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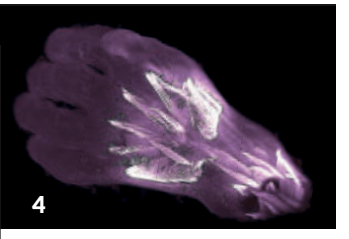
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SOCIETY UPDATE
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COVER Artisans carve rosewood at a furniture factory in China's Jiangsu province in March 2019. *Ji Chunpeng/Xinhua/Alamy Stock Photo*

FROM TOP: COURTESY OF J. DEGL; R. DIOGO, NATALIA SIOMAVA AND YORICK GITTON; GRAPHIC BY KYLE KOSMA IN M.M. KOSMA *ET AL/ROY. SOC. OPEN SCI.* 2019

Fighting poverty and the deep roots of inequality

In 2018, income inequality in the United States reached its highest level since the Census Bureau started studying it in 1967, despite the longest sustained period of economic growth in American history. The issue has become a flash point, with presidential contenders Bernie Sanders and Elizabeth Warren arguing for a wealth tax, while attacks on homeless people, labeled "parasites" and "bums," are on the rise, according to the *New York Times*.

So it was invigorating to read about the winners of this year's Nobel Memorial Prize in Economic Sciences, who took a scientific approach to reducing the harms of poverty (Page 12). The laureates proved it could be done by tackling smaller questions, such as testing whether providing tutors for struggling students in India would make a difference versus expecting children to cope with a one-size-fits-all curriculum. The tailored instruction made for lasting improvements in achievement.

"Our goal is to make sure that the fight against poverty is based on scientific evidence," Esther Duflo, the winner along with Abhijit Banerjee and Michael Kremer, told reporters on October 14. "It starts from the idea that often the poor are reduced to caricatures and often, even people who try to help them do not actually understand what are the deep roots of the problem."

Policies devised to combat poverty often backfire, notes behavioral sciences writer Bruce Bower, who covered the award. These researchers not only helped create the science of development economics, he says, they made randomized controlled trials and fieldwork standard practice in the discipline.

The prize was notable also because Duflo, who works at MIT with Banerjee, is only the second woman to win a Nobel in economics. The field is grappling with long-standing problems with discrimination against women, what former Federal Reserve chief Janet Yellen recently called "an unacceptable culture." After the Nobel announcement, Duflo said she hoped "many, many other women" would be inspired to persevere in economics as a result — and that men would give those women "the respect they deserve."

Now let's ponder a more distant inequality, in the Bronze Age.

About 4,000 years ago, farming households in central Europe included both wealthy individuals and unrelated people of little means (Page 8), Bower reports. The researchers said they were "absolutely surprised" to find such inequity within households. The team also identified genetically unrelated high-status women who had presumably married into the families.

"It's the beginning of a period of expanded social complexity," Bower says of the Bronze Age. It's not clear what role the poor people played in those households, but they may have been the precursors to the slaves common in some ancient Greek and Roman families. And the fact that women from afar married into those households may note the beginnings of a male-dominated society.

Science gives us insights into how human societies develop and change and invents ways we can alleviate suffering, even if that means, as was the case for Duflo and her colleagues, improving the practice of science itself.

— Nancy Shute, Editor in Chief

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50 YEARS AGO

Immune response and cancer therapy

The dream of a cancer vaccine is still just that — a dream. But experimenters at Emory University in Atlanta have shown that the basic mechanism — stimulation of an immune response — can take place.

UPDATE: Researchers have devised several ways of getting the immune system to prevent or control cancer. Vaccinations against human papillomavirus, or HPV, prevent infections that cause cervical and other cancers. Hepatitis B vaccines may head off some forms of liver cancer. Other strategies, like CAR-T cell therapy and PD-1 blockade therapy (*SN: 7/11/15, p. 14*), prompt T cells of the immune system to go after tumors. The U.S. Food and Drug Administration approved the first PD-1 blockade therapy in 2011 and then two CAR-T cell therapies in 2017 for patients with certain types of cancers (*SN: 12/23/17 & 1/6/18, p. 29*). Overstimulating the immune system can produce severe side effects, so scientists are working to develop safer options (*SN: 7/7/18, p. 22*).

Two dorsometacarpales muscles (arrows) in the hand of a 10-week-old human embryo will be lost or fuse with other muscles.

HOW BIZARRE

Human embryos have extra hand muscles found in lizards

Human embryos are more muscle-bound than adult humans, microscope images cataloging early development show.

At seven weeks of gestation, embryonic hands have about 30 muscles. Adults have about 19. As the embryo develops, many of the muscles disappear, and some fuse with others. By 13 weeks of gestation, the muscles have adopted an adult arrangement.

Muscles in the feet, legs, trunk, arms and head also appear and disappear during development, researchers report October 1 in *Development* after analyzing detailed 3-D images of human embryos and fetuses up to 13 weeks of gestation. These appearing and disappearing, or atavistic, muscles are remnants of evolution.

Atavistic muscles are built as a base that's pared down to the muscle set people are born with, says coauthor Rui Diogo, a biologist at Howard University in Washington, D.C. "Losing and specializing, that's what happens in human evolution," he says.

Other animals have kept some of those muscles. Adult chimpanzees and human embryos both have epitrochleoanconeus muscles in their forearms, but most adult humans don't. Humans' mammalian ancestors also lost dorsometacarpales muscles from the back of the hand about 250 million years ago as mammals and reptiles split on the evolutionary tree. Lizards still have those muscles.

— *Tina Hesman Saey*

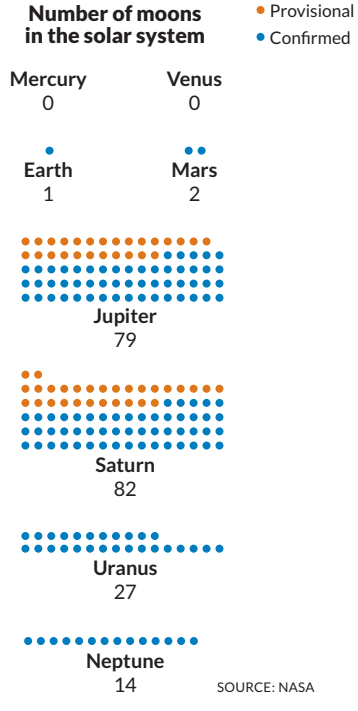
SCIENCE STATS

Saturn is crowned 'moon king'

With 20 new moons found around Saturn, the solar system's sixth planet from the sun now reigns as "moon king."

The new satellites bring the planet's total known moons to 82, surpassing Jupiter with its 79 moons (shown at right), the International Astronomical Union's Minor Planet Center announced October 7.

Each of the newfound moons is 2 to 5 kilometers wide — so small it took years before scientists had the technology to confirm that the specks captured in images from 2004 to 2007 were, in fact, satellites. Newly found moons are considered "provisional" until details of their orbits are worked out. Astronomers found that three new moons orbit in the same direction that Saturn rotates, and 17 travel in the opposite direction. "If we want to find the smaller ones, we have to get bigger telescopes," says Scott Sheppard, an astronomer at the Carnegie Institution for Science in Washington, D.C. — *Sofie Bates*



FROM TOP: R. DIOGO, NATALIA SIOMAVA AND YORICK GITTON; E. OTWELL

SOAPBOX

Plants don't have feelings or consciousness

Lincoln Taiz is peeved. Over the last decade or so, the retired plant biologist has watched the rise of the field of "plant neurobiology" with growing dismay.

That controversial field is based on the idea that plants — which do not possess brains — nonetheless handle information in ways that resemble the abilities of sophisticated animal nervous systems. The implication is that plants could feel happiness or sorrow or pain, make intentional decisions and even possess consciousness. But the chances of that are "effectively nil," Taiz argues.

"There's nothing in the plant remotely comparable to the complexity of the animal brain."

LINCOLN TAIZ

"There's nothing in the plant remotely comparable to the complexity of the animal brain," says Taiz, of the University of California, Santa Cruz. "Nothing. And I'm a plant biologist. I love plants" — not because plants think like humans, he says, but for "how they live their plant lives."

Some plants are capable of sophisticated behavior. Wounded leaves can send warning signals to other parts of the plant, and noxious chemicals can deter munching predators. Some plants may even have a version of short-term memory: Tiny sensing hairs that line Venus flytraps' insect prisons can count the touches that come from a bumbling insect (*SN Online: 1/24/16*).

But plants perform these feats with equipment that's very different from the nervous systems of animals, no brain required, Taiz contends.

In an opinion piece in the Aug. 1 *Trends in Plant Science*, he and colleagues point out methodological flaws in some of the studies that have claimed plants have brainlike command centers, animal-like nerve cells and oscillating patterns of electricity that are reminiscent of activity in animal brains.

Beyond the debate over how these studies are conducted, Taiz's team argues that plant consciousness doesn't even make sense from an evolutionary point of view.

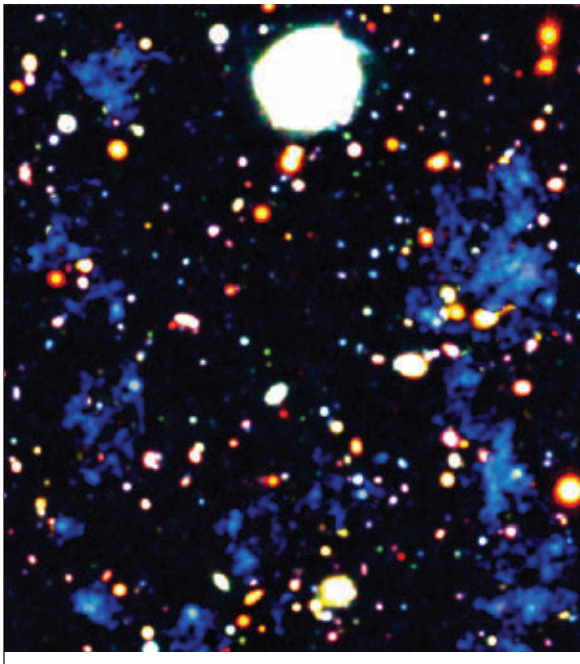
Sophisticated animal brains evolved in part to help an organism catch a meal and avoid becoming one, Taiz says. But plants are rooted to the ground and rely on sunlight for energy, a sedentary lifestyle that doesn't require quick thinking or outwitting a predator — or the energetically expensive nervous system that enables those behaviors.

"What use would consciousness be to a plant?" Taiz asks. The energy required to power awareness would be too costly and the benefit from such awareness too small. If a plant fretted and suffered when faced with a threat, the plant would be wasting so much energy that it wouldn't have any energy left to do anything about that threat, Taiz says.

Imagine a forest fire. "It's unbearable to even consider the idea that plants would be sentient, conscious beings aware of the fact that they're being burned to ashes, watching their saplings die in front of them," Taiz says. The horrifying scenario illustrates "what it would actually cost a plant to have consciousness," he says.

Besides, plants have plenty to do without having to be conscious too. With sunlight, carbon dioxide and water, plants create the compounds that sustain much of the rest of life on Earth, Taiz points out. "Isn't that enough?" — *Laura Sanders*

FROM TOP: HIDEKI UMEHATA; COURTESY OF L. TAIZ



PICTURE THIS

The structure of the cosmic web is revealed

Like strands of a cosmic spider web, gas filaments link galaxies to one another. But just as threads of spider silk can be nearly invisible, this cosmic web is hard to detect. Now astronomers have made the first picture of light emitted by the gas (above), showing that the filaments (blue) extend for millions of light-years.

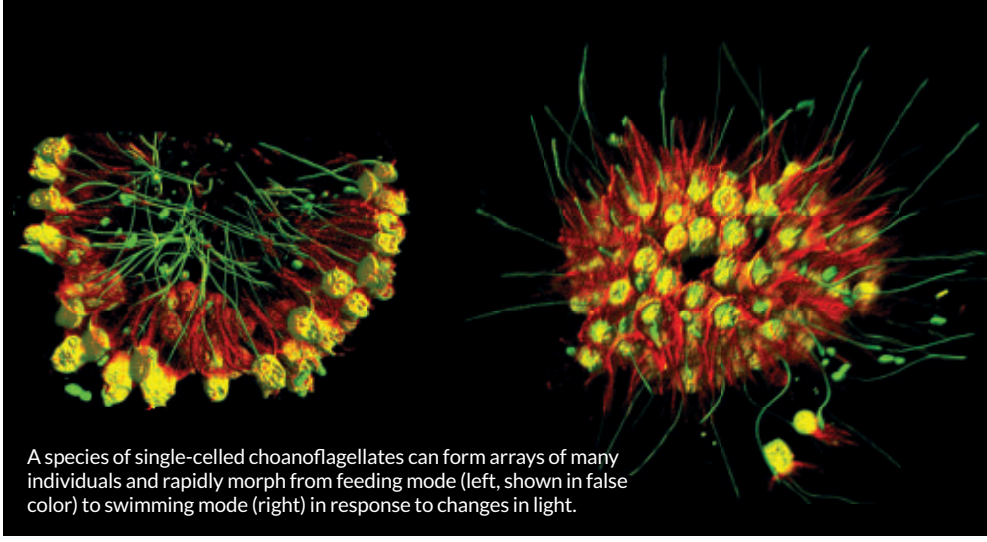
Astronomers had glimpsed a single filament in the past (*SN: 3/8/14, p. 8*), but hadn't seen the network between galaxies. The new image focuses on a forming cluster of galaxies (bright spots) 12 billion light-years from Earth in the constellation Aquarius. The galaxies emit ultraviolet light from stars forming or matter churning around black holes. The gas filaments absorb that light and reemit it. Using the European Southern Observatory's Very Large Telescope in Chile, astronomers detected the reemited light, the team reports in the Oct. 4 *Science*.

The image supports the theory that, after the Big Bang 13.8 billion years ago, gravity caused matter to collapse into sheets and filaments, with galaxies forming where matter was especially dense. — *Emily Conover*

LIFE & EVOLUTION

Microbes team up and change shapes

Collective behavior may give clues to rise of multicellularity



A species of single-celled choanoflagellates can form arrays of many individuals and rapidly morph from feeding mode (left, shown in false color) to swimming mode (right) in response to changes in light.

BY JONATHAN LAMBERT

There's not much to a choanoflagellate. But a new species of these single-celled organisms, animals' closest evolutionary relatives (*SN: 8/8/15, p. 22*), could help provide answers to a fundamental question in biology: How did solitary cells band together long ago to form multicellular coalitions capable of moving, hunting and hiding?

Most choanoflagellates live simple, solitary lives. So when Nicole King, a cell biologist and Howard Hughes Medical Institute investigator at the University of California, Berkeley, and colleagues discovered hundreds of these organisms locked together in a sample collected along the coast of the Caribbean island of Curaçao, the team was surprised. The cells formed a concave sheet, with their tail-like flagella extending from the cupped side.

And the scientists were stunned when, in unison, the organisms making up the sheet inverted into a ball-like shape, tiny flagella flailing outward like tiny oars, allowing the organisms to swim much more swiftly. The team dubbed the choanoflagellates a new species, *Choanoeca flexa*.

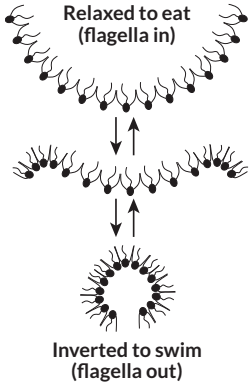
"It was this crazy behavior unlike anything we'd ever heard of in choanoflagellates," King says. "We just had to figure out how they pulled it off."

This collective behavior emerges from cells responding to changes in light, King and colleagues report in the Oct. 18 *Science*. They suggest that the newfound species could offer clues to how a key step in animal evolution happened. "Plus, it's just a really cool phenomenon," King says.

William Ratcliff, an evolutionary biologist at Georgia Tech in Atlanta, agrees. While it's impossible to go back in time to observe how the most recent common ancestor of animals and choanoflagellates evolved into more complicated multicellular creatures, he says, "this study breaks down this huge jump and shows how single cells can adapt and become more complex at the multicellular level."

Each individual *C. flexa* resembles a sort of smooshed sphere. From one end, many tiny, tentacle-like protrusions form a collar that's accented with a single, longer flagellum. Individual choanoflagellates join together by touching these collars. In the concave form, the flagella all point inward, "which aids feeding on bacteria," King says. When the organisms flip into more of a sphere, the flagella all point outward, becoming paddles for swimming.

All together A group of *Choanoeca flexa* cells forms a relaxed sheet shape while feeding but can switch to a ball shape with the cells' tail-like flagella pointing outward for swimming.



The researchers noticed that flipping stopped when the organisms were exposed to a microscope's light for too long. On a whim, King turned off the lights and then turned them back on. In the dark, *C. flexa* cells inverted into the ball shape. "And then we did it again, and did it again and did it again, and every time we changed the illumination, they flipped," King says.

The researchers haven't fleshed out the full mechanism, but they've confirmed that a light-sensitive protein known as rhodopsin plays a role. And the collective behavior doesn't seem to be the result of complicated communication among the cells. Rather, it stems from a simple, musclelike tightening or loosening of each choanoflagellate's collar appendages. In sheet mode, the collars are tighter, pulling the cells into a slightly cupped shape. When the light changes, the collars widen, collectively forcing the sheet to invert into a sphere.

This change in a single choanoflagellate wouldn't amount to much, Ratcliff says. But together, this simple individual action adds up to produce a whole new behavior — swimming or staying put to feed. "It's a beautiful example of how simple groups of cells gain these emergent multicellular traits," he says.

King isn't sure why changes in light trigger this response. But she notes that a consequence of swimming faster in darkness and staying put in light is that *C. flexa* cells tend to move toward well-lit areas that might have more food. Individual cells can't effectively swim toward light; groups of *C. flexa* cells can.

The importance of this shape-shifting extends far beyond choanoflagellates, King says. Key components of animal development involve the folding of tissues as an embryo develops. "Our study shows that the basic cellular machinery necessary for this kind of folding predates the origin of animals," she says. ■

FROM TOP: THIBAUT BRUNET; T. BRUNET *ET AL/SCIENCE* 2019

ATOM & COSMOS

Physicists find a new faux particle

Quasiparticle in crystal resembles dark matter candidate

BY EMILY CONOVER

An elusive hypothetical particle comes in imitation form.

Lurking within a solid crystal is a phenomenon that is mathematically similar to proposed subatomic particles called axions, physicist Johannes Gooth and colleagues report online October 7 in *Nature*.

If axions exist as fundamental particles, they could constitute a hidden form of matter in the cosmos: dark matter. Scientists know dark matter exists thanks to its gravitational pull, but they have yet to identify what it is. Axions are one possibility, but no one has found the particles yet.

Enter the imitators. The axion analogs in the crystal are a type of quasiparticle, a disturbance in a material that can mimic fundamental particles. Quasiparticles result from the coordinated jostling of electrons within a solid material. It's a bit like how birds in a flock seem to take on new forms by syncing their movements.

Axions were first proposed in the context of quantum chromodynamics — the theory that explains the behaviors of quarks, tiny particles that are contained, for example, inside protons. Axions and their new doppelgängers "are mathematically similar but physically totally unrelated," says theoretical physicist Helen Quinn of SLAC National Accelerator Laboratory in Menlo Park, Calif., one of the scientists who formulated the theory behind axions. That means scientists are no closer to solving their dark matter conundrum.

Still, the new study reveals for the first time that axions have a life beyond mere equations, in quasiparticle form. "It's actually amazing," says Gooth, of the Max Planck Institute for Chemical Physics of Solids in Dresden, Germany. The idea of axions is "a very mathematical concept, in a sense, but it still exists in reality."

Gooth and colleagues started with a material that hosts a type of quasiparticle known as a Weyl fermion, which behaves as if massless (*SN: 8/22/15, p. 11*). When the material is cooled, Weyl fermions become locked into place, forming a crystal. That results in the density of electrons varying in a regular pattern across the material, like a stationary wave of electric charge, with peaks in the wave corresponding to more electrons and dips corresponding to fewer electrons.

Applying parallel electric and magnetic fields to the crystal caused the wave to slosh back and forth. That sloshing is the mathematical equivalent of an axion, the researchers say.

To confirm that the sloshing was occurring, the team measured the electric current through the crystal. That current grew quickly as the team ramped up the electric field's strength, in a way that is a fingerprint of axion quasiparticles.

When the scientists changed the direction of the magnetic field so that it no longer aligned with the electric field, the enhanced growth of the electric current was lost, indicating that the axion quasiparticles went away. "This material behaves exactly as you would expect," Gooth says. ■

GRAPHIC BY KYLE KOSMA IN M.M. KOSMA *ET AL/ ROY. SOC. OPEN SCI.* 2019

LIFE & EVOLUTION

How some humpbacks go fishing

To snag a big mouthful of fish, some humpback whales use their flippers. Aerial footage has documented this hunting tactic, known as pectoral herding, in detail for the first time.

Madison Kosma, a whale biologist at the University of Alaska Fairbanks, and colleagues analyzed film of two humpbacks (*Megaptera novaeangliae*) off Alaska from 2016 to 2018. The footage reveals hunts beginning when a whale swims in an upward spiral and blows bubbles underwater to create a circular "net" of bubbles (left in the illustration above) that traps fish (yellow). Next, in the case of one of the whales, the animal would splash a flipper at weak parts of the net to reinforce the barrier (middle) before lunging to capture prey (right), Kosma's group reports in the Oct. 2 *Royal Society Open Science*. The other whale, after creating a bubble net, would raise its flippers — like a referee signaling a touchdown — as it ascended through the net from deeper water, helping guide fish into its mouth. — *Sofie Bates*

HUMANS & SOCIETY

Burials reveal Bronze Age inequality

In central Europe, households included both rich and poor

BY BRUCE BOWER

Families working the land in ancient Europe also cultivated social inequality. A pecking order of "haves" and "have-nots" living in the same household appeared among Bronze Age farmers by about 4,000 years ago, a study suggests.

Ancient DNA, objects in graves and chemical analyses of teeth indicate that farming households in southern Germany's Lech Valley included wealthy individuals related biologically through paternal lines; a biologically unrelated, high-status woman from outside the area; and local, unrelated folks of little means.

Foreign women probably married into male-run households that passed on wealth to descendants, say evolutionary geneticist Alissa Mittnik of Harvard Medical School and colleagues. Poor, low-status household members may have been servants, slaves or laborers, the team reports online October 10 in *Science*.

Researchers have long assumed that central Europe's Bronze Age, from about 4,200 to 2,800 years ago, witnessed rapid social change that prompted a split between wealthy, well-connected households and poor, struggling ones, says archaeologist and study coauthor Philipp Stockhammer.

"We were absolutely surprised to find that social inequality was a phenomenon within households rather than between households," says Stockhammer, of the Max Planck Institute for the Science of Human History in Jena, Germany.

Bronze Age farms foreshadowed family arrangements that started nearly 1,000 years later in ancient Greece and Rome, Stockhammer says. Households in those societies mixed a nuclear family with other biological relatives and slaves.

Mittnik's group extracted DNA from 118 skeletons buried in five Lech Valley cemeteries dating from 4,750 to 3,300 years ago. An analysis of biological relationships among 104 individuals enabled a reconstruction of six family trees, including three Early Bronze Age family trees spanning four generations.

A Bronze Age woman buried with jewelry and a headdress in Germany had grown up several hundred kilometers away, researchers say.

A specific household arrangement appeared shortly after the Bronze Age began. Of 10 pairs of parents and offspring, only male offspring were detected. All except one was an adult. Daughters apparently left home by young adulthood. Mothers had originally come from at least 350 kilometers away. Chemical elements in teeth that provide clues to where a person was born and raised denoted mothers' foreign origins.

Weapons and ornate jewelry were found in the graves of closely related family members and women who had come from afar. Graves of genetically unrelated household members, who were local, had few artifacts and those items were of limited value.

Farms were passed from generation to generation over at least 700 years. "It's difficult to say whether these inheritance rules were new or the continuation of an older system of wealth inheritance in male lines," Stockhammer says.

The Lech Valley sample is too small to reach general conclusions about social practices, says anthropologist Bettina Arnold of the University of Wisconsin–Milwaukee. But the study demonstrates an early start for powerful male lineages that used foreign contacts to find wives. That practice may have led to social systems mandating unequal treatment for men and women, she suspects. ■

BODY & BRAIN

Men with breast cancer fare worse

Male patients have lower survival rates than women

BY ESTHER LANDHUIS

When doctors and scientists come to his table at national cancer meetings, Michael Singer says he feels a bit like a caged specimen. "They look at me with that bewildered look, 'Oh, so this is what a male breast cancer patient looks like,'" says the 59-year-old from the Bronx, N.Y.

With many diseases, women receive drugs that were largely tested in men. Breast cancer has the opposite problem: Men, who make up less than 1 percent of breast cancer cases, often receive treatment based on data collected in women.

Yet breast cancer in men has been on the rise. Diagnoses in the United States have gone from 0.85 per 100,000 men in 1975 to 1.21 per 100,000 in 2016. This year, an estimated 2,670 U.S. men will develop the disease. And a new analysis published online September 19 in *JAMA Oncology* confirms what smaller studies have suggested: Men with breast cancer fare worse than women with breast cancer.

The study, the largest of its kind, analyzed registry data on 1,816,733 U.S. patients, including 16,025 men, who were diagnosed with breast cancer from 2004 to 2014. At three and five years after diagnosis, and at the end of the study period, men had lower survival rates than women. Overall, men's survival rate was 45.8 percent; women's survival rate was 60.4 percent. After adjusting for factors such as socioeconomic status, access to care and tumor characteristics, men's mortality rate was 19 percent higher than women's, says study leader and epidemiologist Xiao-Ou Shu of Vanderbilt University Medical Center in Nashville.

To Laura Esserman, a breast oncologist at the University of California, San Francisco who wasn't involved with the research, "the most striking thing is that there was a difference in treatment." Although 84.5 percent of male patients

ABK SÜD

were "hormone-receptor positive" — the tumors grew in response to estrogen or progesterone — only 57.9 percent of those men got standard endocrine therapy, drugs that stop hormones from helping breast cancer cells grow. By comparison, 75.8 percent of female patients were hormone-receptor positive; 70.2 percent of them got the hormone therapy.

Consistent with past analyses, the study also found that male breast cancer patients were older when diagnosed and more likely to have advanced disease.

Singer isn't surprised. Women are taught to do breast exams and advised to have regular mammograms, he says. "We're never trained to look for early warning signs." When Singer noticed a lump below his left nipple, months passed before he brought it up with his doctor. "I was embarrassed," he says. Weeks later, he learned it was stage 2 breast cancer, and he got a mastectomy.

Aside from delayed diagnoses potentially contributing to poorer outcomes, some experts note that the molecular pathways that produce endocrine effects differ between the sexes, and male patients could have alternative pathways driving tumor growth. So hormone therapies might not work as well in men, says Xiaoxian (Bill) Li, director of breast pathology at Emory University in Atlanta.

To expand treatment options, the U.S. Food and Drug Administration issued in August a draft guidance encouraging drug companies to include men in breast cancer studies. In April, the FDA expanded the indications for the breast cancer drug palbociclib to include men, based on electronic health records and postmarketing data related to patients' real-world experiences.

Over the last two years, the agency has approved several breast cancer drugs for both men and women even though the clinical trials had no men, because the drugs aren't expected to behave differently between the sexes, says Richard Pazdur, director of the FDA's Oncology Center of Excellence. ■

LIFE & EVOLUTION

Burrowing birds sow plant hot spots

In the desert, digging creates fertile patches for germination

BY PRIYANKA RUNWAL

In the Atacama Desert, small patches of sand surprisingly rich in plant life dot the arid landscape. Burrowing birds may be responsible.

Mounds of sandy soil shoveled out by nest-digging birds harbor more seedlings and exclusive plant varieties compared with surrounding undisturbed soils, researchers from the National University of San Marcos in Lima, Peru, report in the October *Journal of Arid Environments*. The structures may provide a sheltered and moist germination environment at the start of the growing season — unlike adjacent crusty soils carpeted with cyanobacteria, lichen, moss and algae.

"The ability of seeds to germinate in the desert is a daunting task," says Jayne Belnap, a U.S. Geological Survey ecologist based in Moab, Utah, "especially if you have a crust."

That soil crust could inhibit seed growth in two ways. Seeds stranded on top are exposed to the harsh environment and may not be able to sprout. And the crust itself can block water from reaching buried seeds.

But when burrowing birds break the crust and dig up sandy soil, seeds can mix into the soil and become buried, and water can pool between the tossed soil and crust, the researchers say.

While it was known that burrowing mammals can break compacted soils and create hot spots for plants, this study is the first to document similar ecosystem engineering by dryland birds.

In 2016, Maria Cristina Rengifo-Faiffer, an ecologist now at Northern Arizona University in Flagstaff, collected soil in the National Reserve of Lachay in Peru. Most plants there rely on winter fog to complete their life cycle.

Soil came from 61 mounds dug up by burrowing owls (*Athene cunicularia*), coastal miners (*Geositta peruviana*) and grayish miners (*G. maritima*) — as well as from adjacent undisturbed areas. Rengifo-Faiffer watered samples and allowed seeds to sprout in a greenhouse, using that as a proxy for how many viable seeds were in the soil. Bird mounds, on average, held 1,015 seeds per square meter; the same-sized crusty areas had 2,740, Rengifo-Faiffer and ecologist Cesar Arana found.

But a catalog of natural germination in the desert found that the bird-tossed soil was more fertile than the crust. On average, 213 seedlings sprouted out of bird mounds compared with 176 in adjacent crusty soils. Five plant species appeared exclusively in the bird-disturbed areas. These "microhabitats" created by burrowing birds are important to maintain plant diversity, Rengifo-Faiffer says. ■

BOTH: M.C. RENGIFO-FAIFFER

Mounds made by burrowing owls (left) and other birds in the Peruvian desert are a microhabitat for seed germination. The mounds (right) can support plants not found in surrounding crusty soils.

BODY & BRAIN

How human brains differ from chimps'

Organoids reveal slower nerve cell development in people

BY LAURA SANDERS

Brainlike blobs made from chimpanzee cells mature faster than those grown from human cells.

That finding, described in the Oct. 17 *Nature*, is one of the latest insights from studies of cerebral organoids — 3-D clumps of cells that mimic aspects of early brain growth (*SN: 3/3/18, p. 22*).

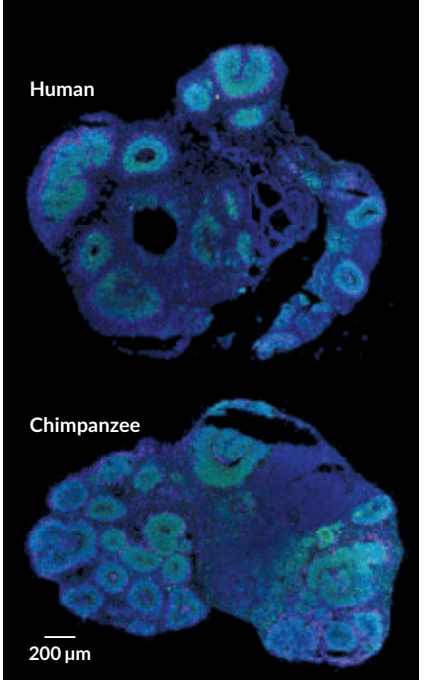
The study "draws interesting parallels, but also highlights important differences" in the way that human and chimp brains develop, says Paola Arlotta, a neurobiologist at Harvard University who was not involved in the study.

To make cerebral organoids from chimps, scientists used cells in blood left over from veterinarians' routine blood draws. In the blood were cells that can be reprogrammed into stem cells, which were then coaxed into blobs of brain cells. "From that, we get something that really looks a lot like the early brain," says study coauthor and stem cell biologist Gray Camp of the Institute of Molecular and Clinical Ophthalmology Basel in Switzerland.

There were no obvious differences in appearance between chimp and human organoids, Camp says. But a look at how genes behaved — and how that behavior changed over time — turned up a big difference in pacing. Chimp organoids grew up faster than their human counterparts.

At the same point in time, chimp nerve cells were more mature than human nerve cells, possessing a profile of gene behavior that comes with cellular age.

Aligning those timelines of growth allowed the team to find genes that behaved differently in the species, beyond simple timing differences. Other analyses revealed differences in how stretches of DNA were used. Some stretches are missing in people, but present in chimps. In chimps, those stretches appeared poised for action, perhaps ready to influence the behavior of certain genes, Camp says.



After 50 days of growth, cerebral organoids made of human cells or chimpanzee cells contain cells in different stages of maturity (green indicates cells that will form nerve cells).

Though organoids are just approximations of the real thing, studying them could reveal processes that would otherwise be hidden, such as brain development in the womb, Arlotta says. ■

BODY & BRAIN

Brain waves duel during slumber

Competing forces strengthen or weaken memories in rats

BY LAURA SANDERS

A sleeping rat may look peaceful. But inside its furry, still head, a war is raging.

Two types of brain waves battle over whether the rat will remember new information or forget it, researchers report in the Oct. 3 *Cell*. Details of this previously hidden clash may help explain how some memories get etched into the brain during sleep, while others are scrubbed away.

By distinguishing between these dueling brain waves, the new study helps reconcile some seemingly contradictory ideas, including how memories can be strengthened (*SN: 7/12/14, p. 8*) and weakened during the same stage of sleep. "It will help unite the field of sleep and learning, because everyone gets to be right," says Gina Poe, a neuroscientist at UCLA who wasn't involved in the study.

Researchers led by neuroscientist Karunesh Ganguly of the University of California, San Francisco taught rats to move a mechanical water spout with nothing but their neural activity. The team soon realized that success with these brain-computer interfaces depended heavily on sleep.

Ganguly and his team monitored the brains of sleeping rats after they practiced moving the spout. The scientists focused on brain waves that wash over the motor cortex — the part of the brain that was controlling the external water spout — during non-REM, or rapid eye movement, sleep. That period accounts for the bulk of an adult human's night.

Brain waves called slow oscillations were already suspected of helping strengthen memories. And that's what the team found. When laser light and genetic tricks stopped these slow oscillations just milliseconds after they began during sleep, a rat took longer to move the spout using its brain after waking up.

Delta waves, another type of brain wave, were three to four times as prevalent as slow oscillations. Stopping delta waves enabled rats to perform better at their task after they awoke, suggesting delta waves promote forgetting.

Still unknown is how the brain decides which memories to keep, and which to chuck. The presence of a reward — either external, like a lick of water for a rat, or internal, like the good feeling a person gets from a friendly conversation — might be key, Ganguly suspects.

The results have implications for treating people learning how to move again after strokes. Delta waves are more common than usual in these people, Ganguly says. ■

S. KANTON *ET AL*/*NATURE* 2019

Summer snow stifles arctic ecosystem

Greenland's unusual weather in 2018 led to reproductive failures

BY JONATHAN LAMBERT

When Jeroen Reneerkens stepped off the plane in Greenland, all he saw was white.

The avian ecologist at the University of Groningen in the Netherlands expected to find snowless tundra teeming with life, as he had each summer for nearly a decade. Reneerkens travels to Zackenberg Research Station in northeastern Greenland to study sanderlings — slight, mottled-brown shorebirds — as they and other migratory birds noisily descend on the open tundra to breed each summer (*SN: 11/13/18, p. 10*).

> "To see failure at so many levels of the food web is highly unusual."
>
> **WARWICK VINCENT**

But when Reneerkens arrived in June 2018, he found only snow and silence. "There were no birds singing, even the river was still frozen," Reneerkens says. "I was shocked."

Reporting in *PLOS Biology* October 15, Reneerkens and colleagues document an ecosystem-wide reproductive collapse around Zackenberg in 2018. Most animals and plants, everything from arctic foxes to tiny *Dryas* flowers, failed to reproduce that year because an extremely snowy winter left much of the ground covered with snow well into summer, the researchers found.

Climate scientists predict that, as the globe warms, parts of the Arctic will see more precipitation and more extreme seasonal fluctuations. If years like 2018 become more common, the authors warn, the consequences for arctic ecosystems could be drastic.

"To see failure at so many levels of the food web is highly unusual," says Warwick Vincent, an arctic ecologist at Laval University in Quebec City who wasn't involved in the study. "Climate change is all about extremes, and this is a compelling example of how we're moving into a world that's less and less predictable."

For more than two decades, researchers at Zackenberg have carefully tracked the rhythms of arctic life. "There's no such thing as a normal arctic summer," says study coauthor Niels Martin Schmidt, an ecologist at Aarhus University in Roskilde, Denmark. But the snow usually melts in early June. "It's like the lid gets pulled off the ecosystem, and everything starts," he says.

Plants peek out of the soil and open their flowers to the long days. Hordes of insects emerge, pollinating plants and becoming food for migratory birds. Arctic fox cubs prowl bird nests looking for eggs, and stolid musk oxen birth calves that quickly join the herd.

"It's a highly interdependent ecosystem that is resilient to variability," says Martin Schmidt, "but only to a point." The extreme snowfall in 2018, more than double what many parts of the field site usually experience, proved too much for the area's wildlife, the researchers found.

BOTH: GREENLAND ECOSYSTEM MONITORING

In 2018, snow in Greenland's Zackenberg Valley (left) lasted long into summer compared with in 2013 (right), a drier year. Both photos shown here were taken on June 10.

By late July 2018, when life on the tundra around the research station is usually in full swing, 45 percent of the landscape was still covered in snow, entombing many plants and insects. Many plants eventually did flower, but their seeds didn't have enough time to sprout before the first freeze in August, the team found. Insects eventually emerged, but mostly too late to feed migratory birds.

That meant that the sanderlings and other birds that had flown halfway around the globe from as far as Namibia in southern Africa and expected a feast arrived to slim pickings.

"Many birds must've turned back. We only saw about a quarter of what we normally see," Reneerkens says. The birds that did arrive huddled close to the field station for food scraps. "They were skeletons with some feathers," he says. "Just super, super lean."

Reneerkens found only one sanderling nest that season, which hatched "ridiculously late," on August 5, he says. Normally, the eggs would hatch in mid-July. Other birds fared just as poorly, and the few young that did hatch probably weren't healthy enough to survive the southward migration that starts in later August.

Mammals were hit hard, too. The researchers saw no arctic fox cubs, and almost no musk ox calves that season. The entire ecosystem essentially came to a reproductive halt, Martin Schmidt says. "I try not to be sentimental, but it was scary. In nearly 25 years of monitoring, we've never seen anything like this."

One bad year, even this bad, doesn't spell disaster for an arctic ecosystem. Plants and animals can reproduce again the next year, with few long-term consequences. But the summer of 2019 swung toward the opposite extreme: Record high temperatures led to a much earlier snowmelt and then drier conditions at Zackenberg. The researchers worry that, as extreme events become more common, one bad breeding year could extend to two or three. "How many years in between do we need before the system collapses for real?" Martin Schmidt asks. "That we don't know." ■

SCIENCE & SOCIETY

Nobel Prize winners announced

Research explored exoplanets, batteries and poverty

This year's Nobel science prizes, announced in October, celebrate basic discoveries of how the world works as well as practical advances that have directly impacted society.

Research that began in the 1990s on how cells sense and respond to oxygen earned Gregg Semenza of Johns Hopkins University, William Kaelin of the Dana-Farber Cancer Institute in Boston and Peter Ratcliffe of the Francis Crick Institute in London the Nobel Prize in physiology or medicine.

Semenza and Ratcliffe discovered that all cells can sense when oxygen levels drop. Semenza identified hypoxia-inducible factor, or HIF, a complex of proteins that turns on genes needed to make proteins that help cells adjust to low-oxygen states. Cells constantly make the HIF proteins, Ratcliffe found, but if there's enough oxygen, cells chew up the proteins. Work by Kaelin and Ratcliffe indicated that proteins called the VHL complex help affix a molecular "eat me" sign to HIF proteins, marking them for destruction.

Researchers are now working on therapies that might shut down HIF proteins as a way to suffocate cancer cells.

Two sets of cosmic discoveries won the physics prize. James Peebles of Princeton University was honored for developing theoretical tools to study the universe. His work helped establish that only 5 percent of the universe is the ordinary matter that makes up planets and people. The rest is dark matter (about 27 percent), which scarcely interacts with ordinary matter except through gravity, and dark energy (about 68 percent), which forces the universe to expand ever faster.

Peebles' work also explains how the universe transformed over eons from a nearly uniform slurry of matter to a cosmos filled with complex structures, like galaxies, as a result of gravity's pull.

Michel Mayor of the University of Geneva and Didier Queloz of the University of Geneva and the University of Cambridge also won, for the first discovery of an exoplanet orbiting a solar-type star (*SN: 11/25/95, p. 358*). In 1995, the pair found a planet orbiting 51 Pegasi by watching the way the planet's gravity tugged on the star. Since then, over 4,000 exoplanets have been found.

The development of lithium-ion batteries won the chemistry prize for John B. Goodenough of the University of Texas at Austin, M. Stanley Whittingham of Binghamton University in New York and Akira Yoshino of the Asahi Kasei Corporation in Tokyo and Meijo University in Nagoya, Japan. These lightweight, rechargeable batteries power everything from portable electronics to electric cars.

Lithium-ion batteries improved on standard batteries' two electrodes, the anode and the cathode. Chemical reactions in the anode release electrons that travel through a circuit and are accepted by the cathode, forming a current.

In the 1970s, Whittingham tested lithium as an anode material because it's lightweight and readily releases electrons and positively charged lithium ions. His rechargeable battery scheme used a cathode made of titanium disulfide, which contains many layers that can house lithium ions released from the anode. His battery boasted two volts.

Goodenough upgraded the cathode by using cobalt oxide, which houses more ions than titanium disulfide, and doubled lithium batteries' voltage potential. In 1985, Yoshino used a by-product of oil production called petroleum coke as an anode. Like cobalt oxide, petroleum coke is finely layered, and while not made of lithium, it can store lithium ions that can be released when the battery is used — similar to the way lithium metal releases these ions. When paired with the cathode that Goodenough designed, Yoshino's anode led to a more durable, lightweight and rechargeable battery. That design was used in the first commercial lithium-ion batteries in 1991.

The Nobel Memorial Prize in Economic Sciences honored a scientific approach to reducing poverty's effects. Abhijit Banerjee and Esther Duflo, both of MIT, and Michael Kremer of Harvard University test interventions aimed at lessening poverty's effects in education, health care and other areas.

In the 1990s, Kremer tested a range of interventions to improve learning among students in Kenya. Banerjee and Duflo, often with Kremer, then did similar studies elsewhere. One line of research developed "Teaching at the Right Level" programs, which enable teachers to target instruction to students' learning levels rather than forcing students through a standardized curriculum for each grade.

The team's studies cemented randomized controlled trials and field experiments as standard practice in development economics, the study of how emerging nations grow into more prosperous ones, says economist Tessa Bold of Stockholm University. And the work showed that the daunting question "How can we fight global poverty?" could be broken into smaller, testable questions, such as "Why do children not attend school?" and "Why do small-scale farmers not use technologies that are known to be profitable?" *— Bruce Bower, Emily Conover, Aimee Cunningham, Lisa Grossman, Jonathan Lambert, Tina Hesman Saey and Maria Temming*

2019 Nobel Laureates

PHYSIOLOGY OR MEDICINE

Gregg Semenza
Johns Hopkins University

William Kaelin
Dana-Farber Cancer Institute

Peter Ratcliffe
Francis Crick Institute

PHYSICS

James Peebles
Princeton University

Michel Mayor
University of Geneva

Didier Queloz
University of Geneva
University of Cambridge

CHEMISTRY

John B. Goodenough
University of Texas at Austin

M. Stanley Whittingham
Binghamton University

Akira Yoshino
Asahi Kasei Corporation
Meijo University

ECONOMIC SCIENCES

Abhijit Banerjee
MIT

Esther Duflo
MIT

Michael Kremer
Harvard University

GENES & CELLS

Fluffy proteins protect tardigrades

Tardigrades may partly owe their ability to survive outer space to having the molecular equivalent of cotton candy.

Tardigrades, microscopic animals, can survive just about anything, including being bombarded with X-rays or doused in hydrogen peroxide. Such radiation and chemical exposure result in production of DNA-damaging hydroxyl radicals.

Previous research indicated that a protein called Dsup, for damage suppressor, shields *Ramazzottius varieornatus* tardigrades from radiation. Now researchers know how.

Puffs of Dsup surround nucleosomes, DNA wound around proteins called histones, "like a fluffy cloud of cotton candy," says molecular biologist James Kadonaga of the University of California, San Diego. That cloud keeps hydroxyl radicals away, Kadonaga and colleagues report October 1 in *eLife*.

Kadonaga says the protein probably evolved to protect tardigrades from hydroxyl radicals when the moss dwellers get dried out, a frequent occurrence. Drying increases the concentration of hydroxyl radicals in cells. And damage can't be repaired while the animals are dormant in a desiccated state.

Humans have similar proteins, but it's not known whether they shield against DNA damage. — *Tina Hesman Saey*

LIFE & EVOLUTION

Big dinosaurs stayed cool thanks to blood vessel clusters in the head

Massive dinosaurs came in many different forms, but they all had the same problem: staying cool. Now, fossilized traces of blood vessels in dinosaur skulls reveal how the animals avoided heatstroke.

Chemical analyses of fossilized sauropod teeth previously suggested that, despite their massive size, the animals maintained body temperatures similar to those of modern mammals (*SN: 7/16/11, p. 10*). One possible explanation for this was thermoregulation, in which blood vessels radiate excess heat, often with the help of evaporative cooling in moist parts of the body, such as the nose and mouth.

Tardigrades (one shown in a false-color micrograph) can survive doses of radiation up to 1,000 times what would kill a human.

To assess how giant dinos might have used thermoregulation, paleontologists at Ohio University in Athens used CT scanning to map blood vessel networks within fossilized dinosaur skulls and skulls of modern birds and reptiles. Various dinosaurs evolved their own ways to beat the heat, the researchers report online October 16 in the *Anatomical Record*.

Heavily armored ankylosaurs had clusters of blood vessels, representing cooling regions, primarily in the nose. Long-necked sauropods had blood vessel clusters in the nostrils and mouth, suggesting the dinos panted to stay cool. Large theropods such as *Tyrannosaurus rex* had an extra air cavity connected to their jaw muscles that was also rich in blood vessels. Opening and closing the jaw would have pumped air in and out of the sinus like a bellows. — *Carolyn Gramling*

ATOM & COSMOS

Second known interstellar visitor makes first interloper seem odder

The second alien space rock seen visiting our solar system is proving just how bizarre the first known interstellar object, 'Oumuamua, really was.

'Oumuamua raised eyebrows when it appeared in 2017 looking like a rocky asteroid instead of an icy comet (*SN: 11/25/17, p. 14*). Because comets form farther from their host stars than asteroids do, it should be easier for comets to escape their star's gravity to wander the galaxy. So astronomers expect most interstellar vagabonds to be icy bodies. But 'Oumuamua didn't sport the gaseous halo or tail that forms when sunlight vaporizes a comet's ice.

New observations confirm that a second interstellar object, first spotted in August (*SN: 10/12/19 & 10/26/19, p. 14*), looks like a comet, researchers in Europe report October 14 in *Nature Astronomy*. That suggests that 'Oumuamua was an anomaly.

The new observations were made in September with the William Herschel Telescope in the Spanish Canary Islands and the Gemini North Telescope in Hawaii. Higher-resolution telescope images may tease out the exact dimensions of the alien comet — 2I/Borisov, originally dubbed C/2019 Q4 (Borisov). Inspecting the wavelengths of light emanating from 2I/Borisov could help flesh out its chemical composition. — *Maria Temming*

MATTER & ENERGY

New cooling method does the twist

A new way to chill out is simple: Just unwind. Called twistocaloric cooling, the method involves unwinding tightly twisted strands of various materials. The technique chilled water by several degrees, scientists report in the Oct. 11 *Science*.

Cooling methods like those used in refrigerators rely on cycles of compressing and expanding gases. Because those gases can contribute to global warming, scientists have been looking for methods based on manipulating solid materials. Consider a rubber band: When stretched, it heats up, becoming warm to the touch. When released, it cools down. The same goes for twisting and untwisting.

A team of scientists from China, the United States and Brazil twisted fibers of rubber, fishing line and wires made of a nickel and titanium alloy. When twisted tightly enough, the various types of strands formed coils or even supercoils — coils of coils. Unwinding a stretched, supercoiled rubber fiber cooled its surface by as much as 15.5 degrees Celsius.

Unraveling cables made of several strands twisted together produced cooling as well. But simply cooling the strands isn't particularly useful. So the researchers created a "twist fridge" that could chill water. Unwinding a three-ply, nickel-titanium cable while water flowed over it dropped the water's temperature by nearly 8 degrees. — *Emily Conover*

STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY/ALAMY STOCK PHOTO

Joy Degl (pictured) was born early and weighed just one pound, four ounces. She spent 121 days in the NICU, fighting infections, eye disease and breathing problems.

COURTESY OF J. DEGL

Predicting premature birth

How to interpret immune markers of early labor

By Amanda Keener

Every Monday, Jennifer Degl leads a group through the halls of the neonatal intensive care unit at Maria Fareri Children's Hospital in Valhalla, N.Y. The volunteers offer support to the parents of babies born early and struggling to survive.

Seven years ago, Degl, a high school science teacher in Putnam County, was one of those anxious parents. Her daughter, Joy, was born at 23 weeks gestation, weighing just over a pound. The baby spent her first four months in that NICU. Degl wasn't allowed to hold Joy or change her diaper for a month.

Although already a mom to three boys, Degl was completely unprepared for the experience.

"People call [the NICU] a roller coaster for a reason," she says. Joy would gain half an ounce and do well enough for Degl to start the 45-minute drive home to spend time with her sons, only to be called back because the baby was having trouble breathing and needed a breathing tube. "There is no smooth NICU ride," Degl says.

Like Joy, roughly 10 percent of children worldwide — an estimated 15 million babies — are born prematurely, or before 37 weeks gestation, each year. In developed countries,

surviving an early birth has become more likely, thanks to the availability of intensive medical care. More than 98 percent of U.S. preemies survive infancy, according to a study published in the *American Journal of Obstetrics and Gynecology* in 2016, though as many as 44 percent of the youngest preemies don't make it. Survival is least likely in nations with the fewest resources. Worldwide, complications associated with preterm birth are the leading cause of death in children younger than 5 years old.

But survival is just step one. Many preemies face breathing problems, infections and other complications that can cause issues well after infancy. Children born prematurely can experience developmental delays and have a higher risk of learning disorders such as attention-deficit/hyperactivity disorder. Many require physical, speech and other types of therapy well into childhood. In the United States, health issues related to prematurity collectively cost more than $26 billion a year.

Joy has needed physical therapy, feeding therapy and occupational therapy. She still receives speech therapy twice a week, and because of scar tissue in her lungs from the NICU ventilators, she wheezes when she exerts herself. A simple cold is dangerous — she's had pneumonia eight times.

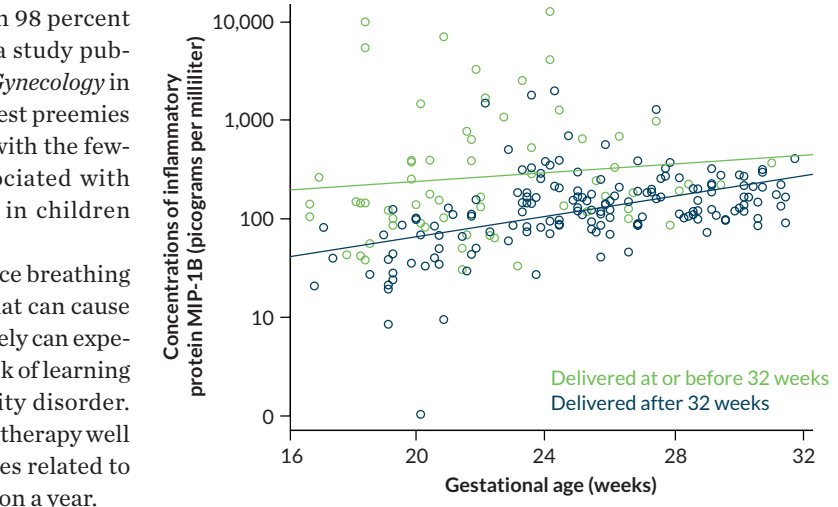
For decades, researchers and clinicians have sought ways to predict and prevent preterm birth with little progress to show for it. "It's extremely frustrating," says neonatologist Sylvain Chemtob of Centre Hospitalier Universitaire Sainte-Justine in Montreal, who has worked in the field for 35 years. The best predictor of preterm labor is whether a woman has experienced it before. Other risk factors include carrying multiples, having a short cervix and medical conditions such as diabetes or high blood pressure.

But about half of preterm deliveries involve no known risk factors at all. "There's plenty of room to improve," says Brice Gaudilliere, a physician-scientist at Stanford University.

Gaudilliere and others are looking to the human immune system for clues. "The immune system is exquisitely sensitive to all sorts of environmental changes," he says, including the mother's nutrition and stress. The immune system could be the biological common denominator for the many known and suspected factors that contribute to preterm labor.

Immune-related genes and proteins involved in inflammation have been linked to preterm birth for decades, but such links have not resulted in predictive tests or treatments. "It's one thing to say that the relationship between inflammation and preterm birth is known," says Nima Aghaeepour, a machine learning scientist at Stanford. "It's another thing to ask what are we going to do with this information."

To bridge this gap, Gaudilliere and Aghaeepour are collaborating to examine the immune system as a whole — dozens of cell types, hundreds of molecules and thousands of genes. These researchers and others are using this systems immunology approach to find ways to predict a woman's risk of premature labor based on a small sample of her blood, and then reduce that risk.



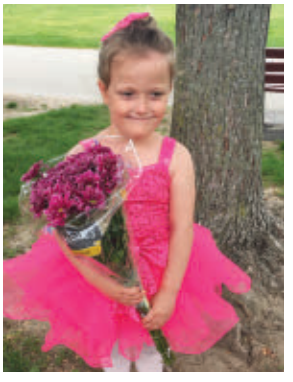
Early signs Women with a short cervix who delivered prematurely, especially at or before 32 weeks, were more likely to have higher levels of a cytokine called macrophage inflammatory protein-1 beta, or MIP-1B, in their amniotic fluid. SOURCE: A. TARCA *ET AL/AM. J. REPRO. IMMUNOL.* 2017

An inflammatory process

As soon as a woman becomes pregnant, her immune system changes. Her body releases chemicals that keep immune cells from attacking the embryo's cells as foreign invaders. Once the early ball of cells implants into the wall of the uterus, a thick layer of tissue called the decidua starts to form between mother and embryo. For the rest of the pregnancy, molecules released by the placenta and uterus, as well as anti-inflammatory immune cells such as regulatory T cells, keep the immune system at bay.

When the pregnancy reaches full term, at 37 to 40 weeks, the uterus somehow switches out of this immune suppression, says Sam Mesiano, a reproductive biologist at Case Western Reserve University in Cleveland. Immune cells flood the area and set off a chain reaction that ultimately triggers the uterus to contract. Inflammation also causes cells to release enzymes that dissolve the membranes surrounding the fetus, which break and release amniotic fluid. "All these things get switched on by this inflammatory process," Mesiano says. "That's what we want to happen." But not before 37 weeks.

Some of the signs of inflammation linked to preterm birth differ from those found during full-term birth, says Nardhy Gomez-Lopez, a reproductive immunologist at Wayne State University in Detroit. For example, in 2017, she and colleagues reported in the *American Journal of Reproductive Immunology* that some



Today, Joy Degl is an active 7-year-old despite lingering breathing difficulties.

FROM TOP: T. TIBBITTS; COURTESY OF J. DEGL

proteins involved in inflammation, called cytokines, were present at higher than normal levels in amniotic fluid from a subset of women who delivered preterm. The earlier the women delivered their babies, the higher the cytokine levels. Infections, which are present in at least a quarter of preterm births, could be the cause, but inflammation and cytokine levels were also elevated when no infection was found.

Obstetricians sometimes measure cytokine levels in amniotic fluid, but only when preterm labor has already begun and an infection is suspected. Gomez-Lopez says researchers have to back up and look for reliable immune markers that are detectable in blood and tie them to the changes seen in the amniotic fluid. "We think that by studying the systemic [immune] response in the mom, we can predict these changes way earlier," she says.

Cast a wide net

Part of the problem with developing a predictive test is that preterm labor isn't just one condition. Thirty years ago, preterm labor was viewed simply as regular labor that happened early, says perinatologist Roberto Romero at Wayne State, who directs the perinatology research branch of the Eunice Kennedy Shriver National Institute of Child Health and Human Development, or NICHD. Although scientists now recognize that the biology of preterm labor is distinct, they still have to grapple with the reality that it varies depending on the underlying cause. The cells and molecules active during preterm labor brought on by infection, for example, are different from those active in labor brought on by a drop in the hormone progesterone.

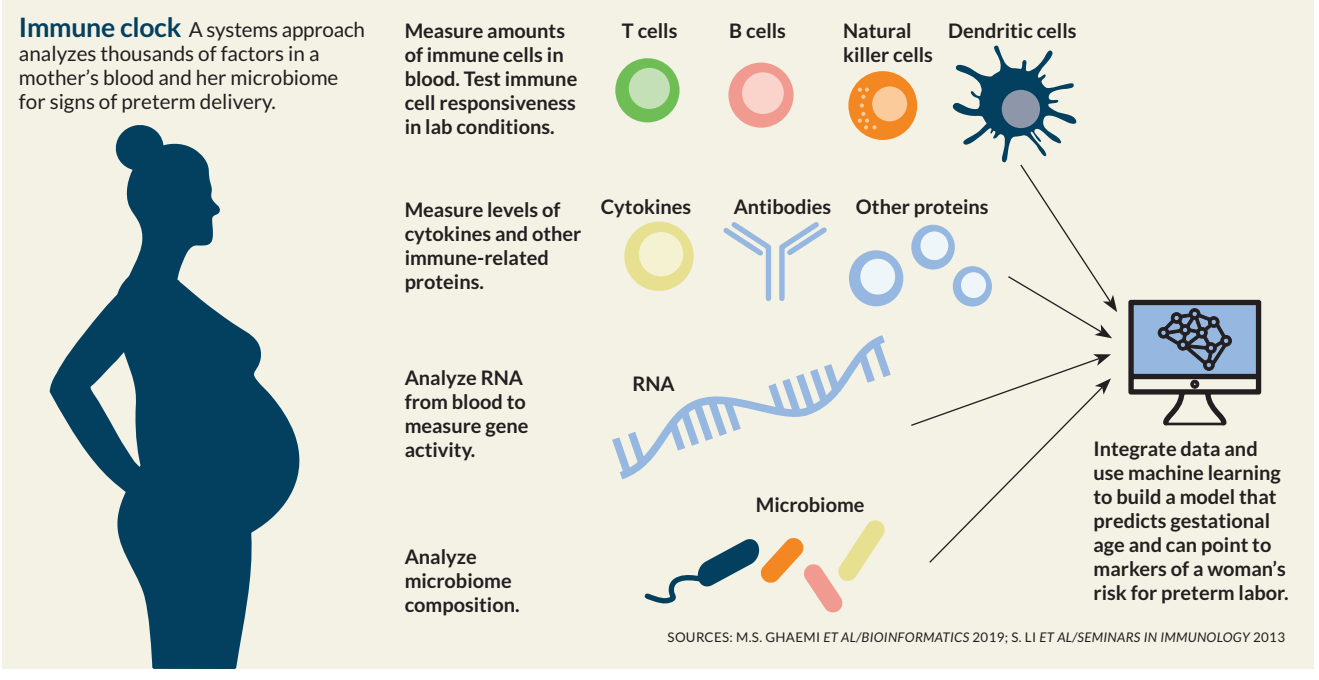
> "From a basic physiological understanding of even normal pregnancy, we're just scratching the surface, especially in the domain of immunology."
>
> BRICE GAUDILLIERE

Because not all causes of preterm labor are known, it is hard to find biological markers for each case, Romero says. A system-wide analysis can help because researchers don't have to know in advance which gene or protein to focus on, he says. By examining, for instance, all the active genes in a woman's white blood cells, or all the proteins present in a blood sample, researchers can flag differences in the immune systems of women who deliver prematurely versus those who deliver full-term.

Wayne State and NICHD recently released gene activity data from the whole blood of 150 Detroit women who delivered preterm, and encouraged researchers to use the data to find predictors of preterm labor, as part of a crowdsourcing collaboration called the DREAM challenge. The challenge is expected to be completed in January 2020.

Aghaeepour and Gaudilliere are taking the systems immunology approach a step further, beyond measuring gene activity. Their teams are also collecting data on the cells that contain those active genes, tracking fluctuations in the numbers of those cells, studying which molecules are produced, how active each cell type is and how those changes affect other immune factors. Casting a wide net is important, Gaudilliere says, because if one type of immune cell is responding to something, other types are probably also involved. "It makes little sense to focus on one or the other cell type," he says.

When Gaudilliere joined the March of Dimes Prematurity Research Center at Stanford in 2015, he quickly realized how little was known about immune cells throughout pregnancy



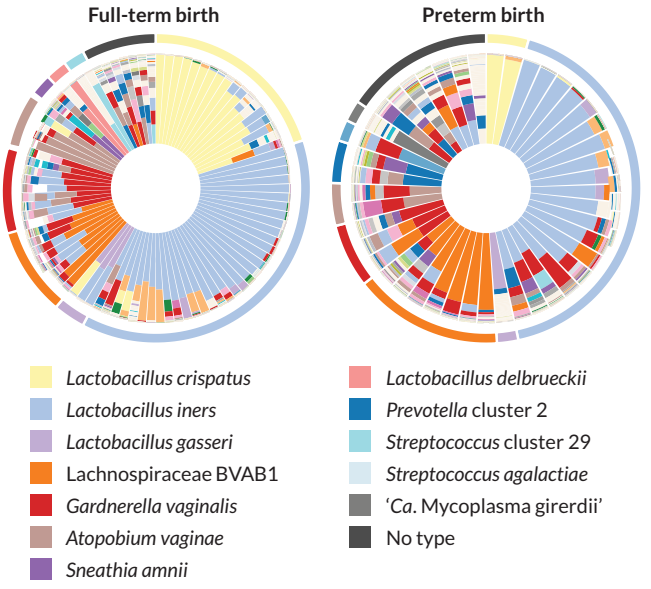
SOURCES: M.S. GHAEMI *ET AL/BIOINFORMATICS* 2019; S. LI *ET AL/SEMINARS IN IMMUNOLOGY* 2013

and labor. "From a basic physiological understanding of even normal pregnancy, we're just scratching the surface, especially in the domain of immunology," Gaudilliere says. One of the first things he and Aghaeepour, who joined in 2017, did was set up a study to establish what the immune system looks like throughout full-term pregnancy. It was part of their homework, Gaudilliere says.

The two recruited 21 women to donate three blood samples over the course of pregnancy and analyzed close to 1,000 features of the women's immune systems at each time point. Features included measurements of 24 types of immune cells, the levels of immune-related molecules present in each cell type and the cells' ability to respond to stimuli in laboratory experiments.

Putting it all together, the team developed an "immune clock" of pregnancy — a mathematical model that links the many immune parameters with how far along a pregnancy is. The model, reported in 2017 in *Science Immunology*, accurately estimated the gestational ages of a new set of 10 pregnancies. Now the team is studying whether women who go on to deliver prematurely diverge from the immune clock. With help from collaborators at the University of Chicago, the group is refining the algorithm by incorporating immune changes found in placentas collected after delivery.

Microbiome diversity was higher in women who delivered preterm



Microbe matters Among U.S. women mainly of African ancestry, those who delivered preterm had a more diverse vaginal microbiome with more microbes related to inflammation, such as Lachnospiraceae BVAB1, than women who delivered at full-term. Combined with other tests, such differences could indicate who is at risk of early delivery.

Making connections

The Stanford team has been trying to boost the clock's accuracy by adding layers of data from outside the immune system. "We established that the immune system does change throughout pregnancy and that it's very systematic," Aghaeepour says. "But we know that the immune system doesn't act in isolation."

The group recently integrated its immune measurements with several other data sources from 17 pregnant women: their gut, vaginal and oral microbiomes, blood levels of proteins and metabolism-related molecules, plus fetal genetic material released into the women's blood. A machine learning algorithm found that the data as a whole were far more accurate at predicting gestational age than any one type alone. The study, published in January in *Bioinformatics*, included thousands of measurements.

Agheeapour says the more samples they can collect to teach the algorithm, the more accurate the program will be, and the better it can point researchers to the important drivers of preterm birth risk. The plan is to pare down the test to make it usable in resource-limited settings.

The Stanford team is not alone in its attempt to combine different kinds of data for one test. Instead of looking to blood, microbiologist Jennifer Fettweis of Virginia Commonwealth University in Richmond and her colleagues are putting together huge datasets from pregnant women's vaginal microbiomes. The researchers recently tracked microbiome composition and microbe gene activity from vaginal swabs collected throughout the pregnancies of 597 women. The researchers combined that data with periodic measurements of the women's vaginal cytokine levels.

In a sample of mostly African-American women, 90 had delivered full-term and 45 had delivered preterm. The women who delivered preterm tended to have a more diverse mix of microbes than those who delivered at term, the group reported in June in *Nature Medicine*. The women who delivered early had much lower levels of *Lactobacillus crispatus* and they carried more of other types of bacteria, such as Lachnospiraceae BVAB1, that are linked to higher levels of cytokines that instigate inflammation and to vitamin D deficiency — two factors previously tied to preterm birth. The researchers suggest that microbiome changes could be a useful predictor of preterm labor risk. But because people's microbiomes vary with geography and diet, among other things, no one microbiome profile will be predictive for everyone.

In an accompanying study, Fettweis and

10 common risks for premature birth

Although more than half of preterm births occur for no known cause, here are some well-known risks

- Previous preterm birth
- Preeclampsia
- Diabetes
- Chronic hypertension
- African-American ethnicity
- Short cervix
- Mother under 20 years old
- Mother over 40 years old
- Carrying multiples
- Smoking

SOURCES: J.P. VOGEL *ET AL/BEST PRACTICES & RES: CLIN. OBSTETRICS & GYNAECOLOGY* 2018; D.M. FERRERO *ET AL/PLOS ONE* 2016

J. FETTWEIS *ET AL/NATURE MEDICINE* 2019

colleagues reported finding differences in microbiome diversity among African-American, Hispanic and white women who delivered full-term babies. The researchers don't yet know why these differences exist, but they hope that the microbiome will hold clues about why African-American women are 1.5 times as likely to give birth prematurely and twice as likely to have very preterm infants (born before 34 weeks) as white women in the United States.

Many researchers think the microbiome differences are related to environmental factors, such as stress and nutrition. A group at Emory University in Atlanta is collecting environmental, microbiome and immune data from more than 500 pregnant African-American women to get some answers.

Drive for more data

As part of the Multi-Omic Microbiome Study-Pregnancy Initiative, Fettweis and others are analyzing microbiome samples from volunteers' mouths, skin, vaginas and rectums, as well as blood and urine samples and health data. Fettweis would also like to explore how microbiome changes associated with preterm birth fit with other types of data. It may be that some links between the activity of certain genes or cells and preterm birth depend on the state of a mother's microbiome, she suggests.

"We need to start thinking about these things together," she says. "We need harmonization in the field."

For data scientist Marina Sirota of the University of California, San Francisco, harmonizing data is a full-time occupation. She mines health data in search of relationships between risk factors and biological markers connected to preterm birth. In a meta-analysis of three studies, Sirota and collaborators found 210 genes with activity in white blood cells that differed in women who delivered preterm. Most of the affected genes were involved in immune responses, the researchers reported in 2018 in *Frontiers in Immunology*.

In a separate study, published in 2018 in *Environment International*, Sirota and colleagues matched California birth records with state data on environmental pollutants. Premature labor was more common among women living in areas with high levels of two drinking water contaminants, arsenic and nitrate. Sirota says many of the genes known to be affected by arsenic exposure are the same genes that she and colleagues found to be affected in their meta-analysis.

Work like Sirota's might eventually point to treatment options to reduce the risk of preterm birth related to environmental exposures. After all, Gaudilliere says, the end goal is to do more than find new risk factors; the aim is to come up with therapies that target the different causes of preterm labor.

In Montreal, Chemtob has been working on a way to block the cytokine interleukin-1, which has been linked to preterm labor. On February 13 in *Frontiers in Chemistry*, he and colleagues described an IL-1 inhibitor that prevents inflammation-induced preterm birth in mice without hindering the cytokine's normal anti-infection activities. The next step, Chemtob says, is lab studies testing women's white blood cells to find the population of women who will most likely benefit.

He's working with Gaudilliere's group to develop a lab test that can identify women whose white blood cells change their activity when exposed to the inhibitor. The researchers plan to pair the results of the blood test with the other measurements to ultimately design a test that predicts preterm birth risk and potential drug response at the same time. "That makes for ideal personalized medicine," Chemtob says.

"We are at the beginning of an exciting period," says Romero at Wayne State. The field is now equipped to start studying preterm birth as a collection of several different syndromes and seek out treatments to address each one, he says.

This shift could not come soon enough. For the youngest infants, even one extra day in the womb can make a huge difference for their health.

After spending the last seven years speaking to and advocating for parents of preemies, and dealing with her daughter's lingering health problems, Degl can attest that new ways to prevent prematurity are needed. If there was anything she could have done to extend her own pregnancy, she says, she would have done it without hesitation. "I think every mom would say that." ■

Current approaches to avoid preterm labor

Few strategies exist to prevent an early delivery, and they help only a small percentage of women.

Strategy	Possible risk reduction
Progesterone given as an injection, oral medication or vaginal cream	Up to 45% in women with history of preterm birth or short cervix
Surgery to sew the cervix closed	20%
Prevent smoking in pregnancy	20%
Dedicated preterm birth prevention clinics that offer patient education, extra prenatal visits and expertise in preterm labor	13%

SOURCE: J.P. NEWNHAM *ET AL/FRONTIERS IN IMMUNOLOGY* 2014

Explore more

■ Nima Aghaeepour *et al*. "An immune clock of human pregnancy." *Science Immunology*. September 1, 2017.

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Tree Sleuths

Scientists hope to use wood forensics to slow timber trafficking

By Edward Carver and Sandy Ong

Jian Zhong Wang's home in the southern Chinese city of Nanning is an inviting place. Light spills in through large bay windows, which offer a stunning view of the garden of thick-stemmed banana plants and chest-high cacti. The room is packed with intricately carved furniture: a dining table flanked by eight straight-backed chairs, a coffee table and a settee, plus four armchairs, a desk, a divan and a TV stand. Each piece is made of rosewood.

"Rosewood furniture is part of our great national culture with over 5,000 years of history," says Wang, a 60-year-old retired government official who began collecting rosewood more than two decades ago. He's not alone.

The furniture is a major status symbol in China, by far the largest importer of rosewood. A canopy bed can fetch as much as $1 million, and an estimated 30,000 companies in China are involved in the rosewood industry, which generated a domestic revenue of over $22 billion in 2014.

Demand for the beautiful, dark pieces comes at a price. Rosewood is the most trafficked wildlife product in the world based on market value — more than elephant ivory, rhino horns and pangolin scales combined. More than one-third of illegally traded plants and animals seized between 2005 and 2014 were rosewood, according to the World Wildlife Seizures database.

Rosewood is a broad term, referring to the darkest, mostly uniformly colored hardwoods that

In Madagascar's Masoala National Park, a man chops down a rosewood tree, exposing its dark red core. The trees are being removed in great numbers, from here and other tropical forests, for production of high-end furniture sold mainly in China.

TOBY SMITH/CONTRIBUTOR/GETTY

come from several genera, including *Dalbergia*, *Pterocarpus* and *Millettia*. The trees are found primarily in Southeast Asia, Africa and Latin America, all areas experiencing forest loss because of logging and trafficking of the wood.

Because many species are involved and not all are protected by regulation from overharvesting, identifying trafficked wood is a challenge. Scientists are trying to help by applying techniques — including microscopy and chemical and genetic analyses — that might allow easier identification of wood. The genetic approach, called DNA barcoding, is being tested for other endangered species as well, including sharks, elephants and parrots.

Learning the species and origin of rosewood logs that have been felled will not save the forests. But the hope is that better identification will allow easier prosecution of traffickers, discouraging them from taking down more trees.

Roots of an industry

Rosewood trees, many of which take centuries to grow to full maturity, are important within their ecosystems. In Madagascar, home to some of the world's most valuable *Dalbergia* species, the trees are crucial forest habitats for lemurs. One litter of red variegated lemurs (*Varecia rubra*) was seen nesting in about 40 large, mature trees in Masoala National Park, according to research published in September 2018 in the *American Journal of Primatology*. As those trees disappear, local extinctions become a risk. In the arid landscapes of mainland Africa, certain rosewood species, such as *Pterocarpus erinaceus*, can help protect against fires. The trees also pull nitrogen from the air and improve soil fertility for nearby plants.

Regulatory efforts to protect the world's rosewood trees have increased, at least on paper. Since 2017, all of the world's *Dalbergia* species — more than 300 — as well as some other rosewoods have come under the Convention on International Trade in Endangered Species, or CITES, an international agreement that protects endangered animals and plants by restricting their trade across borders. Before that, only seven rosewood species were protected by CITES. At the CITES meeting in August, *P. tinctorius*, an African rosewood that has been harvested heavily in recent years, was added to the list.

Most rosewood species are classified under CITES Appendix II, which means that trade is allowed but tightly controlled. Before issuing export permits, the exporting countries must assess if a tree species has been sustainably and legally harvested. To determine whether harvesting is sustainable, CITES' scientific authority in a given country assesses a species's population, patterns of harvest and geographic range.

Pterocarpus logs from Africa sit at China's Zhangjiagang port awaiting transport to wood warehouses or furniture factories.

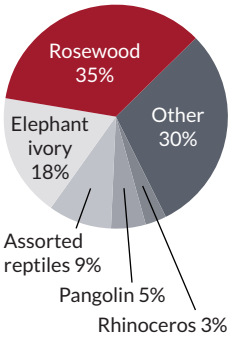
CITES has only a limited ability to pressure countries to follow the regulations. "There's not much the [CITES] secretariat can do besides giving [countries] a slap on the wrist," says Naomi Basik Treanor, who manages the forest policy, trade and finance initiative at Forest Trends, a Washington, D.C.–based nonprofit.

Even though trade restrictions have expanded in recent years, plenty of rosewood still makes its way out of source countries. Law enforcement officials continue to seize huge rosewood shipments at ports across the world. From 2017 to mid-2018, close to 200 tons of logs, worth an estimated $50 million, were seized in Hong Kong alone.

But prosecution is difficult even in the most flagrant cases. In 2014, Singapore authorities seized nearly 30,000 rosewood logs en route to Hong Kong. The logs, which were restricted under CITES, originated in Madagascar. It was one of the largest wildlife seizures in history. Yet in April this year, Singapore's high court acquitted the trader and ordered the wood returned to him.

Because rosewood enters China via long and complex trade routes, enforcement is tricky. Along the way, traders can easily falsify the origin of their logs, or hide illegally harvested logs among legal species. Customs officials in China check the paper work that accompanies incoming timber but don't have the political support or the tools to challenge potentially false claims. And the

Wildlife product seizures, 2005–2014



High value Out of nearly 165,000 wildlife products seized from 120 countries between 2005 and 2014, rosewood was the largest group based on market value.
SOURCE: WORLD WILDLIFE SEIZURES DATABASE

FROM TOP: S. ONG; C. CHANG

country has no laws requiring wood and furniture companies to check their timber supply chains.

In contrast, the United States, Australia, Japan and the European Union in recent years passed legislation requiring companies to ensure that timber entering their supply chains is legally harvested. Enforcement of such laws remains limited, partly because identifying the type and origin of wood is not easy.

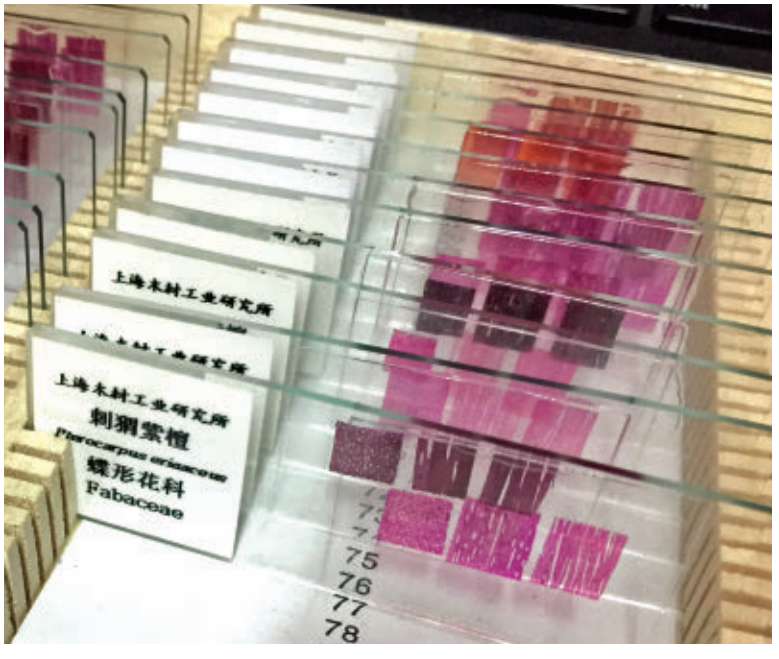
The United States, for example, has one of the strictest laws prohibiting imports of illegally harvested timber. Yet results of a survey and wood product analysis published July 25 in *PLOS ONE* show that more than 60 percent of tested wood specimens from major retailers had been wrongly identified. That's a sign that much of the wood may have been illegally logged and mislabeled at some point in the supply chain.

Ideally, policing tropical forests would stop the tree cutting way before any rosewood logs reach foreign markets. But trafficking networks are agile. When a timber supply dwindles or law enforcement gets serious in one locale, the traffickers move to another source, usually in another low-income country. With rosewood in Southeast Asia largely depleted, West Africa now produces an estimated 70 percent or more of the rosewood going into China, Basik Treanor says.

Certain countries, especially in West Africa, find ways to skirt the CITES regulations. Right now, Sierra Leone, Ghana and Mali are among the largest exporters of rosewood in the world, says Susanne Breitkopf, deputy director of forest campaigns for the Environmental Investigation Agency, a Washington, D.C.–based nonprofit. But that might not be true for long.

"It changes year to year, and even month to month. Rosewood trade is like a virus that keeps spreading, affecting those with the weakest immune system," she says. "If one patient is successfully treated, it immediately jumps on the next, where it can expand with the least resistance."

And the Chinese traders tend to tap into larger criminal networks that capitalize on corruption and other forms of instability, Basik Treanor says. "The criminal networks don't care what they're trafficking in. It could be humans or drugs or weapons or rosewood."



Stained samples of rosewood, sandalwood and other types of wood at the Shanghai Wood Industry Research Institute are used as references when scientists examine the anatomy of a wood sample under a microscope to identify the tree's genus.

S. ONG

Wood forensics

Forensic techniques have long been used to help identify criminals and ensure the safety of food. Now the tools are being adapted for use in tree sleuthing, with some victories for conservationists.

A U.S. case involving Lumber Liquidators is a model for how governments can use forensics to fight timber trafficking. The Virginia-based hardwood-flooring company was fined more than $13 million in 2016 for importing illegal wood. The penalty was the largest to date for a timber-related violation of the Lacey Act, the U.S. law that bans illegally sourced wood products from entering the country. The company pleaded guilty to importing illegal Mongolian oak (*Quercus mongolica*) harvested from forests in eastern Russia. Those forests are protected habitat for the world's last remaining Siberian tigers.

The timber originally had been labeled as Welsh oak from Europe, which is legal to import. Proving the wood's real origins was difficult. U.S. prosecutors turned to Agroisolab, a German-British firm that specializes in stable isotope ratio analysis. The method measures the ratio of different forms, or isotopes, of carbon, hydrogen, oxygen, nitrogen and sometimes sulfur present in a wood sample. Trees absorb and retain varying levels of these elements depending on soil, rainfall and other environmental factors.

To analyze a sample, scientists take a cubic centimeter of wood and grind it into a fine powder and then turn it into a gas for analysis in an isotope ratio mass spectrometer. Separation of the components based on their electric charges and masses indicates the ratio of isotopes present, and therefore which geographic region the wood came from. But as with DNA analysis, there's got to be a robust database of tree samples

Mixed bag Because each approach to identifying trees has drawbacks, people trying to stop trafficking of rosewood logs often cobble together several methods to learn a shipment's species and where it came from.

	Microscopy	DNA barcoding	Stable isotope analysis	Near-infrared spectroscopy
How does it work?	A thin slice of wood is viewed under a microscope to study cell structure and vessel patterns	Analyzes a portion of a tree's DNA	Measures the ratio of isotopes of certain elements (e.g., carbon, nitrogen, oxygen) in a tree, which differs based on soil, rainfall, altitude and distance from coast	Wood is illuminated with near-infrared light; chemical bonds in the sample absorb or reflect the light to create distinctive spectra
Pros	Low cost A good reference database exists for rosewood Portable devices can be used for on-site analysis	Identifies wood at the species level Only slightly more expensive than traditional wood anatomy identification	Can be used on almost all forms of wood, including those that are highly processed or degraded, such as sawn timber or plywood	Rapid Nondestructive; no special sample preparation is needed Portable devices can be used for on-site analysis
Cons	Identifies wood at the genus level	Performance is poor on old, cut wood or highly degraded wood products, such as plywood No comprehensive reference database exists	Cannot distinguish between different tree species that grow in the same area, since environmental factors are the same More expensive than DNA barcoding No comprehensive reference database exists	Data analysis requires sophisticated statistics No comprehensive reference database exists

ICONS: C. CHANG

to compare the results against.

"Let's say I commit a crime and my fingerprints are all over the place," says Pete Lowry, a Paris-based botanist with the Missouri Botanical Garden, a research facility with international reach. Lowry studies some of the world's most valuable rosewoods, including those from Madagascar. "Unless my fingerprint is in a library someplace, no one is going to know it's me."

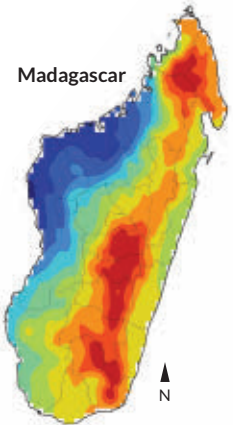
So Lowry and others are taking "fingerprints" of the world's trees. The Lumber Liquidators case was an early success story. When Agroisolab didn't have enough reference material to determine where the company's oak flooring was from, conservation groups fanned out and collected tree samples from 50 sites in Siberia for comparison's sake. The forensic evidence helped seal Lumber Liquidators' fate.

To build the reference databases needed to fight tree crimes, the U.S. government, mainly via the Forest Service, in the last four years has invested hundreds of thousands of dollars in WorldForestID. The network of government bodies, labs and nongovernmental organizations, or NGOs, is creating a library of location-specific wood samples. Researchers from the Forest Stewardship Council, based in Bonn, Germany, are collecting leaf and wood samples from around the world and sending them to London's Kew Gardens, home of the project's main library.

Anatomy lesson

Research happening in Zurich and Madagascar is more specific to rosewood. Some of the work is dedicated to low-cost, traditional wood anatomy studies using microscopy. A seasoned professional usually can tell a wood's genus from its cell structure and vessel pattern, but there are few such experts. Great Britain, for example, has only one.

With microscopy, species-level identification is hard to pull off. Yet good forest policy requires such specificity. Outright bans on logging of entire genera, such as *Dalbergia*, are unlikely to be approved. So conservationists need to know what can and can't be chopped down. Better



Map the trees
This map shows a stable isotope analysis profile of Madagascar, created using five *Dalbergia* species. It reveals the relative abundance of deuterium, a stable heavy isotope of hydrogen, and protium, the most common hydrogen isotope. Red shows higher levels of deuterium versus protium; blue shows higher protium to deuterium. Tree samples can be tested and compared to this reference map to learn where the sample probably came from.

identification techniques could help determine which species, if any, can be sustainably harvested.

"It's surprising, given the value of the woods, that our understanding of them is very poor," says Alex Widmer, a plant ecological geneticist at ETH Zurich who studies Madagascar *Dalbergia*. He presented data in July 2018 in Geneva at a CITES meeting showing that at least 12 known *Dalbergia* species are each, in fact, more than one species. He used DNA barcoding, which identifies a species based on a short strand of mitochondrial DNA.

Tendro Radanielina is a plant geneticist who has been doing DNA barcoding on rosewood at the University of Antananarivo in Madagascar since 2018. The technology is spreading to the low-income countries that are taking the brunt of the tree loss. The challenge is that the technique requires excellent samples. DNA is easiest to obtain from fresh leaves, or from a tree's bark or outer sapwood. But the wood doesn't always come that way.

Many logs sit in stockpiles for years waiting to be exported, or in warehouses waiting to be used. If the wood is already sawed into planks or made into a finished product, the DNA is even more degraded and harder to analyze, says Darren Thomas, CEO of Singapore-based Double Helix Tracking Technologies, a timber verification company.

Because each method has limitations, and no one method can perfectly identify a piece of wood, scientists cobble together a combination of techniques. Radanielina's university colleague, Tahiana Ramananantoandro, runs a near-infrared spectroscopy lab that is just beginning to conduct rosewood research. A forestry engineer, she's worked with scientists in Brazil who are developing a portable device that uses the method to distinguish wood species that look similar under a microscope. In Brazil, the scientists' concern is bigleaf mahogany (*Swietenia macrophylla*), which is also protected under CITES but is easily confused with the more plentiful crabwoods and cedars.

Near-infrared spectroscopy involves illuminating a thin wood sample with near-infrared light. Chemical bonds within the sample dictate how much light is reflected or absorbed. The result is a characteristic light spectrum, which Ramananantoandro and other researchers can use to help identify the wood.

Harisoa Ravaomanalina runs the wood anatomy lab at the University of Antananarivo in Madagascar. She sometimes tests finished products, such as this ebony statuette. Behind her is a shelf full of samples from rosewood and ebony trees.

Shifting demand

For now, a world in which all customs officials have easy access to even one wood identification tool is a distant dream. Less than 1 percent of timber traded around the world is subjected to forensic testing, says forest ecologist Pieter Zuidema of Wageningen University and Research in the Netherlands. Zuidema leads Timtrace, which provides commercial timber tracking services using both genetic and chemical tracing methods.

"One of the barriers is clearly in the development of those techniques and the quality they can deliver," he says. "Another one is limited knowledge and awareness ... and little capacity at customs and authorities to implement them."

While forensic science offers a glimmer of hope in the fight against deforestation, the fate of rosewood will depend largely on how well the trade is controlled in China. It will take a cultural and political shift to convince people like Jian Zhong Wang to see these trees as more than beautiful furniture worth collecting. ■

Explore more

- Alex C. Wiedenhoeft *et al.* "Fraud and misrepresentation in retail forest products exceeds U.S. forensic wood science capacity." *PLOS ONE*. July 25, 2019.
- United Nations Office on Drugs and Crime. "World Wildlife Crime Report: Trafficking in protected species." 2016.

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FROM TOP: AGROISOLAB 2019; SAFIDY ANDRIANANTENAINA

MEL Science

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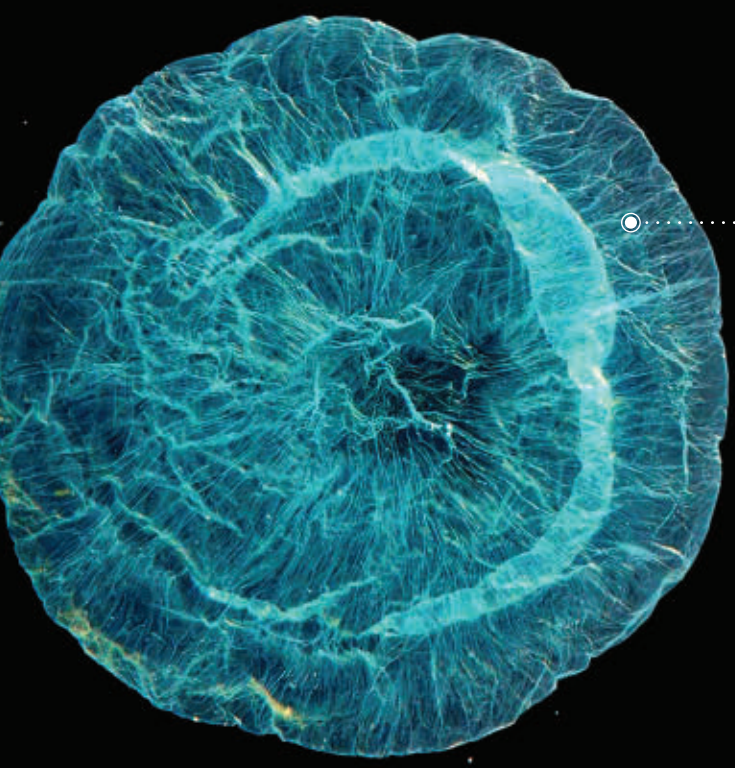
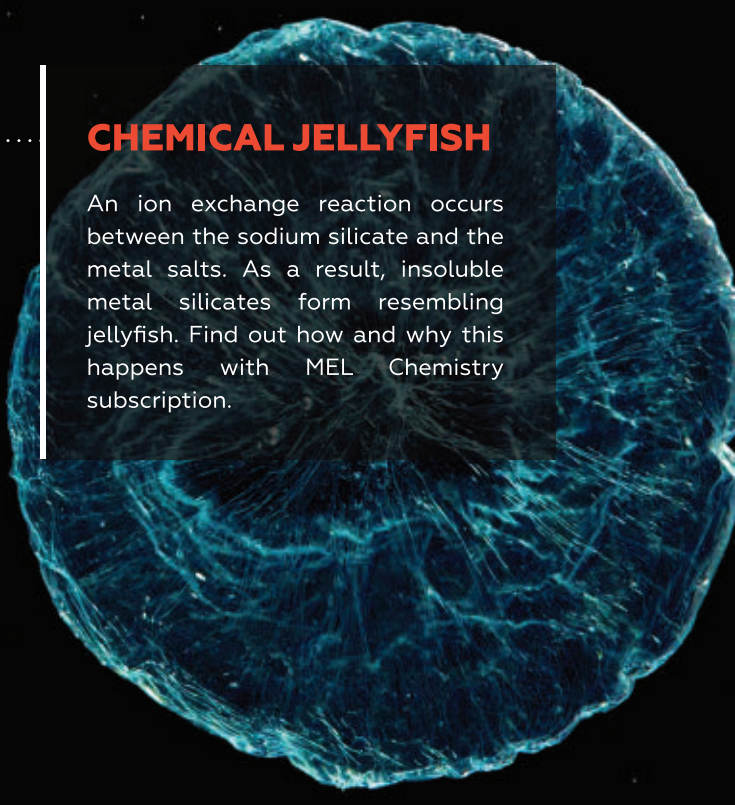
VR-POWERED NEXT GENERATION CHEMISTRY SET





CHEMICAL JELLYFISH

An ion exchange reaction occurs between the sodium silicate and the metal salts. As a result, insoluble metal silicates form resembling jellyfish. Find out how and why this happens with MEL Chemistry subscription.

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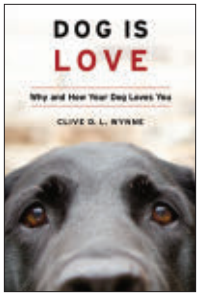
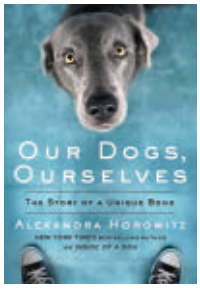


Dog Is Love
Clive D.L. Wynne
HOUGHTON MIFFLIN HARCOURT, $28



Our Dogs, Ourselves
Alexandra Horowitz
SCRIBNER, $28

BOOKSHELF

New books offer different takes on our bond with dogs

My 65-pound black mutt is feeling playful. She rams her head into the couch cushions and launches her butt into the air, snuffling and growling excitedly. She achieves a partial headstand and her hind legs kick wildly. She is the embodiment of joy, and that joy is infectious.

Dogs have been jubilantly kicking their legs in the air for at least 14,000 years, and during that time, they became our devoted companions. Two new books offer different takes on this interspecies bond. The first makes a compelling case that dogs do far more than just obey us — they love us. The other book offers a broader look at all the complexities and contradictions of the human-dog relationship.

Clive Wynne, a canine behaviorist and founding director of the Canine Science Collaboratory at Arizona State University in Tempe, has always loved dogs, but it took him many years to become convinced that the feeling is reciprocated. In *Dog Is Love*, readers accompany Wynne on his scientific journey from skeptic to believer. Not only do dogs love us, he argues, but it is their capacity and desire to connect with humans that makes dogs unique.

Many scientists are loath to talk about the emotional lives of animals, love in particular (*SN: 3/2/19, p. 28*). The concept "seems too soppy and imprecise," Wynne writes, and we risk anthropomorphizing dogs. But acknowledging their capacity for love is the only way to make sense of why dogs are so devoted to us and thrive in our company, he argues. *Dog Is Love* takes readers all the way from theories about how dogs became domesticated to recent behavioral and genetics research that provides convincing evidence that our canine companions feel affection. Dogs' genetic makeups predispose them to be loving (*SN: 8/19/17, p. 8*), Wynne argues, and early exposure to humans (or even other animals) solidifies the connection.

Not only do dogs love us, but it is their capacity and desire to connect with humans that makes dogs unique.

Our Dogs, Ourselves offers a more comprehensive exploration of the human-dog relationship. Alexandra Horowitz, a cognitive scientist who heads the Dog Cognition Lab at Barnard College in New York City and wrote the 2009 *New York Times* bestseller *Inside of a Dog*, gives an overview of the culture of dogdom — the way people acquire, name, train, raise, treat, talk to and see dogs. She explores the lighter side of this culture, including our fixation with dog accessories — everything from dog bathrobes and canine body sprays to fake testicles.

But Horowitz also tackles the darker side and poses some thought-provoking ethical questions: Should we view dogs as property? Is spaying and neutering dogs the right way to deal with overpopulation? Should dogs be used in scientific research?

Both books address a particularly thorny problem: dog breeding. Initially, dogs were bred for specific purposes — hunting or providing comfort, for example. But in the late 1800s, the emphasis became purity, Horowitz writes. Today, purebred dogs are descended from a relatively small pool of founders and inbreeding is rampant. A purebred's family tree might reveal that "his father is also his grandfather and his mother's uncle to boot," Wynne writes. Because the gene pool for each breed is closed, genetic defects crop up. Dalmatians are predisposed to deafness and a urinary tract disorder. German shepherds are prone to hip problems.

Some of the defining physical characteristics of certain breeds can also present serious health challenges. Bulldogs have such enormous heads that puppies must typically be delivered via cesarean section. Pugs and other flat-faced dogs often have trouble breathing. Breed standards, which describe how a breed should look, "glorify disease and deformity," Horowitz writes. The puzzling thing isn't that these animals are diseased, she adds, "it's that it is *we* who made them sick."

Horowitz and Wynne agree that we can do better for dogs. That might mean changing laws that govern dog ownership and how we treat dogs, rethinking our devotion to purebreds and finding better ways to control overpopulation and deal with strays. Wynne argues that no-kill shelters often become "canine warehouses," housing dogs that have no hope of being adopted. He proposes some modest changes that might improve the lives of shelter dogs and adoption rates.

We also must help our dogs lead richer, more satisfying lives, Wynne and Horowitz argue. Dogs are suited to be companions, but many spend the majority of their lives alone, awaiting the return of their humans. "The cruelest thing you can do to a highly social being is shut him up all day where he cannot interact with anyone," Wynne writes. Yet that has become the norm in many places.

If you want a deep dive into the research that suggests dogs are capable of love, how this capability came to be and what dog owners can do to foster it, grab *Dog Is Love*. For a wide-ranging exploration of the human-dog relationship, including its perils and pitfalls, pick up *Our Dogs, Ourselves*. Both books will make you see dogs in new ways. And both are best enjoyed with a dog's head in your lap. — *Cassandra Willyard*

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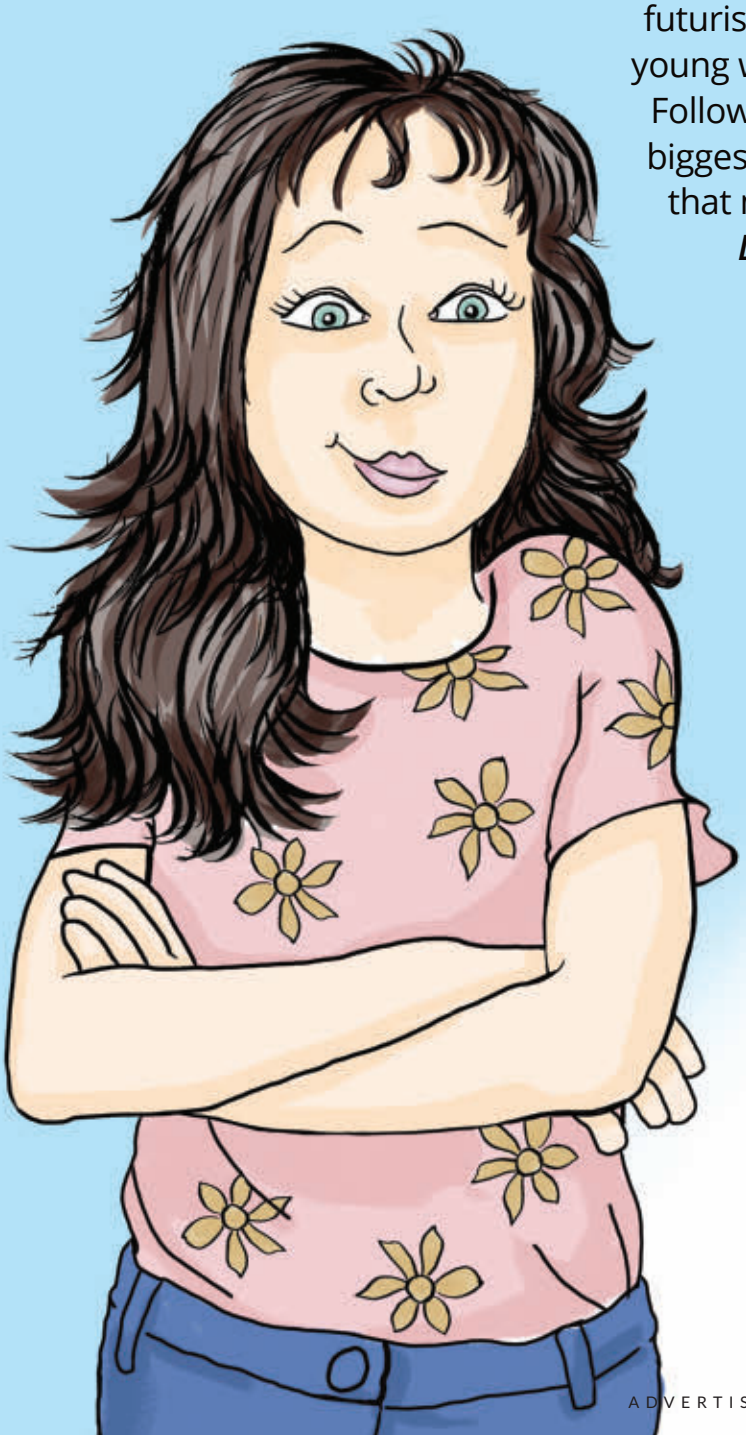

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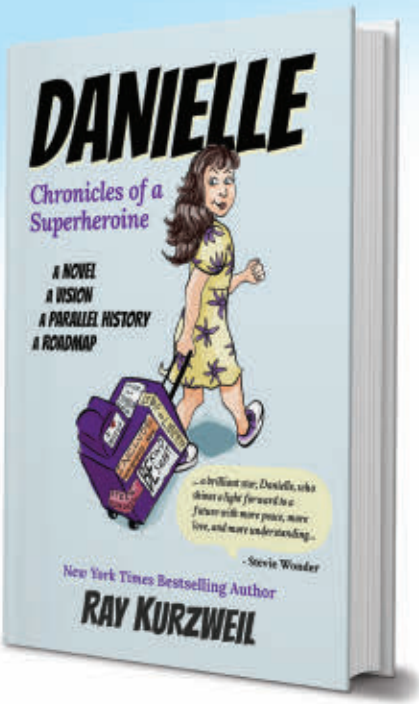

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SEPTEMBER 14, 2019

SOCIAL MEDIA

Don't rock the boat

A structure designed to redirect waves around an object in a fluid might some day help prevent cargo ships from rocking too wildly in harbors, **Emily Conover** reported in "Invisibility cloaks take to the water" (*SN: 9/14/19, p. 12*). On Facebook, reader **Nour Kassar** noted another potential benefit: "Bye–bye motion sickness."

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Vaccine varieties

Polio is close to being eradicated worldwide, but the virus still circulates in Afghanistan and Pakistan, ***Tina Hesman Saey*** *reported* (SN: 9/14/19, p. 4) *in an update to a 1969 story, "Polio could come back"* (SN: 9/13/69, p. 206).

In African countries, one source of polio cases are vaccines made with viral strains that rarely can become disease-causing, **Saey** reported. Reader **Mike Bushroe** wondered why those vaccines are used.

"It's a complicated issue," says **Oliver Rosenbauer**, spokesman for the Global Polio Eradication Initiative in Geneva. There are two types of polio vaccines — oral vaccines and the inactivated vaccine, which is given as a shot.

Oral vaccines contain weakened viral strains and offer two benefits: They can spark a person's immune system to make a memory of the virus without the person getting sick, and the weakened strains can spread to people close by, passively immunizing them, **Rosenbauer** says. Oral vaccines are safe, effective, provide long-lasting protection and are inexpensive and easy to give, he says. But in the rare instance when too few people in a community are vaccinated, weakened strains circulating in the population can, over the course of about a year, pick up genetic changes to become disease-causing.

The other polio vaccine is made with inactivated viral strains and cannot cause polio. But this vaccine protects only people who get the shots; it doesn't offer passive immunity to others close by. "In areas where polio is circulating, you need the oral vaccine to stop it," **Rosenbauer** says.

Countries that have eradicated polio, including the United States, used oral vaccines to stop widespread transmission, then switched to the inactivated vaccine. The World Health Organization recommends this strategy for countries that are still fighting the disease.

Unwrapped

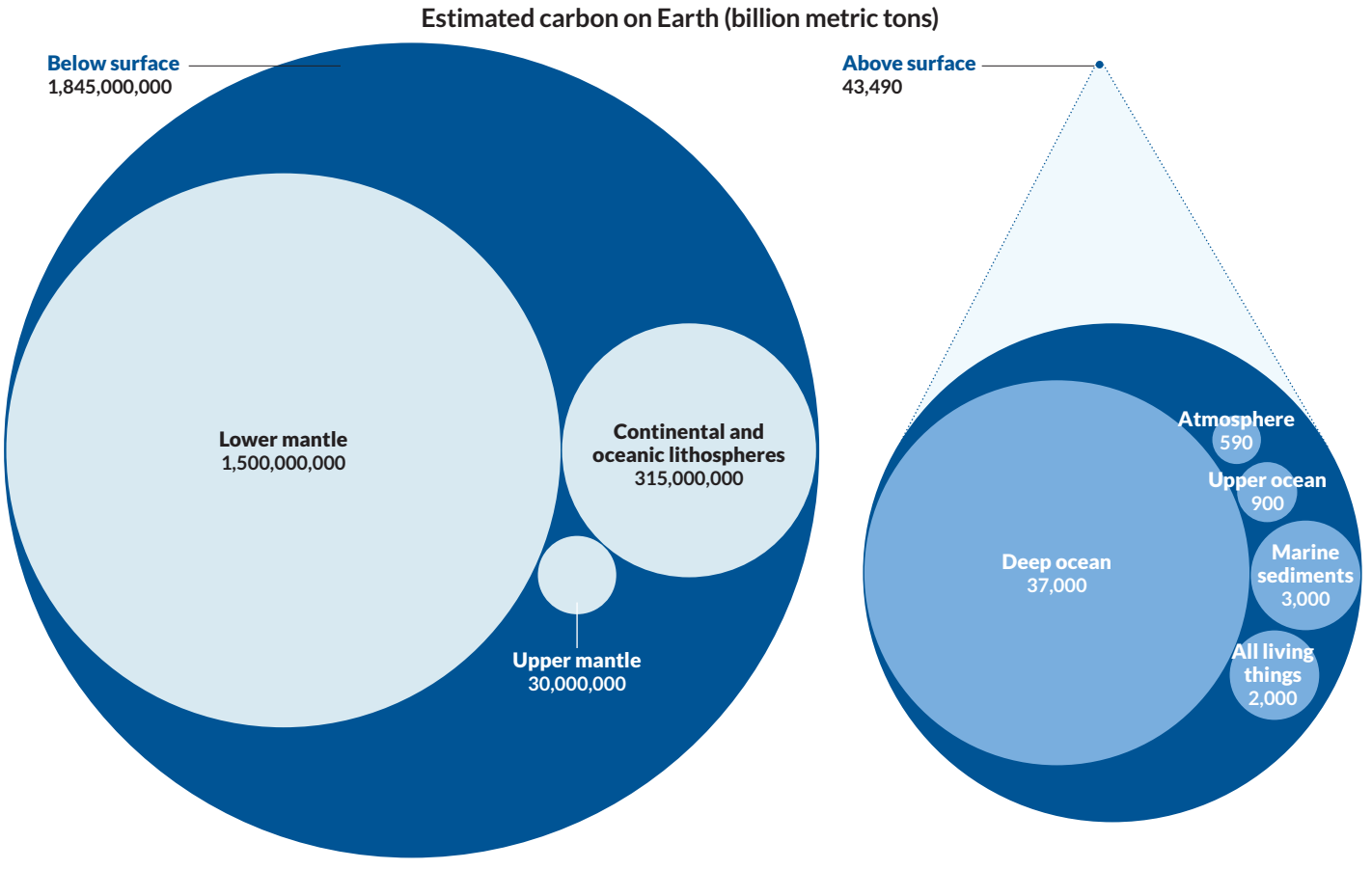
The Sept. 14, 2019 issue arrived in mailboxes wrapped in plastic.

Subscribers complained about the delivery. "Plastic? Really? With everything that is known about plastic pollution and its impacts, much of it reported in *Science News*, I was astonished to see my issue arrive packaged in this way!" reader **Lynn Lozier** wrote.

We delivered the issue in a plastic wrapper to accommodate a special offer from one of our advertisers, says **Kathlene Collins**, chief marketing officer for Society for Science & the Public, which publishes *Science News*. "We will not be wrapping any future issues for subscribers in plastic," she says. "Thanks to our readers for the candid feedback."

Correction

The credit for a photo of a Western meadowlark shown in "North America has lost billions of birds" (*SN: 10/12/19 & 10/26/19, p. 7*) misspelled the photographer's name as well as Macaulay. It should read Matthew Pendleton/Macaulay Library/Cornell Lab of Ornithology.



Where Earth stores its carbon

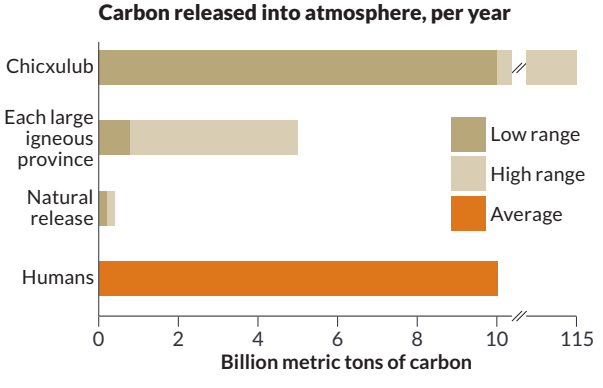
Human-driven carbon pollution is wreaking havoc on the climate, bleaching corals and melting ice caps. But the amount of carbon in Earth's oceans and atmosphere barely scratches the surface of the planet's vast carbon reservoirs.

Most carbon is stored inside the planet, with a whopping 1.845 billion billion metric tons in the mantle and crust and a meager 43,490 billion tons above the surface (dark blue bubbles represent overall totals; lighter blue bubbles are scaled proportionally to bubbles of the same color). Those estimates, reported in the October *Elements*, come from the Deep Carbon Observatory collaboration, which has also taken stock of how that carbon cycles through the planet.

The numbers don't quite capture every last bit of carbon; some of it is in the core. But estimates of that carbon are murky, and, besides, "core carbon is pretty locked up," says Deep Carbon Observatory geologist Celina Suarez of the University of Arkansas in Fayetteville. Mantle carbon, however, continually escapes through volcanoes and mid-ocean ridges, and sinks back down with subducting tectonic plates.

Although that cycle has generally kept most carbon stashed underground, asteroid impacts and massive volcanic outpourings have at times released catastrophic amounts of carbon.

Analyses of rocks show that the Chicxulub asteroid strike, thought to have wiped out nonavian dinosaurs 66 million years ago, vaporized carbon-rich rock, releasing hundreds of billions of tons of carbon over several years. And giant magma outpourings called large igneous provinces, which each covered up to a million square kilometers, could have each released a few billion tons of carbon per year as they erupted. These events, such as one dubbed the Siberian Traps that occurred about 252 million years ago, may have contributed to mass die-offs. Today, people flood the air with carbon at a rate of about 10 billion tons annually, up to 45 times as much as Earth's current, natural emissions (graphed below). — *Maria Temming*



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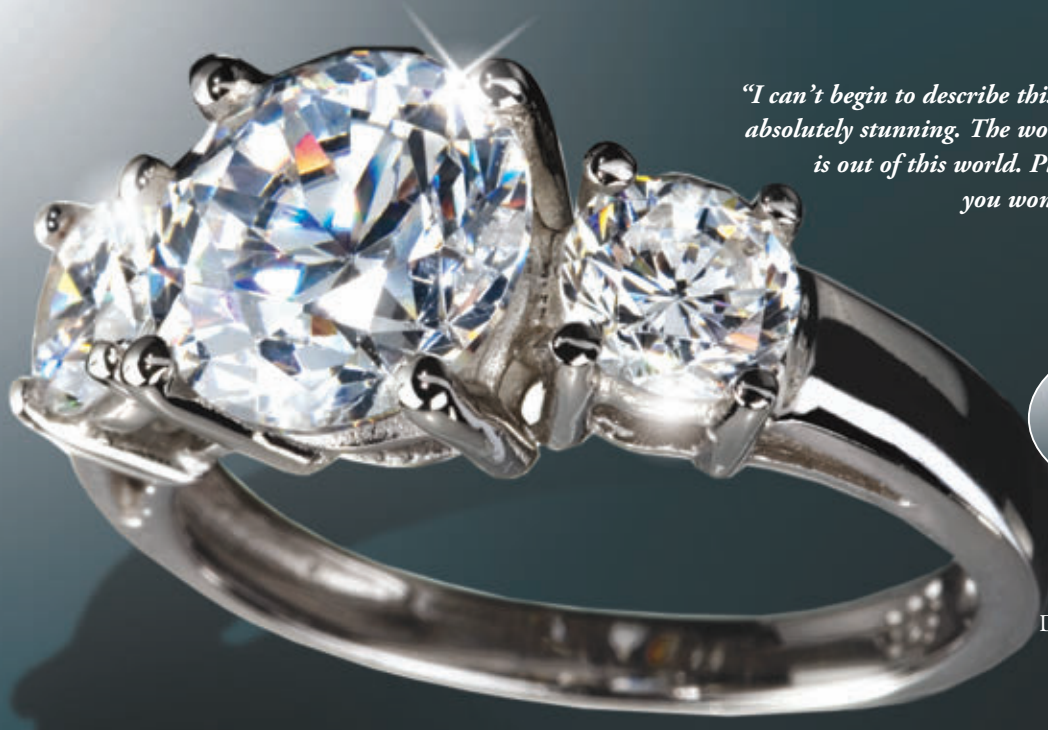

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