the southeast edge of the cape.

North of Cape Blanco, the Sixes River meanders over its floodplain. An example of how its channel changes position through time is the large cutoff meander that occupies the floodplain about 2 miles (3.2 km) from the river's mouth. The road to the cape crosses this area where it descends almost to sea level before rising up to the terrace, about 1 mile (1.6 km) east of the parking lot.

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