Quantum Supremacy Claim | North America Has Lost Billions of Birds

Science News

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ OCTOBER 12, 2019 & OCTOBER 26, 2019

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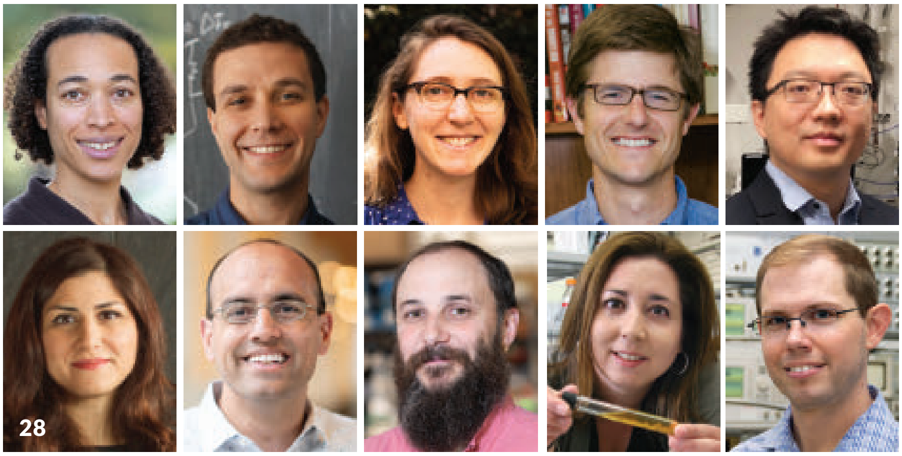
ScienceNews



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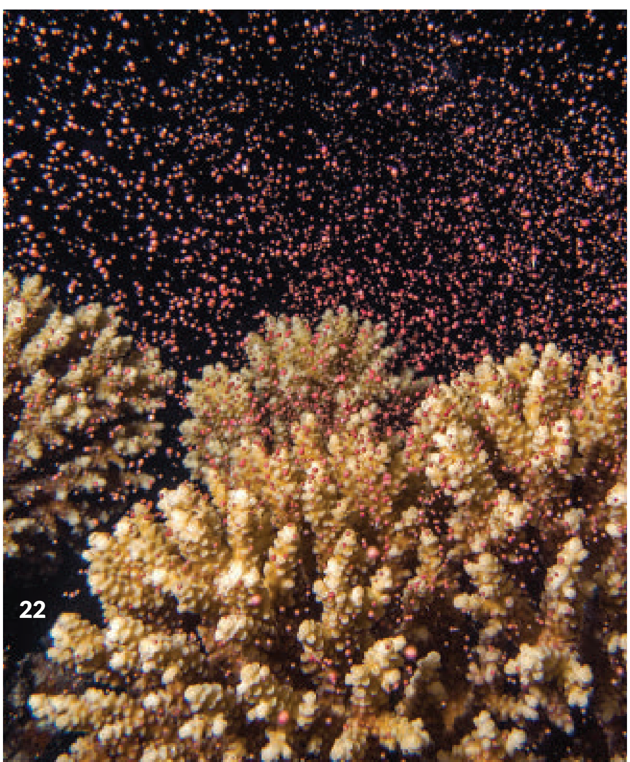

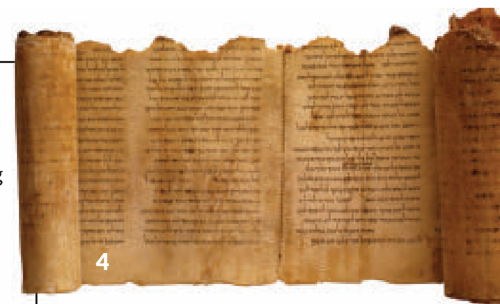

Departments

COVER This year's SN 10 crew dives with the fishes, sees movies in microbes and more. *Sam Falconer*

SN 10, CLOCKWISE FROM TOP LEFT: DAWN HARMER/SLAC NATIONAL ACCELERATOR LABORATORY; SONIA FERNANDEZ; UNIV. OF WASHINGTON; JEFF HECKMAN, COURTESY OF RUTGERS UNIV; COURTESY OF S. QI; COURTESY OF B. MCGUIRE; UC SANTA BARBARA; LAUREN BAYLESS/GLADSTONE INSTITUTES; BRYCE VICKMARK; USC VITERBI; OTHER PHOTOS, FROM TOP: WWW.BIBLELANDPICTURES.COM/ALAMY STOCK PHOTO; T. SHLESINGER

Scientists who aren't afraid to range across disciplines

When I was in grade school, science seemed like the stuff of solitary geniuses. We learned about Edison, Einstein and Darwin as great men laboring alone in search of their breakthrough discovery. But science is a team sport, a fact that's often obscured by the "lone genius" trope. Edison, for one, employed dozens of young men, whom he called "muckers," to develop materials for phonograph records and insulation for electrical wires. Many of his assistants went on to do great things on their own, but Edison's is the name that endures in the textbooks.

This issue of *Science News* marks our fifth year celebrating the work of early- and mid-career scientists (Page 28). Although we recognize 10 individuals a year, it's striking how for many of them, collaborating and making cross-disciplinary connections is central to their work, revealing modern science as a diverse global enterprise.

This year's class of "SN 10" achievers, all men and women under age 40, exemplify that diversity. They're applying their curiosity about the world and their formidable technical skills to solving real-world problems. And some of the scientists have ranged far from their original field of study. They include a chemist who probes the cosmos, an economist trying to make school choice more equitable and an engineer who wants our brains to be able to command machines just by thinking.

Interviewing these fascinating people and introducing them to our readers is a treat for us, since so much of the time we're focused on the results of scientific studies. "So rarely do we get to peek into the lives of the scientists," says Elizabeth Quill, special projects editor for *Science News*. Quill directs the SN 10 enterprise, which itself is a collaborative effort involving dozens of people, including British artist Sam Falconer, who brings each scientist's work to life in his delightful cover illustration. Quill is particularly intrigued by the spark that leads young people to devote themselves to science, and that keeps them going through incorrect hypotheses, data dead ends and funding challenges.

We hope you'll enjoy reading about these remarkable young scientists as much as we have enjoyed profiling them. And we invite you to join us on October 22 for a live online discussion with earth and climate writer Carolyn Gramling and Malin Pinsky, an SN 10 scientist who investigates how climate change is affecting fish populations. Details about the event are available at sciencenews.org/webinars.

And as always, in this issue we're keeping you up to date on the latest news in science, including the discovery that a planet beyond our solar system may have cloudy skies and rain showers, raising the question of whether the planet could be "habitable" (Page 6). Physics writer Emily Conover reports on a leaked paper that describes how researchers at Google may have achieved "quantum supremacy," with a quantum computer performing a calculation that could not be done by a standard computer (Page 8). Will these turn out to be major discoveries, or intriguing blips? We'll stay on the case and keep you informed as these stories develop. *—Nancy Shute, Editor in Chief*

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SSP

Excerpt from the October 11, 1969 issue of *Science News*

50 YEARS AGO

Fossil search in Antarctica

A search for further fossil evidence that Antarctica was once joined to other continents will be conducted.... A 17-man group will seek fossils of ancient land vertebrates similar to those found on continents now separated from Antarctica by up to 2,000 miles of ocean.

UPDATE: That same year, 1969, scientists found fossil evidence of the supercontinent Gondwana. Reptile bones found in Antarctica included a 200-million-year-old hippolike creature called *Lystrosaurus* (*SN: 12/13/69, p. 549*). The animal lived on the continental mash-up of South America, Africa, India, Australia and Antarctica that existed from around 600 million to 180 million years ago. Another Antarctic expedition, in 1970, found a 200-million-year-old skeleton of a cynodont reptile, which resembled remains found in South America and India (*SN: 12/5/70, p. 428*). The fossils and other geologic evidence all but confirmed Gondwana's existence (*SN: 1/16/71, p. 49*). Scientists later figured out how this continental jigsaw puzzle fit together (*SN: 6/11/77, p. 372*).

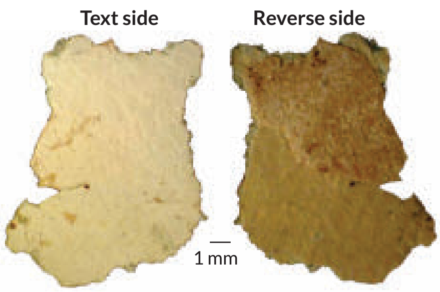
RETHINK

A standout scroll

The longest of the Dead Sea Scrolls is surprisingly salty. Chemical analysis of the Temple Scroll (above) has revealed a salt coating on the scroll's text side that hadn't previously been found on the other scrolls.

The unusual finish suggests that the Temple Scroll's remarkably bright parchment was manufactured differently from other ancient documents, researchers report September 6 in *Science Advances*.

It's not clear how the mineral coating may have contributed to the 8.1-meter-long scroll's appearance, MIT materials scientist Admir Masic says. Understanding the properties of this manuscript and the other Dead Sea Scrolls could help in preserving the 2,000-year-old documents, which include sections of the Hebrew Bible, and may help with spotting forgeries.



Using both X-ray and Raman spectroscopy to examine a fragment of the Temple Scroll (two views shown), scientists identified a strange salt coating on the text side of the scroll that wasn't previously found on other Dead Sea Scrolls.

Masic and colleagues looked at a fragment of the Temple Scroll using both X-ray and Raman spectroscopy. These methods involve shining radiation on a sample and measuring the light reflected back to map the material's chemical composition.

The mixture atop the Temple Scroll mostly comprises sulfate salts, including the minerals gypsum, glauberite and thenardite, not seen before on the scrolls. "Sometimes you find a lot of inorganic components on these scrolls or fragments, and they probably came from the caves" in which the documents were found, Masic says. But the minerals on the Temple Scroll aren't generally found near the Dead Sea, so the materials probably were used in the scroll's production, the scientists say.

This salt-finishing technique may not have been unique to the Temple Scroll. Traces of similar salts were also found on a bit of Dead Sea Scroll manuscript from another cave. The next step is to identify where the minerals occur naturally and whether the materials used to make the scrolls were imported from another region, Masic says. *— Maria Temming*

THE –EST

The Milky Way's black hole gets flashy

For the Milky Way's supermassive black hole, it's glow time.

Sagittarius A*, the behemoth at the galaxy's center (shown in this NASA X-ray image released in 2012), dazzled astronomers on May 13 with the most brilliant light show ever recorded in over 20 years of monitoring the black hole. When observed in near-infrared wavelengths of light, the black hole appeared about twice as bright as the previous brightest observation, researchers report in the Sept. 10 *Astrophysical Journal Letters*.

Scientists aren't sure why Sgr A* flared. Gas and dust heat up and produce light on their way into the black hole. So the boost in brightness indicates that the black hole probably was swallowing matter faster than usual. A few million years ago, the black hole may have been eating even faster (see Page 48). *— Emily Conover*

FROM TOP: WWW.BIBLELANDPICTURES.COM/ALAMY STOCK PHOTO; R. SCHUETZ *ET AL/SCI. ADV.* 2019; CXC/NASA, MIT, F. BAGANOFF ET AL

THE SCIENCE LIFE

A biologist chases storms to study spider evolution

Colonies of tiny, comb-footed spiders that live through hurricanes may do better in a storm-ravaged environment if they're aggressive.

FROM TOP: THOMAS C. JONES/EAST TENNESSEE STATE UNIV.; U.S. COAST GUARD

Don't just sit there. If you want to study evolution and spider aggression, drive into a hurricane.

That idea turned Jonathan Pruitt into evolutionary biology's storm chaser. He has rushed to the southeastern United States to collect spider data before and after storms. "I grew up in Florida," Pruitt says. So he knows hurricanes.

Normally, studies of how hurricanes affect wildlife result from storms trashing research sites in forests, bird colonies or other areas. But storm studies need replication and undamaged sites for comparison. Otherwise "you just have one site where something bad happened," says Pruitt, of McMaster University in Hamilton, Canada.

What sparked him to try something different was an unusual 2018 report in *Nature* involving a species of anole lizard in Turks and Caicos before and weeks after two strong hurricanes blasted the Caribbean islands. Surviving anoles tended to have bigger toe pads than usual, which the researchers proposed might give the lizards a better grip in high winds. The finding suggested that intense storms, even if sporadic, might count as an evolutionary force that can tweak animal traits.

That paper inspired Pruitt to set up pop-up research sites before an impending storm. As Hurricane Michael barreled toward Florida in October 2018, Pruitt set up research headquarters in Macon, Ga., as well as a group of spider test sites in the storm's path and another site facing less risk that was meant as a control.

Even Macon got hit, with power lines downed and trees blocking roads, he says. So getting to the test sites "was a bit of a kerfuffle." Luckily, locals helped by rushing out to explore roads and posting damage pictures to social media. People with chain saws would even carve paths for Pruitt, because "they [thought] it's funny that someone would be out there studying spiders."

The comb-footed spiders he studies are "tiny little brown things," he says. *Anelosimus studiosus* spiders "don't start trouble with anybody, unless you're prey snared in their web." When a fly or other meal prospect bumbles into the web, some colonies react aggressively. Five or six spiders swarm toward the victim, instead of just one or two (*SN: 4/21/12, p. 26*). To quantify aggression, Pruitt counts how many spiders first venture out to check on prey. To mimic flailing prey, he sticks a bit of paper to the web and makes it flutter with the touch of an electric toothbrush.

Colonies, aggressive or meek, died at random during storms. But poststorm, the more aggressive ones fared better in the damaged landscape, Pruitt and colleagues report in the September *Nature Ecology & Evolution*. Aggressive surviving colonies were more likely than timid ones to have more offspring after the storm. In a 100-year historical view, spider colonies were more aggressive in counties hit by more hurricanes than in places hit by fewer storms.

Picking these comparison sites at the last minute is a "really powerful technique," says Colin Donihue, an evolutionary ecologist at Washington University in St. Louis who studied the anole lizards. *—Susan Milius*

MYSTERY SOLVED

How Kilauea's lava fed a phytoplankton bloom

Kilauea's 2018 eruption boosted ocean algae, but how it did so was a mystery. Metals in the lava might have helped nourish a 150-kilometer-long phytoplankton bloom off Hawaii. But heat, it turns out, was the more important ingredient.

Kilauea spewed 50 to 100 cubic meters of metal- and nutrient-rich lava per second into the ocean each day from June 3 to August 6, 2018 (*SN: 2/2/19, p. 22*). That superhot lava probably churned up buoyant plumes of deep-sea nutrients to feed the tiny algae, researchers report in the Sept. 6 *Science*. Three days after the lava had entered the ocean, satellite images showed a patch of water enriched in chlorophyll a, the pigment that can make plants and algae green.

In analyzing the patch's seawater, scientists found a fertilizing serum of nitrate, silicic acid and phosphate, as well as iron, manganese and cobalt. Concentrations of silicic acid and trace metals, some of which can help algae grow, were similar to those of Kilauea's basalt lava. But nitrate, probably stirred up from the deep by the heat, was the primary driver for the bloom, the researchers say. *—Carolyn Gramling*

Days after lava from Kilauea started entering the Pacific Ocean, a vast field of algae bloomed off Hawaii's Big Island.

News

K2 18b (at right in this artist's impression) may be the first known temperate exoplanet with a watery atmosphere.

M. KORNMESSER, HUBBLE/ESA

ATOM & COSMOS

Distant exoplanet may host rain clouds

Water is found on a world that sits in its star's habitable zone

BY LISA GROSSMAN

Clouds of water droplets and even rain may exist in the soggy skies of a faraway exoplanet.

A combination of observations with space telescopes and simulations suggests that planet K2 18b has water vapor in its atmosphere and might be the first planet orbiting a distant star found to support liquid water, thought to be an essential ingredient for life.

"Water vapor exists everywhere in the universe," says astronomer Björn Benneke of the University of Montreal, who reported the potential discovery in a paper posted September 10 at arXiv.org. "But it's not so easy to make liquid water; you need the right pressure and the right temperature. That's what makes this planet special."

Discovered in 2015 by the Kepler space telescope, K2 18b orbits a dim red dwarf star about 110 light-years from Earth and is bigger and heavier than Earth: about 2.5 times Earth's radius and about eight times its mass.

"From the beginning, that makes it not an Earthlike planet," astronomer Angelos Tsiaras of University College London said September 10 at a news conference.

His team independently detected water vapor in K2 18b's atmosphere and reported the finding September 11 in *Nature Astronomy*. Tantalizingly, the planet's distance from its star places K2 18b in the star's habitable zone, the region around a star where a planet could have temperatures conducive to liquid water.

In 2016 and 2017, researchers led by Benneke used the Hubble Space Telescope to probe K2 18b for signs of an atmosphere as the planet passed in front of its star. Molecules in the planet's atmosphere absorbed certain wavelengths of the star's light, alerting astronomers to the molecules' presence.

After accessing that data from a public archive and using specially designed software for analysis, Tsiaras and colleagues found that the planet has an atmosphere, and that the filtered starlight reveals the telltale signature of water vapor molecules. The atmosphere also contains hydrogen and helium, the team reports.

"Until now, the planets for which we had the atmosphere observed and found water were gas giants, planets more similar to Jupiter, Saturn or Neptune," Tsiaras says. K2 18b's size, location in the habitable zone and watery atmosphere mean that "this is the best candidate for habitability that we now have."

Benneke and colleagues took the work a step further and observed K2 18b with the Spitzer Space Telescope. The combination of Hubble, Spitzer and Kepler observations suggests that clouds form at a certain level in the planet's atmosphere.

Simulations of the planet's climate suggest that the region where the clouds condense could have the right pressure and temperature for liquid water to form. That means liquid water droplets could condense out of the clouds and rain down, Benneke says.

"It's quite likely that this planet has liquid rain on it," he says. "This is actually one of the most exciting findings from this data."

Benneke thinks K2 18b's raindrops would never hit solid ground (if the planet even has solid ground). Instead, they would reach a point in the planet's thick atmosphere where the pressure and temperature would be so great that the droplets would evaporate. Then the water would rise up in the atmosphere again, condense into clouds and rain back down. "There's a bit of a water cycle," he suggests.

Other exoplanet experts remain skeptical about the possibility of raindrops. "There is no definitive proof," says astronomer Sara Seager of MIT. "It's a solid but still speculative statement."

Liquid water, if it exists on K2 18b, doesn't mean anything lives — or can live — on the planet. Its size places it somewhere between the girth of Earth and Neptune, so it's not clear if the exoplanet has a rocky surface where life as we know it could evolve. Most exoplanets in the Milky Way fall in this size range, and it's hard to tell if these places are rocky super-Earths, gassy mini-Neptunes or sodden water worlds.

"It's one of these really mysterious planets that are the most common type of planet in our galaxy, as far as we can tell," Seager says. "We have no idea what they are." Future observations with NASA's planned James Webb Space Telescope may be able to pin down how much water K2 18b contains (*SN: 4/30/16, p. 32*), which would help researchers figure out its composition, she says. ■

EARTH & ENVIRONMENT

North America has lost billions of birds

Population declines since 1970 include rare and common species

Populations of rare and common birds are decreasing across North America, including (from top) snowy owls, sanderlings, cactus wrens and Western meadowlarks.

FROM TOP: DOUG HITCHCOX; ANDY ECKERSON; BRIAN SULLIVAN; MATTHEW PENDELTON/MACAULEY LIBRARY/CORNELL LAB OF ORNITHOLOGY

BY JONATHAN LAMBERT

Nearly 3 billion fewer birds exist in North America today than in 1970.

While scientists have known for decades that certain kinds of birds have struggled as humans (and bird-gobbling cats) encroach on bird habitats, a new comprehensive tally shows the staggering extent of the loss. Nearly 1 in 3 birds — or 29 percent — has vanished in the last half century, researchers report online September 19 in *Science*.

"Three billion is a punch in the gut," says conservation biologist Peter Marra of Georgetown University in Washington, D.C. The loss is widespread, affecting rare and common birds alike. "Our study is a wake-up call," Marra says. "We're experiencing an ecological crisis."

Looking at the loss of individual birds sets this study apart, says ecologist Hillary Young of the University of California, Santa Barbara, who was not involved in the research. "So much of the focus in conservation is on the loss of species," but individual birds play an important role in ecosystems, including pollinating plants, dispersing seeds and controlling pests.

"Often it's the common, abundant birds that keep these ecosystems ticking," Young says. Some biologists argue that, as rarer birds disappear, more common ones will swoop in and fill their niches. These common birds might be more adaptable and able to persist as habitats shrink, keeping the overall numbers of birds stable and basic ecosystem services intact.

But without a broad beak count over many decades, "we just didn't know for sure," says Kenneth Rosenberg, an ornithologist at Cornell University.

So Rosenberg, Marra and colleagues mined 12 databases built from decades of on-the-ground bird observations in North America, often made by citizen scientists. Yearly observations built a record of population-level changes in 529 species, representing 76 percent of birds that breed in the continental United States and Canada. A statistical analysis of these data let the team estimate population trends since 1970 and compare historical levels with current best estimates of population size.

The numbers paint a grim picture: Most habitats and species have experienced tremendous losses, especially migratory birds. Grassland species fared the worst. Some 700 million individual birds across 31 species, including meadowlarks, have vanished since 1970, a 53 percent drop. American sparrows, such as the little brown birds commonly seen flitting through backyards, saw the largest drop of any group of birds. About a quarter — 862 million — have disappeared over roughly the last five decades. Even invasive species like European starlings, which are highly adaptive generalists, experienced massive losses, with populations declining 63 percent.

"What's scary to me is that the common birds, even invasive ones, aren't faring any better than the rare birds," Young says. "These results clearly show they're just as vulnerable."

The researchers confirmed this trend with a completely different way of monitoring birds: weather radar. Radar systems tracking the movement of clouds across the United States also register other large masses moving through the air, including flocks of migrating birds. After distinguishing these flocks from clouds, the researchers estimated the change in total biomass of birds migrating at night and found a roughly 14 percent drop from 2007 to 2017.

While not directly comparable, the two methods reveal steep declines. "That [both methods] came to the same conclusion suggests these numbers aren't just being pulled out of a hat," says Morgan Tingley, an ornithologist at the University of Connecticut in Storrs. "They're real."

The study doesn't address why birds are disappearing, but many face habitat degradation and loss. "As habitats diminish, birds have nowhere to go," Rosenberg says. In the United States, cats may kill more than a billion birds a year (*SN: 2/23/13, p. 14*), while nearly a billion more die in collisions with buildings (*SN: 3/22/14, p. 8*), previous studies have found.

But the new study offers some hope. Populations of waterfowl, like mallard ducks and Canada geese, have grown 56 percent since 1970. "This increase is no accident," Rosenberg says. "It's a direct result of decades of conservation efforts made by hunters and billions of dollars to protect these birds and their habitat." Rosenberg says he hopes this study will spur similar concern for all birds.

"This paper doesn't tell us what the future holds," Tingley says. "Only what has happened up to this point. It's up to us to decide what to do next." ■

MATH & TECHNOLOGY

Claim of quantum supremacy reported

Google machine does a calculation that a classical computer can't

BY EMILY CONOVER

A leaked paper suggests that Google has achieved a milestone known as quantum supremacy, using a quantum computer to perform a calculation that couldn't be achieved even with the world's most powerful supercomputers.

It's a hotly anticipated goal, and one intended to mark the beginning of a new era of quantum computation (*SN: 7/8/17 & 7/22/17, p. 28*). But it's also largely symbolic: The calculation in question serves little practical purpose and is designed to be difficult for standard computers that are not rooted in quantum physics.

On September 20, the *Financial Times* reported that a scientific paper, briefly posted on a NASA website before being removed, claims that Google has built a quantum computer that achieves quantum supremacy. It's a benchmark that the company's quantum researchers, led by physicist John Martinis of the University of California, Santa Barbara, have set their sights on for years (*SN: 3/31/18, p. 13*). An apparent plain text version of the paper, posted anonymously on the website Pastebin, has since been circulating among scientists and on Twitter. A spokesperson for Google declined to comment to *Science News*.

According to the Pastebin version of the paper, Google created a quantum computer named Sycamore with 54 quantum bits, or qubits, 53 of which were functional. The researchers used it to perform a series of operations in about 200 seconds that would take a supercomputer about 10,000 years to complete.

The calculation consists of performing random operations on the qubits and reading out the result. After doing this many times, the researchers are left with a nearly random assortment of numbers, one that is extremely difficult to reproduce with a classical computer.

Despite its relative lack of applications, quantum supremacy has been billed as a major breakthrough in the quest for a quantum computer that could eventually perform useful calculations that are not possible with classical computers. "This dramatic speedup relative to all known classical algorithms provides an experimental realization of quantum supremacy on a computational task and heralds the advent of a much-anticipated computing paradigm," the text of the paper posted on Pastebin reads.

The machines might eventually be capable of defeating encryption techniques used to secure certain transmissions, such as financial transactions made by computers. But that advance will require many more qubits and a method to correct the errors that inevitably creep into quantum calculations. "While this is a milestone, it is *very* far from being a quantum computer that can compute anything useful," physicist Jonathan Oppenheim of University College London wrote on Twitter.

Not everyone agrees that quantum supremacy is a useful benchmark. "Quantum computers are not 'supreme' against classical computers because of a laboratory experiment designed to essentially (and almost certainly exclusively) implement one very specific quantum sampling procedure with no practical applications," Dario Gil, IBM's director of research, wrote in a statement sent to *Science News*.

IBM is developing its own line of quantum computers (*SN: 12/9/17, p. 18*), and researchers there prefer to talk about "quantum advantage," which they define as "the point at which quantum applications deliver a significant, practical benefit beyond what classical computers alone are capable." The new result falls short of that standard. ■

BODY & BRAIN

Prosthetic leg reduces phantom pain

A prosthetic leg that can feel helped two men walk faster, more smoothly and with greater confidence. The artificial leg (shown at right), outfitted with sensors that detect pressure and motion, also curbed phantom pain from the men's missing legs, researchers report online September 9 in *Nature Medicine*.

Neuroengineer Stanisa Raspopovic of EHT Zurich and colleagues tested the device in men who had a leg amputated above the knee. The new prosthetic legs were outfitted with seven sensors that detect foot pressure on the ground and one sensor that decodes the angles of the knee joint. Electrodes implanted on the sciatic nerve stimulated the nerve with signals from the sensors.

When those signals were present, the men walked faster and more confidently, even over difficult sandy terrain. And feelings of phantom pain lessened. After about a month, one of the men reported no phantom pain at all and the other said his pain was sporadic. *—Laura Sanders*

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Researchers tracked white-crowned sparrows dosed with a neonicotinoid to study the pesticide's effect on bird migration.

EARTH & ENVIRONMENT

Pesticide delayed birds' migration

Ingesting a neonicotinoid led sparrows to lose weight too

BY MAANVI SINGH

The world's most widely used insecticides may delay the migrations of songbirds and hurt their chances of mating.

In the first experiment to track the effects of a neonicotinoid on wild birds, scientists captured white-crowned sparrows (*Zonotrichia leucophrys*) as they migrated north from Mexico and the southern United States to Canada and Alaska. The team fed 12 sparrows a low dose of imidacloprid, an insecticide commonly used in the United States, and gave 12 more sparrows a slightly higher dose.

Within hours, the birds lost weight and ate less, the researchers report in the Sept. 13 *Science*. Birds given the higher dose (3.9 milligrams per kilogram of body mass) lost 6 percent of their body mass within six hours. That's about 1.6 grams for an average bird weighing 27 grams. After being released, dosed birds lagged behind 12 control birds given just sunflower oil when continuing their migration to summer mating grounds.

Even a slight delay in migration could affect a bird's chances of finding a mate and nesting, says Christy Morrissey, an ecotoxicologist at the University of Saskatchewan in Saskatoon, Canada.

The findings suggest that neonicotinoids, already implicated in declining bee populations, could also have a hand in the decline of bird populations across North America (see Page 7). From 1966 to 2013, the populations of nearly three-quarters of farmland bird species across the continent precipitously dropped.

Wild birds might feed on seeds coated with imidacloprid. The highest dose that the birds received "is the equivalent of if they ate one-tenth of [a single] pesticide-coated corn seed," Morrissey says. "These were minuscule doses we gave the birds."

Birds given just sunflower oil flew away from where they were captured after about half a day. The highest-dosed birds stayed a median of 3.5 days longer — possibly to recover and regain strength — and birds with the lower dose (1.2 mg/kg of body mass) stuck around for a median of 2.5 days longer than controls.

"Given that we've been seeing increasing evidence that these pesticides harm pollinators and insects, I can't say I'm shocked or surprised that they also have an effect on birds," says Melissa Perry, an environmental and occupational health scientist at George Washington University in Washington, D.C. Neonicotinoids were introduced as an alternative to more toxic insecticides, she says. "I don't think we ever really anticipated the environmental impact." ■

BODY & BRAIN

Supercooling extends organ's shelf life

New technique could help patients waiting for a transplant

BY MARIA TEMMING

A method to keep donor organs colder than ice cold could extend the length of time that organs are viable for transplant.

Typically, donor organs stay viable for several hours on ice at about 4° Celsius. Tissue can last longer at lower temperatures, but below zero degrees, the formation of ice crystals can ruin an organ. Now, using chemicals that prevent an organ from freezing, researchers successfully preserved five human livers at –4°. The system tripled the livers' typical shelf life from nine to 27 hours, researchers report online September 9 in *Nature Biotechnology*.

This technology "would be huge for transplantation," says Jedediah Lewis, president and CEO of the Organ Preservation Alliance in Berkeley, Calif., a nonprofit that supports organ preservation research but wasn't involved in this study.

Every year, thousands of livers and other donor organs are discarded for various reasons, including the inability to find a suitable patient close enough to receive the organ before it goes bad. If donor tissue were viable longer, doctors could perform more lifesaving surgeries for patients waiting for a transplant — currently more than 100,000 people in the United States alone.

Reinier de Vries, a doctor and mechanical engineer, and colleagues devised a cocktail of cryoprotectant chemicals, including trehalose and glycerol, to combat ice formation and protect cells at low temperatures. To ensure each liver was saturated, the team used a machine perfusion system, which pumps fluids into an organ in a way that imitates blood flow, says de Vries, of Harvard Medical School.

This scheme is a more sophisticated version of a chemical injection shown to preserve rat livers for several days at –6° (*SN: 8/9/14, p. 18*). Additional cryoprotectants and the machine perfusion equipment allowed the setup to handle human livers, which are harder to supercool because they're so much bigger.

The next step is to transplant organs stored at subzero temps into large animals like pigs, says study coauthor and Harvard biomedical engineer Shannon Tessier. "We actually want to show that the animals survive transplantation," she says. "Then, hopefully we can think about clinical trials." ■

MARGARET ENG

HUMANS & SOCIETY

DNA traces migrations into South Asia

More than 500 skeletons reveal genetic and cultural ancestry

BY BRUCE BOWER

A DNA study of unprecedented size has unveiled ancient human movements that shaped the genetic makeup of present-day South Asians. Those long-ago treks may even have determined the types of languages still spoken in a region that includes what's now India and Pakistan.

The investigation addresses two controversial issues: First, who brought farming to South Asia? Genetic comparisons indicate that farming was either invented locally by South Asian hunter-gatherers or launched via borrowing of knowledge from other cultures, rather than brought by Near Eastern farmers from what's now Turkey.

Second, where did local languages originate? New DNA evidence supports the idea that mobile herders from Eurasian steppe grasslands, rather than Near Eastern farmers, brought Indo-European languages to South Asia.

Ancient DNA had already suggested that the Yamnaya, Eurasian herders who spoke Indo-European languages, reached parts of early Bronze Age Europe by about 5,000 years ago (*SN: 11/25/17, p. 16*). Yamnaya-related ancestry appeared among South Asians between about 3,900 and 3,500 years ago, a team reports in the Sept. 6 *Science*.

"By the early Bronze Age, human movements were stirring the genetic pot throughout Asia," says archaeologist Michael Frachetti of Washington University in St. Louis. He led the project along with Harvard Medical School geneticists David Reich and Vagheesh Narasimhan and archaeologist Ron Pinhasi of the University of Vienna.

What stands out, Frachetti adds, is that Eurasian herders entered South Asian urban centers in relatively small numbers. So a South Asian transition to speaking Indo-European tongues need not have resulted from a big wave of herders rapidly migrating into the area. Scientific scenarios of a change in language have often been predicated on movements of entire populations that transformed how people spoke elsewhere.

The team analyzed DNA extracted from 523 skeletons excavated in Central Asia and northern parts of South Asia. These finds date from around 14,000 to 2,000 years ago. Comparisons were made with previously published examples of ancient DNA from across Eurasia and with present-day Eurasians' DNA.

Genetic evidence, plus archaeological evidence of farming tools, indicates that Near Eastern farmers moved north through Asian mountain valleys into what's now Iran by about 5,000 years ago, the researchers say. At the same time, DNA indicates that steppe herders moved south through the same mountain corridors to reach the same area.

Near Eastern farmers appear to have traveled no farther east than Iran, roughly 1,500 kilometers from South Asia's western outskirts. No genetic trace of Near Eastern farmers appeared in 11 individuals who lived just west of South Asia, in eastern Iran and Turkmenistan, between around 5,300 and 4,000 years ago. Instead, their ancestry came from ancient Iranians and Southeast Asian hunter-gatherers and resembled that of a 4,000- to 5,000-year-old individual from the Indus Valley Civilization, also called the Harappans, Reich and colleagues report online September 5 in *Cell*.

Harappans provided the largest source of ancestry for South Asians today, the team says. And because Harappan DNA contains no contributions from farming groups, scientists suggest that locals either invented or borrowed farming techniques.

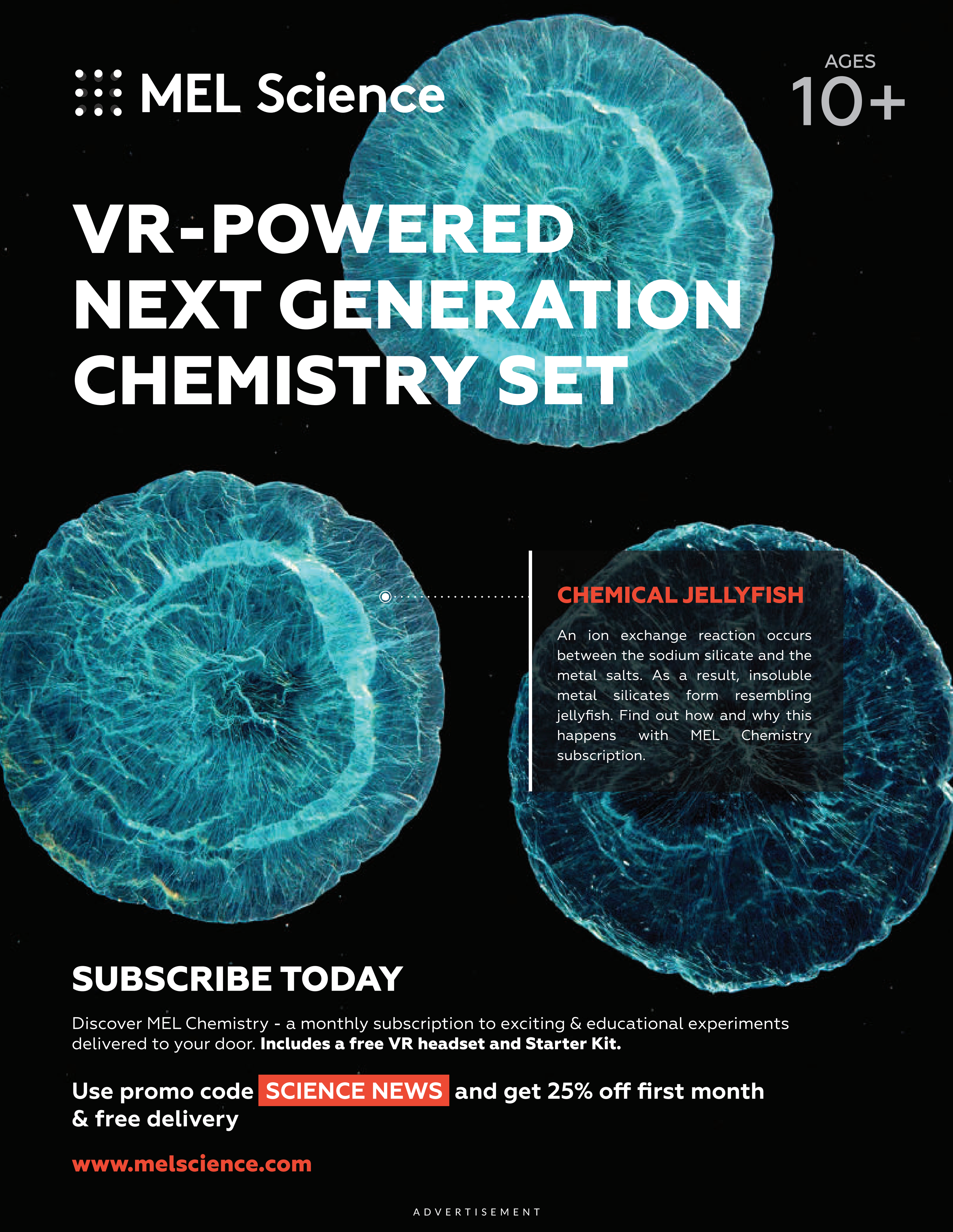
DNA from Yamnaya herders accounts for a minority of present-day South Asians' ancestry. Relatively small numbers of Indo-European–speaking migrants moving into South Asian communities between 4,000 and 3,000 years ago could have influenced the development of new forms of Indo-European speech, Frachetti suggests.

Findings in the study in *Science* do indicate that some mobile herders trekked from Europe to what's now India shortly after 4,000 years ago, influencing South Asian ancestry and languages, says Kristian Kristiansen, an archaeologist at the University of Gothenburg in Sweden who did not participate in the study.

But the origins and spread of Indo-European languages remain controversial. Yamnaya herders contributed much less DNA to ancient South Asians than they did to Europeans, says linguist Paul Heggarty of the Max Planck Institute for the Science of Human History in Jena, Germany. The new findings suggest that ancient Iranians, estimated to have spoken Indo-European tongues roughly 7,000 to 6,000 years ago, brought these languages to South Asia, Heggarty says. ■

Ancient DNA from human skeletons (one shown) unearthed in and around northern South Asia has yielded clues to how migrations sculpted languages and farming starting 4,000 years ago or more.

ROBERTO MICHELI AND MASSIMO VIDALE/ISMEO-ITALIAN ARCHAEOLOGICAL MISSION IN PAKISTAN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ATOM & COSMOS

‘Ringing’ black hole appears to be bald

Study of gravitational waves supports the no-hair theorem

BY EMILY CONOVER

For black holes, it’s tough to stand out from the crowd: Donning a mohawk is a no-no.

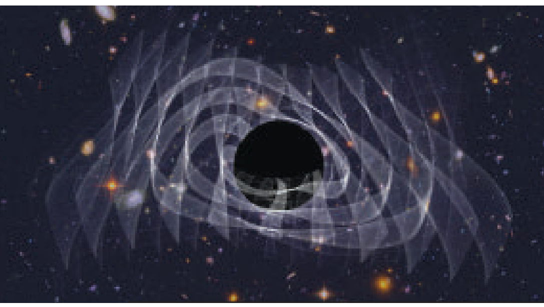
Ripples in spacetime produced as two black holes merged suggest that the behemoths have no “hair,” scientists report in the Sept. 13 *Physical Review Letters*. That’s another way of saying that, as predicted by Albert Einstein’s general theory of relativity, black holes have no distinguishing characteristics aside from mass and the rate at which they spin.

“Black holes are very simple objects, in some sense,” says Maximiliano Isi, a physicist at MIT.

The ripples, detected by the Advanced Laser Interferometer Gravitational-Wave Observatory, LIGO, in 2015, resulted when two black holes spiraled around each other and crashed together to form one big black hole. In the aftermath, the resulting black hole went through a “ringdown” period. It oscillated over several milliseconds as it emitted gravitational waves, similar to how a struck bell makes sound waves before quieting.

Reverberating black holes emit gravitational waves at one main frequency with additional, short-lived frequencies called overtones — much like a bell rings with multiple tones plus its main pitch.

By measuring the black hole’s main frequency and one overtone, Isi and colleagues could compare those waves with the prediction for a hairless black hole. The results agreed within 20 percent.



After two black holes crash and merge, the new black hole rings like a bell (illustrated), emitting gravitational waves before settling down.

That result leaves wiggle room for the no-hair theorem to be proved wrong. But “it’s a clear demonstration that the method works,” says physicist Leo Stein of the University of Mississippi in Oxford, who was not involved with the new work.

The researchers also calculated the black hole’s mass and spin using waves from the ringdown period. The figures agreed with the values estimated from the entire event, including the spiraling and merging of the original two black holes, reinforcing the idea that the resulting black hole’s behavior was determined by only its mass and spin.

But just as a bald man may sport a few strands, black holes could reveal some hair on closer inspection. If so, that might help solve the information paradox, a puzzle about what happens to information that falls into a black hole. In a 2016 attempt to resolve the paradox, Stephen Hawking and colleagues suggested black holes might have “soft hair.” ■

ATOM & COSMOS

Solar system gets another visitor

Astronomers spot a potential comet from interstellar space

BY LISA GROSSMAN

An object that seems to be a comet from around another star is speeding through the solar system. The comet, dubbed C/2019 Q4 (Borisov), marks the second time that astronomers have seen an interstellar visitor on its way past the sun.

On August 30, amateur astronomer Gennady Borisov spotted the comet. Other astronomers then took enough observations to show that the comet’s orbit is not bound to the sun, a telltale sign that the object is from interstellar space, says astrophysicist Matthew Holman. He directs the International Astronomical Union’s Minor Planet Center in Cambridge, Mass., which in a Sept. 11 public bulletin reported C/2019 Q4’s trajectory.

“This is an unusual thing. You always want to be extra careful when you get an answer that’s not typical,” Holman says. “That said, I think it will hold up.”

The first known interstellar object, named ‘Oumuamua, was spotted in 2017 as it sped away from the solar system (*SN: 11/25/17, p. 14*). Astronomers caught only fleeting glimpses of ‘Oumuamua on its way out the door. That left many theories for what the object was — an asteroid, a fluffy ice fractal, a skeleton of a comet, even an alien spaceship. But little data existed to back up any of those ideas.

C/2019 Q4, on the other hand, is just within the solar system’s doorstep, on a trajectory that will take it between the orbits of Jupiter and Mars. It will make its closest approach to Earth on December 29. “We’ll be able to observe it for probably a year,” says astronomer Michele Bannister of Queen’s University Belfast in Northern Ireland. ‘Oumuamua was tracked for just 2.5 months.

Already, C/2019 Q4 looks different from its predecessor. ‘Oumuamua resembled an asteroid, with no obvious cloud of gases. C/2019 Q4 is surrounded by a bright cometlike halo, indicating that it’s sloughing off gas and dust.

That cometlike appearance is what astronomers had expected from ‘Oumuamua, Bannister says. Comets are a type of leftover planetary building block, called planetesimals, and most planetesimals form far from their stars and are therefore icy. “Almost all the planetesimals that each planetary system makes end up being scattered out to go wander the galaxy,” Bannister says.

Further observations will reveal more about C/2019 Q4’s orbit, size and origin. Astronomers will also study the comet’s composition and see how it differs from that of comets born in this solar system. ■

M. ISI/MIT, NASA

GEOLOGIC ROAD TRIP OF THE MONTH

SENECA ROCKS

Seneca Rocks is located on the east side of the North Fork of the South Branch of the Potomac, across the valley from the base of the Allegheny Front, the boundary between the Appalachian Plateaus and Valley and Ridge Provinces. Extending more than 500 feet above the valley floor, Seneca Rocks consists of the Tuscarora Sandstone, a very dense, quartz-rich rock, which accounts for its resistance to erosion and its comparatively light color. It was deposited as beach sands along a coast in Early Silurian time.

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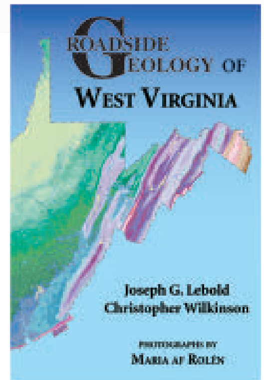
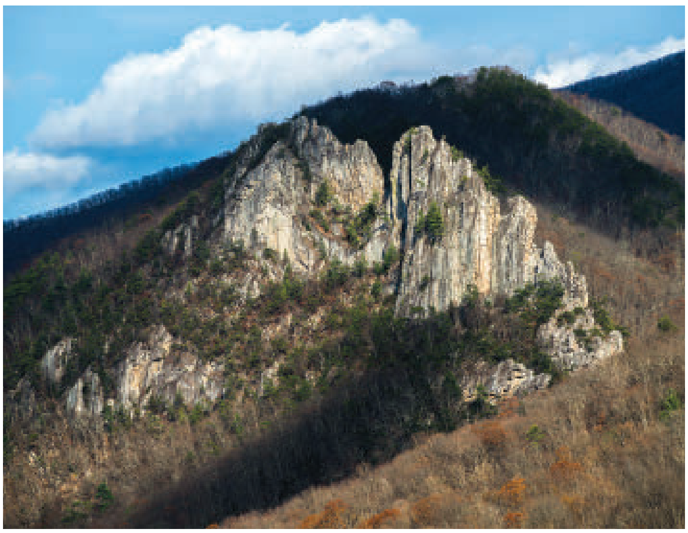


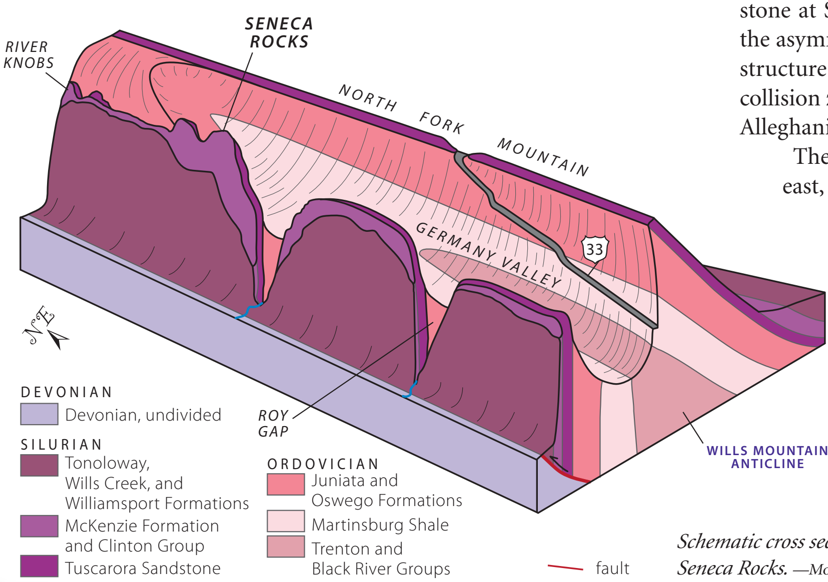


Vertical beds of the resistant Tuscarora Sandstone form Seneca Rocks on the west limb of the Wills Mountain Anticline, the westernmost fold in the Valley and Ridge.

To visit Seneca Rocks, either head north on WV 28 from the junction of US 33 and WV 28 and make a quick right into the Seneca Rocks Picnic Area, or head south and then left into the Seneca Rocks Discovery Center. While the Discovery Center provides much information about Seneca Rocks and the surrounding area in a modern facility, the picnic area lies at the head of a 1.5-mile trail that utilizes several switchbacks in a gentle climb to an observation platform near the top of Seneca Rocks. Once at the platform, the entire vertical extent of the Allegheny Front is visible to the west, quite possibly one of the best views of this important topographical and geological boundary in the Mountain State.

Standing close to the base of Seneca Rocks, say near the visitor center or the picnic area in the park, both of which lie between the river and the cliff, you might easily conclude that the rocks are horizontal and the outcrop is simply the result of erosion that removed the weaker rocks and let the stronger sandstone remain. Not so. Instead, the Tuscarora Sandstone at Seneca Rocks is nearly vertical and part of the western limb of the asymmetrical Wills Mountain Anticline. This fold is the westernmost structure in the Valley and Ridge Province and thus farthest away from the collision zone between the North American and African Plates during the Alleghanian Orogeny.

The fold's presence here suggests that the irresistible force to the east, namely the push of the African Plate, could not overcome what in this location had become an immovable object: the North American Plate. The latter would not yield any more territory. Instead, the intense compressional stress that was being transmitted by a subsurface thrust fault was directed upward, and the layers of rock, including the Tuscarora Sandstone, folded as they were dragged along the fault. The upward movement, or displacement, of rock becomes evident because the Tuscarora Sandstone at the surface here lies nearly 2 miles below the Appalachian Plateaus to the west.



Schematic cross section of the Wills Mountain Anticline at Seneca Rocks. —Modified from Renton, undated

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EARTH & ENVIRONMENT

Greenland slabs boost sea level rise

Growth of ice layers is sending more meltwater into the ocean

BY CAROLYN GRAMLING

Hidden slabs of frozen meltwater have grown rapidly beneath Greenland's snowy surface since 2001, scientists say. And these slabs are amping up the island's contribution to rising seas.

By forcing more meltwater to run along the surface and pour directly into the sea, the impermeable slabs could increase Greenland's contribution to global sea level rise from seven to 74 millimeters by 2100, depending on future greenhouse gas emissions, simulations suggest. So far, additional meltwater runoff due to the slabs has added about one millimeter to global sea levels, researchers report in the Sept. 19 *Nature*.

Greenland's melting, set off by global warming due to higher levels of carbon dioxide and other greenhouse gases in the atmosphere, has increased dramatically in the last few decades. From 1972 to 2018, the island has contributed about 14 millimeters to sea level rise, but much of that melting occurred after the turn of the century.

Typically during summer, meltwater seeps back into Greenland's ice sheet, trickling down into porous, partially compacted layers of granular snow, called firn. Sometimes, pockets of meltwater within the firn refreeze into small, scattered bodies of hard ice, called ice lenses.

But record-breaking summer melting in 2002, 2007, 2012 and 2019 resulted in meltwater refreezing into thick, impermeable layers of ice around Greenland's perimeter, says Michael MacFerrin, a glaciologist at the University of Colorado Boulder. Some of these "ice slabs" can stretch for tens of kilometers, MacFerrin and colleagues report.

It was while drilling ice cores in 2012 in southwestern Greenland that MacFerrin and colleagues first got a hint that instead of isolated lenses, there might be widespread layers of frozen ice just beneath the surface. "We did not expect to find meter after meter after meter of solid ice," MacFerrin says. Those ice slabs, the team suggests, act as a barrier to percolating meltwater, funneling the water more quickly to the ocean.

To map the slabs' extent, MacFerrin and colleagues examined five years of airborne radar observations collected by NASA's Operation IceBridge mission from 2010 to 2014. The team also created images of the subsurface in 2013 using ground-penetrating radar, which can distinguish between firn layers saturated in liquid water and layers of impermeable ice.

By combining those data, the team created a map of the horizontal and vertical extent of the subsurface ice slabs across the entire island. In 2014, ice slabs covered up to 69,400 square kilometers, about 4 percent of the ice sheet's total area. The slabs were between 1 and 16 meters thick.

Those observations, as well as the core data collected in 2012 and climate data, helped the team simulate slab growth back to the 1990s. It wasn't until the beginning of the 21st century that growth really took off, MacFerrin says. "2002 was a record-breaking year of melt in Greenland. That's when these big solid layers started freezing, and they have been expanding since then."

The team also projected growth up to the year 2100. Because there are different computer simulations of future climate conditions in the Arctic, as well as different projections of future global greenhouse gas emissions, the team ran numerous projections to estimate maximum and minimum slab growth.

"Under the lower greenhouse gas emission scenario, in which greenhouse gas emissions are reduced around 2050, we see ice slabs growing through the middle of the century and then the process slows down," MacFerrin says. But under the highest future emissions scenario, in which current emissions are not reduced, slab growth could extend all the way to the center of the ice sheet.

That's a sea change for Greenland, says MacFerrin. The fringes of Greenland's ice sheet are rapidly melting. "But the majority of the interior has been pretty stable," he says. "Now we're watching an ice sheet transform itself before our eyes.... The cold, boring interior of Greenland is waking up."

Ice cores drilled into the Greenland ice sheet in 2012 revealed large, meters-thick slabs of frozen meltwater beneath the snow.

BABIS CHARALAMPIDIS/BAVARIAN ACADEMY OF SCIENCES AND HUMANITIES, GEOLOGICAL SURVEY OF DENMARK AND GREENLAND (© 2012 GEUS)

Increased meltwater runoff due to ice slabs might also have a deeper impact on Greenland by changing the internal dynamics of the ice sheet that covers the island, says glaciologist Laura Stevens of Columbia University's Lamont-Doherty Earth Observatory in Palisades, N.Y. Those extra rivulets of meltwater pour into lakes and streams on the surface of the ice sheet but might also find ways to sink much deeper via cracks and crevasses — possibly down to the base of the sheet, where it meets land, she says.

Adding meltwater to the base of the ice sheet could act as a kind of lubricant, possibly speeding up the flow of the ice sheet toward the ocean. For now, there's too little information about how the ice slabs, meltwater and ice sheet might be interacting to say whether such a scenario is realistic or likely, Stevens adds. But, she says, this study reveals that the role of slabs is another line of evidence that scientists should investigate to know the fate of Greenland's ice. ■


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HUMANS & SOCIETY

Early Americans had far-flung ties

Distant hunter-gatherers had direct contact 4,000 years ago

BY BRUCE BOWER

Ancient hunter-gatherers in North America had direct contacts with people living halfway across the continent, researchers say.

A ceremonial copper object and related evidence of burial customs at a roughly 4,000-year-old human grave site encircled by a massive ring of seashells in the southeastern United States closely correspond to those previously found at hunter-gatherer sites near the Great Lakes.

Because the object and practices appear together, emissaries, traders or perhaps religious pilgrims must have traveled most or all of the more than 1,500 kilometers from the Upper Midwest to St. Catherines Island, off Georgia's coast, the researchers conclude online September 2 in *American Antiquity*.

Until now, "there was no clear evidence for direct, long-distance exchange among ancient hunter-gatherers in eastern North America," says anthropologist Matthew Sanger of Binghamton University in New York. Finds at the McQueen Shell Ring on St. Catherines Island suggest that such exchanges involved objects and ideas that had spiritual significance, such as how to bury the dead.

Only a massive, enigmatic earthworks in northern Louisiana called Poverty Point, inhabited from around 3,700 to 3,200 years ago, has yielded copper and other artifacts apparently obtained directly from groups based hundreds of kilometers or more away. But the findings at the McQueen Shell Ring show for the first time that such exchanges weren't limited to great gatherings but also occurred between smaller groups going about their daily lives, says Harvard University anthropological archaeologist S. Margaret Spivey-Faulkner, who was not involved in the study.

Close ties among ancient hunter-gatherers across eastern North America "would have been a hard sell in [archaeology] even a decade ago," she adds.

The McQueen Shell Ring consists of a massive circle of seashells, about 70 meters across, surrounding an earthen plaza. More than 50 such circular or arcing shell rings, dating to between about 5,800 and 3,200 years ago, have been found at hunter-gatherer campsites along the Atlantic and Gulf coasts. Some shell rings measure more than 200 meters across and were piled more than 5 meters high; others are less than 50 meters across and relatively flat.

Researchers once thought that direct ties between populations spanning much of North America emerged only around 2,000 years ago among farming communities. That would have been 12,000 years or more after people first reached North America, including what's now Florida (*SN: 6/11/16, p. 8*).

Ancient hunter-gatherers in eastern North America were thought to have traded stone tools and other items over long distances, starting roughly 5,000 years ago, but only via a string of shorter-distance exchanges between nearby groups, which eventually spread the valued objects to distant locales. In those instances, hunter-gatherers who initiated the trades would have had no influence on how an object was used by its final recipients.

But that wasn't the case for the objects at the McQueen Shell Ring, Sanger's team found. Excavations in the center of the shell ring uncovered a burial pit filled with more than 80,000 ash-encrusted bone and tooth fragments, a copper band and remnants of stone tools. An analysis of the copper band's chemical composition by Sanger and colleagues, published in the April *Journal of Archaeological Science: Reports*, indicates that the metal came from any of several ancient copper mines bordering Lake Superior and located on islands in that lake. Copper mining there dates to as early as 7,900 years ago. Radiocarbon dating of burned material in the McQueen Shell Ring burial pit places the copper band between 4,300 and 3,800 years old.

Crucially, the hunter-gatherers at McQueen also appear to have adopted ways of using the copper band into new customs for treating the dead. The shell ring grave contained the remains of at least seven people, all of whom were cremated. Burials of cremated individuals along with copper objects and other items characterized ancient hunter-gatherers in the Great Lakes area, and occasionally occurred in the Ohio River Valley and the Little Tennessee River Valley. Clear examples of ancient cremations in the coastal southeastern United States are rare.

The McQueen Shell Ring and a nearby shell ring on the island may have hosted gatherings of people in the late winter or early spring. Both circular structures contain remains of fish that were caught year-round, numerous clams and oysters harvested toward the end of winter and in early spring, and nuts such as hickory and acorns that were harvested in the fall and could be stored for later use.

Hunter-gatherer groups based in the area may have gathered for seasonal ceremonies that included burial customs imported from the Upper Midwest, Sanger suspects. ■

A copper band discovered at a roughly 4,000-year-old archaeological site on an island off Georgia's coast originated in the Great Lakes region, researchers say.

M. SANGER

BODY & BRAIN

Foot artists have specialized brains

Scans find neural 'toe maps' in painters born without arms

BY LAURA SANDERS

Two artists who paint with their toes have unusual neural footprints in their brains. Individual toes each take over discrete territory, creating a well-organized "toe map," researchers report in the Sept. 10 *Cell Reports*.

Similar brain organization isn't thought to exist in people with typical toe dexterity. So finding these specialized maps brings scientists closer to understanding how the brain senses the body, even when body designs differ (*SN: 7/6/19 & 7/20/19, p. 16*).

"Sometimes, having the unusual case — even the very rare one — might give you important insight into how things work," says Denis Schluppeck, a neuroscientist at the University of Nottingham in England who was not involved in the study.

The two artists in the study were born without arms due to the drug thalidomide, formerly used to treat morning sickness in pregnant women. Both men rely heavily on their feet, which possess the dexterity to use cutlery, write and use computers.

The brain carries a map of areas that handle sensations from different body parts; sensitive fingers and lips, for example, have big corresponding areas. But so far, scientists haven't had much luck in pinpointing areas of the human brain that respond to individual toes (although toe regions have been found in the brains of nonhuman primates). Because these men use their feet in unusually skilled ways, researchers wondered if the men's brains might represent toes a bit differently.

When each toe was touched, a patch of brain became active.

The two artists, along with nine other people with no special foot abilities, underwent functional MRI scans while an experimenter gently touched each toe. For many people, the brain areas that correspond to individual toes aren't discrete, says neuroscientist Daan Wesselink of University College London. But in the foot artists' brains, "we found very distinct locations for each of their toes." When each toe was touched, a patch of brain became active, linking neighboring toes to similarly neighboring areas of the brain.

Researchers don't yet know when this map in the brain gets drawn. Wesselink suspects that the artists' toe maps were created very early on and sharpened over decades of sophisticated toe use. "When you use your body in a different way, from very young, your brain develops differently," he says.

Dan Feldman, a neuroscientist at the University of California, Berkeley, describes the mark that the toes leave on the brain as a kind of sensory autobiography. "Here, these two individuals had a particularly unique sensory experience," he says, "and one can see the trace of that in their brains." ■

MATH & TECHNOLOGY

Nighttime panel makes electricity

Cold-harnessing device could be useful in remote locations

BY MARIA TEMMING

A new device is an anti–solar panel, harvesting energy from the cold night sky.

By harnessing the temperature difference between Earth and outer space, a prototype of the device produced enough electricity at night to power a small LED light. A bigger version of this nighttime generator could someday light rooms, charge phones or power other electronics in remote or low-resource areas that lack electricity at night, when solar panels don't work, researchers report online September 12 in *Joule*.

The core of the new night-light is a thermoelectric generator, which produces electricity when one side of the generator is cooler than the other. The sky-facing side is attached to an aluminum plate sealed beneath a transparent cover and surrounded with insulation to keep heat out. This plate stays cooler than the ambient air by shedding any heat it absorbs as infrared radiation. That radiation zips up through the transparent cover and into the atmosphere toward the cold sink of outer space.

Meanwhile, the generator's bottom is attached to an exposed aluminum plate that is continually warmed by ambient air. At night, when not baking under the sun, the top plate gets a couple of degrees Celsius cooler than the bottom of the generator.

Stanford University engineer Wei Li and colleagues tested a 20-centimeter-wide prototype on a December night in Stanford, Calif. The generator produced up to about 25 milliwatts of power per square meter of device — enough to light a small light-emitting diode, or LED, bulb. The team estimates that design improvements, like better insulation around the cool top plate, could boost production up to at least 0.5 watts per square meter.

"It's a very clever idea," says Yuan Yang, a materials scientist at Columbia University not involved in the work. "The power generation is much less than solar panels," which generally produce at least 100 watts per square meter. But this nighttime generator may be useful for emergency backup power, or energy for people living off the grid, Yang says.

Coauthor Aaswath Raman, a UCLA materials scientist and engineer, sees the generator as a way to power remote weather stations or other environmental sensors. This may come in handy in polar areas that don't see sunlight for months at a time, Raman says. "If you have some low-power load and you need to power it through three months of darkness, this might be a way." ■

LIFE & EVOLUTION

Coral sex may be losing its rhythm

Out-of-sync spawning could be an effect of climate change

BY SUSAN MILIUS

Bad timing for coral sex might be an underappreciated threat of climate change.

Spawning could be out of sync for at least three coral species in the Red Sea, says Tom Shlesinger, a marine biologist at Tel Aviv University. Warmer seawater could be playing a role.

Records from the 1980s suggest that each coral species typically has its own night or nights for releasing colorful egg-sperm bundles into the water, Shlesinger says. Corals release their sex cells in a big synchronized cloud, gaining a chance at fertilization during the brief time that they survive on their own. It's "a wonder of nature," he says.

But after four years of monitoring, Shlesinger argues that three of five species studied no longer tightly synchronize gamete releases on species-specific nights. Few if any new colonies of these kinds of corals are showing up in recent surveys, so the species might dwindle away in the region, Shlesinger and Yossi Loya, also of Tel Aviv University, warn in the Sept. 6 *Science*.

Shlesinger didn't set out to compare local spawning synchrony. "It's something that kind of grabbed me," he says. After realizing some corals weren't spawning when expected, "I started going to the sea at night."

By the second year of his questing, he was snorkeling or diving several hours a night during spawning months. Some 150 species of corals mingle in the long, narrow gulf of the Red Sea that stretches northeast past Eilat in Israel and Aqaba in Jordan. Unlike the Great Barrier Reef in Australia, where more than 100 coral species can release their gametes together on the same night, the Red Sea's corals spawn one species or a few at a time on their own special nights.

Shlesinger had seen corals spawn elsewhere, but the night he finally got the timing right to catch an event in the Red Sea was "magical," he says. He first spotted small, pink egg-sperm bundles drifting up from a single coral. Soon he was swimming through "a colorful snowstorm" of little pink capsules rising from hundreds or even thousands of corals.

A whole species can synchronize spawning to the same half hour. That precision depends on an interlocking set of environmental cues. Water temperature, sunlight and wind affect the month of the event, researchers have found. The phase of the moon matters in determining the night; local sunset cues the time.

Data from 1980 to 1982 on the five studied species show consistent, synchronous patterns of mass spawning, based on regular lab exams of coral samples plus nighttime swims. But in 225 swim surveys from 2015 through 2018, Shlesinger discovered that only two of the five species still managed to spawn en masse during just a few nights. Three species didn't synchronize tightly. In 2018, for instance, at least a few big lumps of the brain coral *Platygyra lamellina* spawned just about every night from June 12 to July 18. Mini releases don't create a thick enough soup of gametes to make fertilization likely, especially after fish finish feasting on the bundles.

Little pink bundles that contain eggs and sperm lift off from Red Sea colonies of the branching coral *Acropora eurystoma*.

T. SHLESINGER

The moon still waxes and wanes regularly, but other spawning cues may be wavering. For instance, since 1982, during the earlier surveys, water in the northern part of the gulf has warmed about 0.31 degrees Celsius per decade, the researchers calculate. Pollutants, especially hormone-disrupting ones, might also be sabotaging coral reproduction, the scientists say.

Corals around the world are already threatened by rising temperatures, which can cause corals to bleach severely and die (*SN: 2/3/18, p. 16*), among other threats. Various efforts are under way to help rehab and protect these spectacular ecosystems (*SN: 10/29/16, p. 18*).

Biologists have certainly fretted that climate change might also knock coral spawning synchrony askew, says James Guest, a coral biologist at Newcastle University in England. It's not easy finding old records with methods comparable to today's, however. Older data might have missed some of the smaller blips in synchrony that showed up in Shlesinger's diligent swimming, Guest says.

Some corals have a bit of natural play in their timing, says coral biologist Taryn Foster of the California Academy of Sciences in San Francisco. In her work off the coast of Australia, she's found that corals in Scott Reef observe a sort of leap year. Every two or three seasons, they split their spawning into two separate bursts, thus coping with the way moon phases cycle faster than annual cues. These corals, however, break their spawning into roughly equal parts. It's the small bursts of spawning described in the new study that she worries about.

That's the menace to the three corals, Shlesinger says. In 10 sample plots at Eilat that he has monitored, some other species are doing well. Yet the three species he flagged as spawning out of sync did not have enough tiny new corals to replace the old colonies. ■

HUMANS & SOCIETY

DNA offers a first look at Denisovans

Only a few fossils of the enigmatic hominids have been found

BY BRUCE BOWER

Scientists have painted a portrait of a young female who belonged to a mysterious, humanlike population known as Denisovans at least 50,000 years ago.

Here's the kicker: Only a handful of Denisovan fossils have been found, including the youngster's pinkie finger. So a team led by evolutionary geneticists David Gokhman and Liran Carmel of Hebrew University of Jerusalem reconstructed the Denisovan teen's skeleton using only a palette of ancient DNA patterns. A description of how the team transformed DNA into a physical appearance is in the Sept. 19 *Cell*.

"This is the first reconstruction of the skeletal anatomy of Denisovans," Carmel says. A drawing based on that skeleton shows the Denisovan gazing ahead coolly with wide, dark eyes framing the bridge of a broad nose. That profile, and the rest of the girl's appearance, was gleaned from key changes to parts of DNA that regulate the activity of genes involved in skeletal development, the team says.

Scientific reactions to the Denisovan girl's genetically informed appearance range from cautious curiosity to outright skepticism. This is "a pioneering piece of research, which at first glance seems almost like science fiction," says paleoanthropologist Chris Stringer of the Natural History Museum in London. A final verdict on the accuracy of the girl's portrait awaits discoveries of more Denisovan skeletal parts, he adds.

Denisovans have posed an evolutionary enigma since the Siberian discovery of part of the ancient girl's little finger in 2008 (*SN: 9/22/12, p. 5*). Only a few other Denisovan fossils have been found — several teeth, a limb bone and a lower jaw (*SN: 6/8/19, p. 6*). Ancient DNA analyses indicate that Denisovans, who are thought to have inhabited parts of Asia from about 300,000 to 50,000 years ago, were more closely related to Neandertals than to *Homo sapiens*. Some present-day human populations carry small amounts of Denisovan ancestry.

A reconstruction of a Denisovan girl who lived in Siberia at least 50,000 years ago is based on an analysis of her DNA.

Gokhman, now at Stanford University, and Carmel's group examined molecular markers of DNA methylation, a process that changes the activity of a segment of DNA without altering the chemical sequence. The researchers analyzed methylation patterns in DNA from the Denisovan girl, two Neandertals who lived about 50,000 years ago and five *H. sapiens* dating from 45,000 to 7,500 years ago. Together with methylation data from 55 present-day humans and five chimpanzees, the team identified places where these species have methylation differences.

Previous studies of human skeletal disorders in which specific genes that control methylation lose their function helped the scientists estimate how methylation differences between species would affect bone shapes, such as making an upper leg longer or shorter. And, as a test of the technique, the researchers used the methylation patterns to identify known anatomical differences between Neandertal and chimp skeletons with at least 85 percent accuracy.

Methylation comparisons indicated that Denisovans probably shared many skeletal traits with Neandertals, such as wide hips and a low forehead. Denisovan traits that probably evolved independently include wide dental arches and a broad braincase.

Methylation-based predictions correctly identified many traits seen on the previously discovered Denisovan jaw, the team says. Two partial, unidentified *Homo* braincases from China, which date to between 130,000 and 100,000 years ago, also appear to have Denisovan features reported in the study.

The new approach to reconstructing skeletons from methylation data shows promise, but much remains unknown about how DNA contributes to species differences, says evolutionary geneticist Pontus Skoglund of the Francis Crick Institute in London. "We don't know exactly what it is in the genome that makes a chimpanzee a chimpanzee and a human a human."

What's more, the researchers didn't account for complex ways in which skeletons of, say, Neandertals and *H. sapiens* differ, says paleoanthropologist John Hawks of the University of Wisconsin–Madison. For instance, the team assumes that Neandertals' hip bones were larger in all ways than those of *H. sapiens*. Neandertal hip fossils tend to be especially wide, but include thinner pubic bones at the front of the pelvis than those observed in most people today, Hawks says. Complicated mixes of traits in the pelvis and other body parts raise doubts about the accuracy of the methylation predictions, he contends.

So does a study posted February 19 at bioRxiv.org. In that research, DNA methylation patterns specific to five nonhuman primate species, including chimps and baboons, display generally weak links to differences in upper-leg bone shapes, reported a team led by evolutionary biologist Genevieve Housman, now at the University of Chicago.

Researchers have yet to evaluate whether methylation differences predict bone shapes in living people, Hawks says. ■

MAAYAN HAREL

BODY & BRAIN

Air pollution can reach the womb

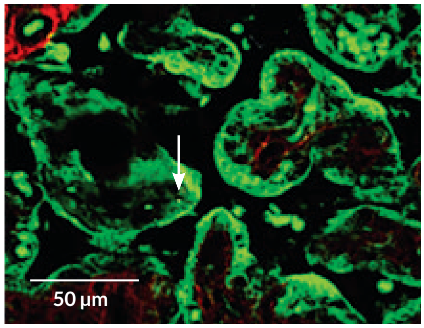
Placentas collected after birth contained soot particles

BY AIMEE CUNNINGHAM

Breathing in polluted air may send soot far beyond a pregnant woman's lungs. It can travel all the way to the womb surrounding her developing baby.

Samples of placentas collected after women gave birth contained soot, or black carbon, researchers report online September 17 in *Nature Communications*. The placenta, which provides nourishment to the fetus, is attached to the inside of the womb. Black carbon reached all the way to the side of the placenta that faces the fetus, and the amount of soot embedded in placental tissue correlated with a woman's air pollution exposure.

"There's no doubt that air pollution harms a developing baby," says Amy Kalkbrenner, an environmental epidemiologist the University of Wisconsin–Milwaukee who wasn't involved in the work. Mothers who encounter air pollution regularly are at higher risk of having babies born prematurely or with low birth weight, studies have shown.



Black carbon that a pregnant woman breathes (white dot, pointed out by the arrow) can embed in placental tissue (green).

Both problems have been tied to an inflammatory response to air pollution in a mother's body. But the new findings, Kalkbrenner says, may indicate that "air pollution itself is getting into the developing baby."

The study looked at black carbon, emitted in the burning of fossil fuels such as diesel and coal. Researchers in Belgium at Hasselt University in Diepenbeek and Katholieke Universiteit Leuven used femtosecond pulsed laser illumination to test samples for soot. The method involves using fast laser bursts to excite electrons within the tissue, which then emits light. Different tissues generate certain colors, such as red for collagen and green for placental cells. The team detected black carbon, which glowed white.

The team also looked at whether the amount of black carbon detected in 20 samples matched a woman's air pollution exposure, estimated based on where she lived in Belgium. More soot was found in the samples from 10 women with higher pollution levels in their residential areas than in the samples from 10 women living with lower levels.

The study hints that it may be possible to test for a person's pollution exposure from tissue samples or even blood, says Kalkbrenner. Scientists mainly estimate exposure based on where a person lives, which can leave out other sources such as those encountered at work. ■

BODY & BRAIN

Birth mode shapes baby microbiomes

C-sections lead to newborns with fewer helpful bacteria

BY LAURA SANDERS

Babies born by cesarean section may miss out on many of mom's helpful gut microbes. Instead, these infants' guts harbor more bacteria that commonly lurk in hospital rooms, scientists report online September 18 in *Nature*.

The finding adds weight to the idea that C-sections, and the antibiotics that mom takes for the procedure, affect the type of bacteria that take up residence in a newborn's gut. Early colonization of the gut microbiome may be important for long-term health, some scientists suspect.

The results shouldn't dissuade women from receiving C-sections if needed, says Lisa Stinson, a reproductive biologist at the University of Western Australia in Perth. But "we need a better understanding of their long-term effects."

Microbiome imbalances have been linked to asthma, allergies and other inflammatory diseases. But scientists don't know whether a baby's nascent microbiome influences these disorders. Nor has it been clear whether birth details shape early microbial colonization.

Genomicist Yan Shao of the Wellcome Sanger Institute in Hinxton, England, and colleagues studied fecal samples that included gut bacteria from 596 full-term, healthy babies. In the 314 babies born vaginally, helpful gut microbes such as *Bifidobacterium* and *Bacteroides* made up an average of 68 percent of the total gut bacteria. But in babies born by C-section, species commonly found in hospitals, such as potentially harmful *Enterococcus* and *Clostridium*, accounted for an average of 68 percent of the gut bacteria.

Neither group had much bacteria from mothers' vaginas, an absence that calls into question the usefulness of smearing vaginal fluids onto babies born via C-section as a way to restore normal gut microbiota. The study "found no evidence to support controversial 'vaginal swabbing' practices," Shao says.

Antibiotics given to women during delivery also shape which bacteria set up shop in babies' guts, the study suggests. Mothers who undergo C-sections may receive antibiotics to prevent infections. Along with removing threats, these drugs can kill helpful bacteria. Even babies born vaginally but whose moms took antibiotics had fewer helpful *Bacteroides* bacteria, which suggests that some of the bacterial differences are "related to maternal antibiotic exposure," Stinson says.

As babies grew older and began eating solid foods, differences in gut bacteria composition shrank, the team found by looking at a subset of the babies. ■

H. BOVÉ *ET AL*/*NAT. COMMUN.* 2019

THE SN 10 SCIENTISTS TO WATCH

Meet 10 scientists with a passion for solving problems

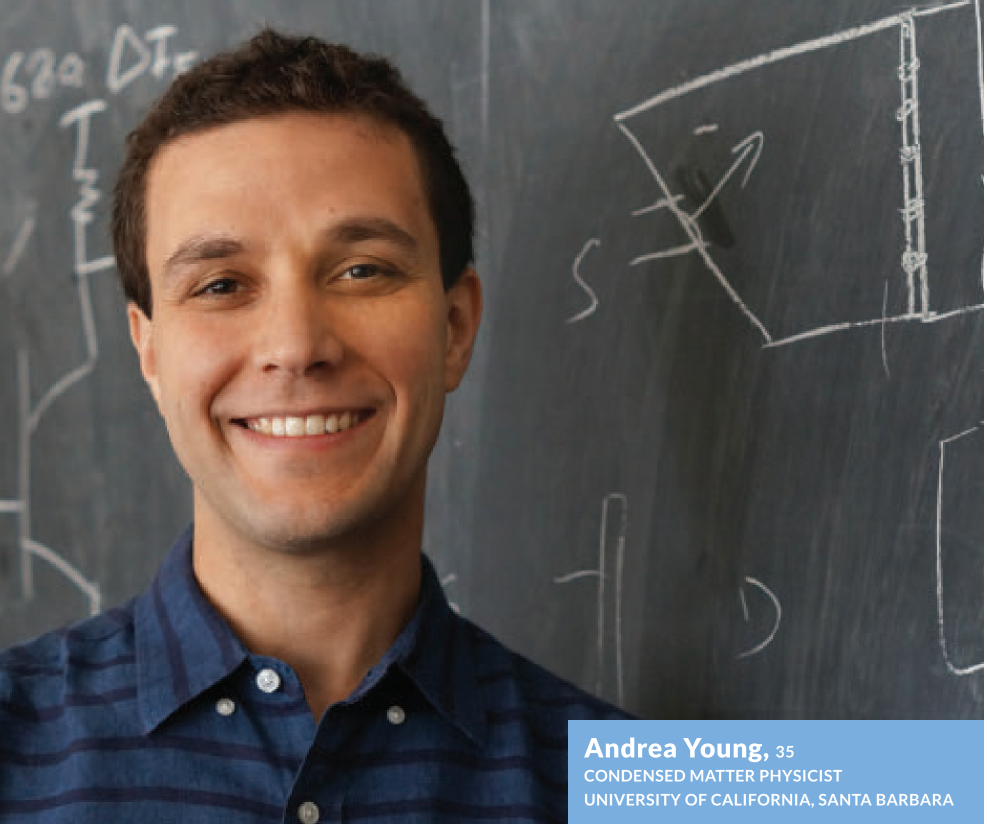
After nearly four years of painstaking work, in 1902 Marie Curie produced one-tenth of a gram of radium chloride from several tons of uranium ore. It took her another eight years to isolate pure radium. The effort won her a second Nobel Prize and cemented her legacy as one of science's most tenacious minds. "One never notices what has been done; one can only see what remains to be done," Curie once wrote to her brother, Józef Skłodowski.

Doing science, and doing it well, can be frustrating, tedious and messy. There are long days at the computer, finicky experimental setups, do-overs and dead ends. And for one researcher featured on the pages that follow — digging into goat poop. Yet this year's SN 10: Scientists to Watch appear to take it in stride. Why? They enjoy the work.

For the fifth consecutive year, *Science News* is spotlighting 10 early- and mid-career scientists who are persistent enough to make headway on science's big questions. Some are tackling problems of societal importance: studying how climate change will affect food supplies, for example, or trying to make education more equitable. Others are seeking knowledge to answer fundamental questions, such as how the chemistry of space gives rise to the chemistry of life. Members of this year's group are developing new tools to see deep into cells or into the mind, and are finding new routes to green fuels (thank you, goats).

And they're doing it all before age 40. Nominations came in from Nobel laureates and recently elected members of the National Academy of Sciences. For the first time, our list also includes a name submitted by a previous SN 10 scientist; we had a hunch that young researchers would have intel on their standout peers. A *Science News* staff committee scrutinized the lot for contributions to science thus far and signs of future success.

For all their persistence, these scientists have equal amounts of passion. I was lucky enough to write one of this year's profiles — indulging my own delight in writing about the complexities of physics. As Monika Schleier-Smith told me during our interview, "I feel very fortunate to have a job where the work feels like play." Read on; she's not alone. — *Elizabeth Quill*



Strange physics from flat materials

By Emily Conover

Speaking with Andrea Young feels like watching a racehorse holding itself back at the starting gate. We met on the campus of the University of California, Santa Barbara, where he's a condensed matter physicist, to chat about his work on 2-D materials. His mind seems to be working faster than the conversation can flow. My sense is, once the reins are loosened — and he's back in the lab — he'll take off.

Young's colleagues confirm that's the case. "He's a whirlwind," says physicist Raymond Ashoori of MIT. When Young was a postdoc in his lab, Ashoori says, it felt like "an idea a minute."

Young, 35, has a way with substances shaved to the thickness of a single atom, such as the sheets of carbon known as graphene (*SN: 8/13/11, p. 26*). His research has revealed new states of matter and advanced scientists' understanding of the strange physics that arises when materials are sliced thin.

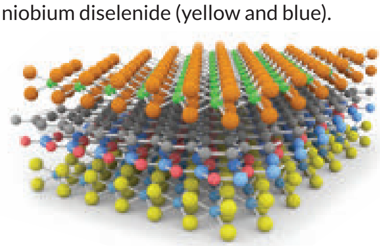
"Things change a lot when you change the number of dimensions," Young says.

As a graduate student at Columbia University, Young helped create a new type of material that transformed how scientists study graphene. Along with physicists Cory Dean, Philip Kim and colleagues, Young devised a technique for layering graphene with other materials, in particular another compound that forms 2-D sheets called hexagonal boron nitride. The combination makes the sometimes-finicky graphene easier to work with. And the material's electrons can be coaxed to behave in unusual ways.

Reported in *Nature Nanotechnology* in 2010, the technique was quickly adopted by scientists around the world. "Everybody uses it now," Ashoori says.

After his time at Columbia, Young went on to stints at MIT and the Weizmann Institute of Science in Rehovot, Israel, before landing at UC Santa Barbara in 2015. So far, Young has used his layering technique to reveal new quantum phenomena and states of matter with tongue-twisting names like Hofstadter's butterfly and fractional Chern insulators. In many of the materials Young studies, electrons exhibit collective behavior, resulting in quasiparticles, excitations in a material that mimic a real subatomic particle (*SN: 10/18/14, p. 22*). It's a bit like how a crowd of individual people can do the wave by working together.

Andrea Young studies how materials behave when 2-D sheets are layered atop one another. The material below includes layers of graphene (gray) and hexagonal boron nitride (red and blue), which are sandwiched by tungsten diselenide (orange and green) and niobium diselenide (yellow and blue).



Keeping up with Young's rapid progress in the lab kept his graduate adviser, Kim, busy. "He's extremely brilliant and very energetic," says Kim, now at Harvard University. Young's understanding of theoretical concepts, combined with experimental know-how, makes him quick to generate and implement new ideas, or follow up on hot research topics.

In 2018, he, Dean and colleagues were the first to replicate a blockbuster result in condensed matter physics: Two sheets of graphene, when layered and rotated with respect to one another, become superconducting, allowing electrons to flow without resistance. Young and colleagues added their own twist, reporting this March in *Science* that the material's superconductivity could be tuned by putting it under pressure.

Young's swiftness seems to take multiple forms — quickness of thought, experimental agility and even fleetness of foot. During a particularly frenzied time, Dean, who has collaborated with Young for years, was headed to the lab bright and early at around 7 a.m. When Dean looked up, "100 yards ahead of me was Andrea, rushing even faster to get to the lab."

Young's fascination with physics came on quickly, too: "From my earliest memories, I wanted to be a physicist, and it's not clear where that idea got nucleated," says Young, who grew up in Washington, D.C. But he doesn't see himself as fast. Rather than aiming for quick developments, he's motivated by big-picture, long-term questions.

His current passion is searching for

FROM TOP: SONIA FERNANDEZ; C. DEAN

a proposed new class of quasiparticles, called non-abelian anyons. "That's become the thing that … I'm obsessed with," he says.

Scientists have discovered a wide variety of quasiparticles, but anyons don't fit into either of the two categories all other particles do. They aren't fermions, familiar particles like electrons, protons and neutrons; nor are they bosons, which include force-carrying particles, such as photons, particles of light that transmit electromagnetic forces.

Anyons, which appear only in two dimensions, are misfits. Non-abelian anyons are stranger still. Theory suggests that they can be "braided" with one another by swapping their locations in a material. The braiding could protect fragile quantum information from becoming corrupt, potentially allowing scientists to create quantum computers that can perform calculations no standard computer can.

But no one has definitively shown that non-abelian anyons exist and have useful properties for quantum computing. A new state of matter called a fractional Chern insulator, which Young and colleagues reported for the first time in 2018 in *Science*, could be a hiding place.

Young — hunter of strange denizens of 2-D matter — is in pursuit. ■

Melding minds and machines

By Maria Temming

Maryam Shanechi, 38
NEURAL ENGINEER
UNIVERSITY OF SOUTHERN CALIFORNIA

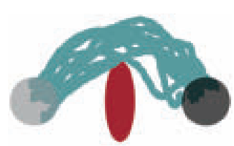
Mind reading may sound like a sci-fi dream, but it's Maryam Shanechi's day job.

This neural engineer doesn't need mind melds or magic spells to tap into brain activity. Rather, Shanechi develops computer algorithms that translate electrical blips emitted by brain cells into machine commands. Shanechi has designed and tested systems that harness neural firings to control computer cursors or administer just the right amount of anesthetic.

Now, Shanechi is forging into a new frontier — mind control. She's on a mission to create brain-machine interfaces that not only eavesdrop on cells, but also stimulate them to alter mood. This mental manipulation may one day offer a better treatment to millions of patients with psychiatric disorders, like anxiety or depression, who don't respond to existing therapies.

Shanechi, 38, arrived on the neuroscience scene almost by accident. In graduate school, she was studying techniques to decode wireless communication signals. But one rainy morning in her MIT dorm, Shanechi stumbled across a video of a computer algorithm that could predict a rat's location in a maze based solely on the rodent's brain activity. Despite knowing nothing about neuroscience, Shanechi thought, "How cool would it be if I could decode brain signals?"

Ziv Williams, who worked with Shanechi when she was in graduate school, says she easily adapted to neuroscience research methods, like working with live animals. With degrees in computer science and electrical engineering, Shanechi brings skills to brain-machine interfaces that "neuroscientists who come at it from a biological perspective do not have," says Williams, a neurosurgeon at Harvard University and Massachusetts General Hospital in Boston.



Monkeys hooked up to a brain-machine interface that decoded intended movement at millisecond timescales were deftly able to move a computer cursor from one gray dot to another while avoiding a red oval (cursor tracks are shown in blue).

Engineers have been developing brain-machine interfaces to allow paralyzed patients to move computer cursors or robotic limbs for two decades (*SN: 12/29/12, p. 20*). But such devices are still largely limited to research settings.

Shanechi designed her first mind reading algorithm to figure out how a monkey wanted to move a computer cursor, based on signals collected by electrodes implanted in the monkey's premotor cortex. Whereas other machinery had processed intended motions one by one, Shanechi's system anticipated an entire series of movements for finer control. The work was reported in 2012 in *Nature Neuroscience*. Seeing her algorithm correctly predict a monkey's movements for the first time was "the most exciting moment in my whole career," Shanechi says.

When something sparks Shanechi's interest, "she goes all the way," says her father, Hassan. He recalls an English class Shanechi took after the family moved from Iran to Canada, when Shanechi was a teenager. She wanted to take an advanced literature course but was told her English wasn't good enough. Undeterred, she enrolled in a class for students learning English as a second language and then reapplied a few months later. She was admitted to

FROM TOP: USC VITERBI; M.M. SHANECHI *ET AL/NAT. COMMUN.* 2017 the class and performed so well that she was exempt from the final exam.

Now at the University of Southern California in Los Angeles, Shanechi devises new algorithms to seamlessly put thoughts into motion. In *Nature Communications* in 2017, her team reported a brain-machine interface that tracks individual nerve cell firings to decipher intended movement at millisecond timescales — a major upgrade from systems that decode movements based on the number of nerve cell firings in 50- to 100-millisecond intervals.

Tailoring a brain-machine interface to monitor individual nerve cell firings is the kind of design rigor that makes Shanechi stand out, says Emery Brown, a statistician and anesthesiologist at MIT and Mass General and Shanechi's graduate school adviser.

Shanechi is now laying the groundwork for a new generation of devices that would stimulate the brain to coax patients with psychiatric disorders into healthier headspaces. Unlike typical deep-brain stimulation that has to be manually adjusted, these devices would monitor a patient's symptoms and adjust stimulation automatically.

Deciphering mood is harder than interpreting movement, Shanechi says, because the nerve cells responsible for mood span several brain regions, and scientists don't yet understand how the cells coordinate.

Last year, Shanechi's team demonstrated that a computer algorithm can use a person's brain activity to judge how good or bad the person feels (*SN: 2/16/19, p. 22*). And because a mood-improving device also needs to know how different kinds of electrical stimulation tickle different brain cells, Shanechi is working on a system that feeds a train of electrical pulses into the brain and catalogs how nerve cells react.

Despite the sci-fi–sounding nature of her work, Shanechi's motivation is the real-world impact her technology could have. "What I really enjoy," she says, "is to see a mathematical concept making its way toward making a difference in people's lives." ■

FROM TOP: COURTESY OF B. MCGUIRE; ESO

Brett McGuire, 32
ASTROCHEMIST
NATIONAL RADIO ASTRONOMY OBSERVATORY

A chemical census of interstellar space

By Lisa Grossman

In a different reality, space might smell like almonds. After all, scientists surveying the chemicals in the cosmos have found benzonitrile; just a bit of the compound would fill your nostrils with a bitter almond scent.

But our cosmos is too vast. "Space smells like nothing," says Brett McGuire. "There's not enough to get an actual whiff."

McGuire, 32, an astrochemist at the National Radio Astronomy Observatory in Charlottesville, Va., confirmed the presence of benzonitrile in a dark cloud in the Milky Way. He also discovered some of the other most complex molecules in space to date. By figuring out which molecules are out there, he and others hope to learn how the organic chemistry that undergirds all life on Earth — and perhaps elsewhere in the universe — gets started in space.

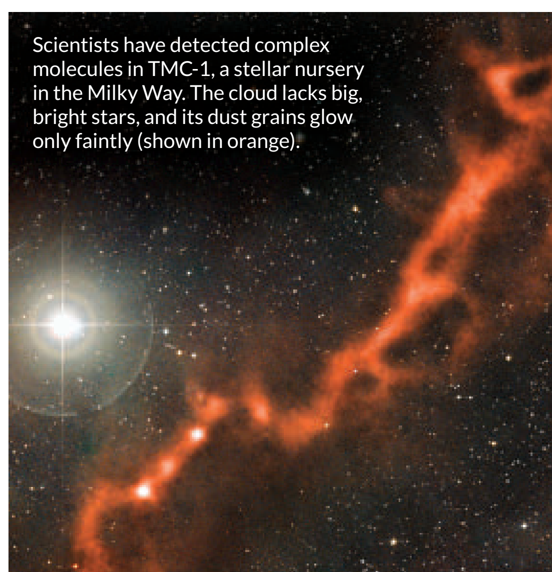
McGuire got his start in space as an undergraduate majoring in chemistry at the University of Illinois at Urbana-Champaign. He remembers Ben McCall, a former astrochemist who is now a sustainability expert at the University of Dayton in Ohio, explaining his work. McCall said something like, "I blow shit up, torture it with lasers and then I look for it in space," McGuire recalls.

Enough said. McGuire spent that summer working in McCall's lab, building a spectrometer to study how hydrogen gas, H_2, reacts with H_3^+ — three hydrogen atoms with only two electrons. Some of McCall's research included zapping gases of simple molecules with electricity — "an actual miniature lightning bolt," McGuire says — to force atoms to recombine into new compounds.

"Brett was a very precocious young scientist," McCall says. "This was the only time I've had a student who really started a new instrument from scratch as an undergrad."

Because space is so big and mostly empty, at least by Earth standards, it can take millions of years for two molecules flying around like billiard balls to get close enough to interact. "But it's not just neutral billiard balls out there," McGuire says. A charged molecule, like H_3^+, can pull other molecules closer. "More or less all chemistry in space can trace itself back to H_3^+ at some point."

And all that chemistry includes some tantalizingly lifelike stuff. In 2016, McGuire and colleagues reported discovering propylene oxide in a gas cloud within the Milky Way. That was the first molecule seen in space that, like the amino acids that make up proteins and are essential to life on Earth, has two forms that mirror each other (*SN: 7/9/16, p. 9*). Large rings of carbon and hydrogen, called polycyclic aromatic hydrocarbons, or PAHs, have also been spotted around dead or dying stars — though it's been



Scientists have detected complex molecules in TMC-1, a stellar nursery in the Milky Way. The cloud lacks big, bright stars, and its dust grains glow only faintly (shown in orange).

hard to tell how many carbons and hydrogens the PAHs contain.

PAHs are thought to be the seeds of dust, planets and organic chemistry in our galaxy and other galaxies, McGuire says. So how do they form? "How do you go from H_3^+ to things that literally click together to make the building blocks of life?" he asks.

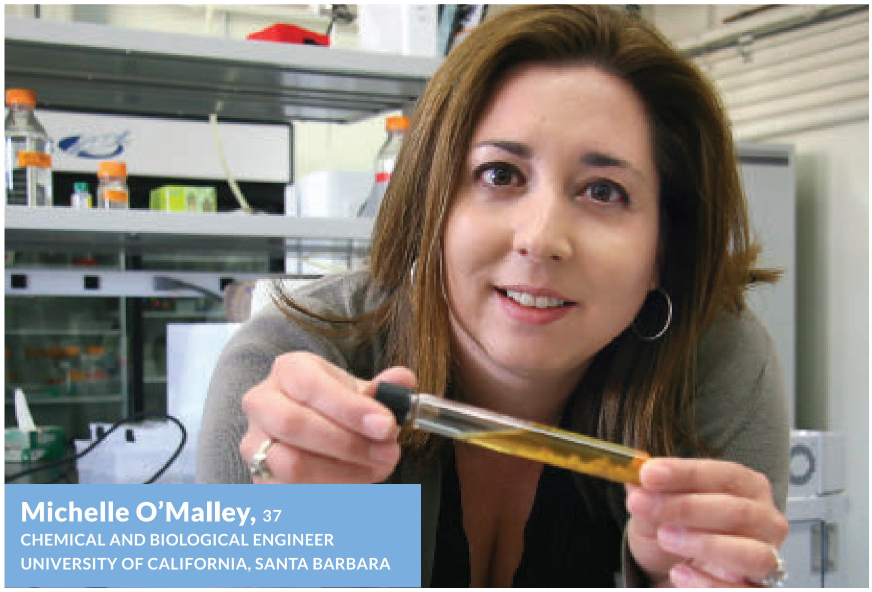
The work of enumerating what's out there mostly takes place in a lab on Earth. McGuire injects a puff of gas of the molecule he's interested in into a large vacuum chamber, where the low temperature and pressure make the gas expand. Then he hits the gas with a pulse of intense microwave or radio radiation, sending the molecules tumbling. As they tumble, the molecules emit photons at a specific frequency. That light signature is what McGuire looks for when he turns to radio telescopes to search for those molecules in space.

Many scientists focus on the laboratory spectroscopy or the interstellar astronomy; only a few have expertise in both. "Brett is one of those very few people," McCall says.

To sniff almonds in space, McGuire and colleagues focused the Robert C. Byrd Green Bank Telescope in West Virginia on TMC-1, a dark stellar nursery about 450 light-years from Earth. Forty hours of observing confirmed that benzonitrile, a benzene ring with a cyanide molecule stuck on the end, was there.

Lately, McGuire and colleagues are closing in on a bigger prize: specific PAHs in the space between stars. Knowing the makeup of PAHs in space will help reveal how they click together from smaller molecules, McGuire says, and would show that advanced chemistry is happening, in some cases before stars begin forming.

Benzonitrile and the more complex molecules it hints at are "the first clear marker" of carbon-based chemistry in space, says Ryan Fortenberry, an astrochemist at the University of Mississippi in Oxford who wasn't involved in the benzonitrile finding. "Before this, we were just kind of wandering around in the wilderness," he says. "Now we have found the trail." ■



Michelle O'Malley, 37
CHEMICAL AND BIOLOGICAL ENGINEER
UNIVERSITY OF CALIFORNIA, SANTA BARBARA

UC SANTA BARBARA

The next champs of green chemistry

By Aimee Cunningham

If you've visited the Santa Barbara Zoo, you may have seen members of Michelle O'Malley's research team. They're the folks in lab coats and gloves, hanging out with the San Clemente Island goats and the Navajo-Churro sheep, awaiting specimens that could radically change the source of the world's fuels and chemicals.

"It can be hard to tell the difference between goat and sheep poop," says O'Malley, 37, a chemical and biological engineer at the University of California, Santa Barbara. It helps to "watch the donation take place." Once collected, the pellets go to the lab, where team members coax out the microbes that enable these animals to digest certain plants.

Specifically, O'Malley is after the anaerobic fungi that live in the digestive tract of herbivores such as sheep, goats, cows, giraffes and elephants. Along with some anaerobic bacteria, these fungi can break down grass and other plants, releasing sugars and nutrients. These particular microbial helpers are not typically members of the human digestive tract; the indigestible parts of plants pass through our guts as fiber.

O'Malley had to learn what she calls "very old-school technology" to grow the finicky fungi. Then she turned to investigating the distinctive plant-degrading enzymes the fungi make. Her big-picture plan is to sweep aside nonrenewable petroleum and pursue a more sustainable route to chemical and energy production that starts with agricultural leftovers — corn stover and wheat straw, for example — and other inedible plant material.

"As we've really delved into the discovery of these anaerobic fungi," O'Malley says, "we've certainly found enzymes that could be transferred into industry that could be really good at breaking down cellulose, hemicellulose and even lignin" — the components of lignocellulose, the fibrous parts of plants.

Lignocellulose has loads of carbon, the base of fuels and backbone of many drugs and other chemicals. The problem is that lignin, which serves "to keep microbes and their enzymes out" of plant cell walls, O'Malley says, makes it difficult to get to the sugars cellulose and hemicellulose, which contain the carbon. For industrial uses, the lignin is chemically or physically removed — a process that is often costly, toxic and wasteful, as lignin itself contains valuable chemical components.

Some fungi have a better approach. After a goat's grassy lunch, anaerobic fungi called Neocallimastigomycota burrow into the plant cell walls and release enzymes that break down lignocellulose — lignin and all.

That O'Malley took on these challenging fungi doesn't surprise her graduate school adviser, chemical engineer Anne Robinson of Carnegie Mellon University in Pittsburgh. Robinson remembers her former student as "very unafraid to tackle problems" and "able to recognize the interesting or unusual result."

After graduate school, O'Malley contacted scientists who had published research on anaerobic fungi. Most had abandoned the study of the difficult microbes. The only one who responded with an invitation to work together was Michael Theodorou, who pioneered research on the fungi and is now at Harper Adams University in Newport, England. At the time, Theodorou was in Wales, where he taught O'Malley how to isolate and grow the microbes.

It's challenging to meet the fungi's nutrient needs and keep oxygen out. The team begins with roll tubes, which are like 3-D petri dishes that offer an anaerobic environment. Carbon dioxide and a growth medium with digestive fluids are added to closed tubes. Next, the team rolls the tubes to get an even coat. Then comes a fungi-containing poop slurry, and the tubes are rolled again. If the process works, fungal colonies grow. "All of this requires a lot of careful, coordinated, quick movements," O'Malley says. It's "a lost art."

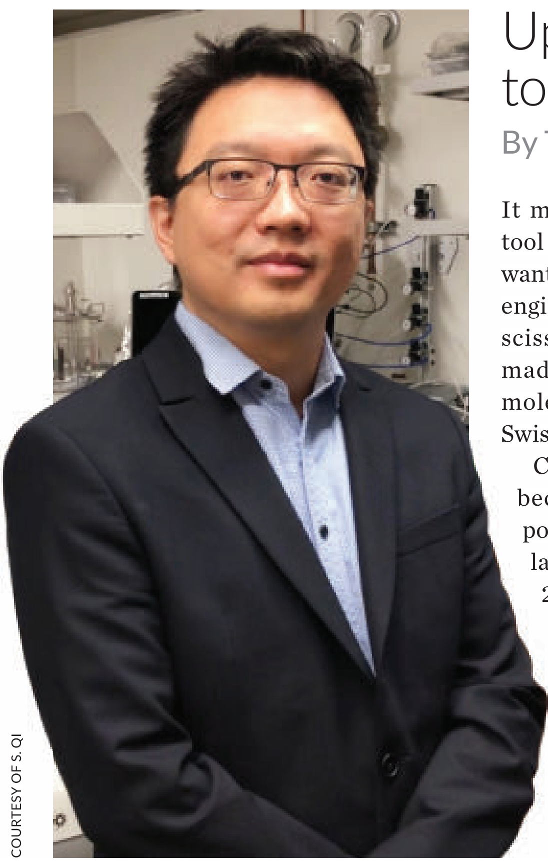
In her UC Santa Barbara lab, O'Malley has been isolating fungi from zoo samples and studying their enzymes. "Nobody really knew their true power," she says. Neocallimastigomycota, it turns out, have genetic instructions for the largest number of biomass-degrading enzymes known in nature, she and colleagues reported in *Science* in 2016.

472
Number of biomass-degrading enzymes in the fungus *Neocallimastix californiae*

The researchers have also partnered the anaerobic fungi with brewers' yeast (*Saccharomyces cerevisiae*), a mainstay of the biochemical industry, in a two-step process. The fungi efficiently broke down lignocellulose in reed canary grass, freeing the sugars to be converted to other products by the yeast, O'Malley and colleagues reported in *Biotechnology and Bioengineering* in 2018.

With the goal of unleashing these powers for the biotechnology industry, O'Malley and her group are exploring whether it makes sense to harvest the enzymes from the fungi or to turn yeast and bacteria into enzyme-making machines by incorporating fungal DNA.

Figuring out the ideal method to degrade lignocellulose biomass "has been a really intractable problem for a long time," says biochemical engineer Michael Betenbaugh of Johns Hopkins University. O'Malley "kind of forged out on her own by looking for these unusual microbes that have been doing [it] for millennia." ■



COURTESY OF S. QI

Upending genetic tools of the trade

By Tina Hesman Saey

Stanley Qi, 36
BIOENGINEER
STANFORD UNIVERSITY

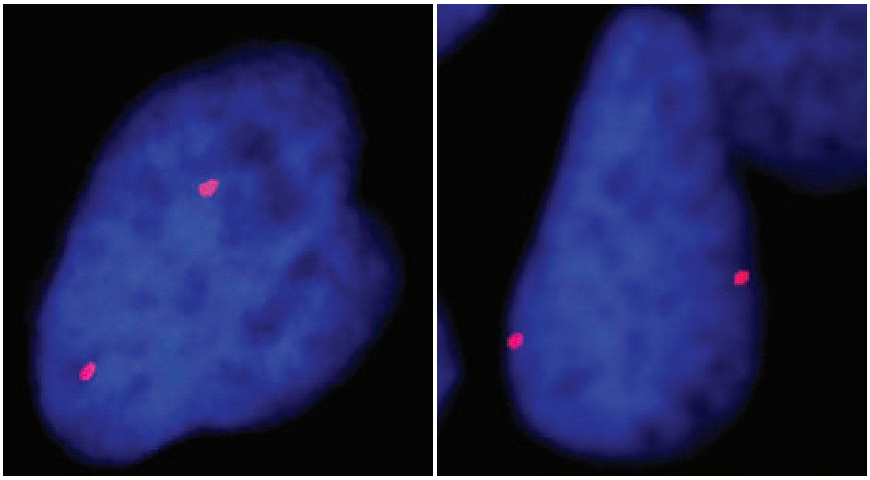
It might seem that dulling a cutting tool is the last thing an engineer would want to do, but Stanley Qi is no ordinary engineer. By blunting the gene-editing scissors known as CRISPR/Cas9, he made them even more useful — the molecular equivalent of a Swiss Army knife.

CRISPR/Cas9 has become one of the most powerful tools in molecular biology since its introduction in 2012. It is composed of an RNA (the CRISPR part) that guides a DNA-cutting enzyme called Cas9 to specific places in an organism's genetic instruction book.

As a graduate student, Qi, now 36 and a bioengineer and biotechnologist at Stanford University, disabled Cas9 so it could no longer cut DNA. The result was dead Cas9, or dCas9. Strapping enzymes, fluorescent tags or other molecules to dCas9's back has created an entire toolbox worth of DNA manipulators (*SN: 9/3/16, p. 22*). Before dCas9, researchers could use CRISPR/Cas9 only to alter the DNA bases, or letters, within a gene. After Qi and colleagues' invention, scientists could turn genes on or off, up or down, says Rodolphe Barrangou, a researcher at North Carolina State University in Raleigh and editor of the *CRISPR Journal*.

Qi not only develops the tools, he's also using them to study how cells sense the environment, how stem cells work and how to take charge of the genetic instruction book, or genome, to one day cure some genetic diseases. "He's a true synthetic biologist," Barrangou says.

Qi didn't start out in biology. The son of two accountants, he grew up in Weifang on China's eastern coast. Qi's father had always dreamed of being a scientist, but China's cultural revolution and



With a tool called CRISPR-GO, researchers moved a gene (bright spots in both images) from inside the nucleus (left) to its edge (right) — which generally has the effect of shutting the gene off.

other factors didn't allow him to study science. As a result, Qi's father learned natural sciences on his own. "As I grew up, I was strongly influenced by that kind of hopes and dreams," Qi says.

Weifang "is famous for its factories," Qi says, "but there were no good universities there." So he ended up at Tsinghua University in Beijing, where he studied physics and math. He moved to the University of California, Berkeley to study physics as a graduate student with Nobel Prize–winner Steven Chu. When Chu became Secretary of Energy and shut down his research lab, Qi changed disciplines to study bioengineering. Berkeley's free-thinking culture, especially how people explore new ideas and fields, influenced him the most, he says. "Even now as I run my lab, I always encourage people to carry this freedom of mind ... instead of narrowing yourself to one particular topic," Qi says.

Qi was intrigued by CRISPR, and soon learned everything he could about the RNA-guided system. It didn't take long back then. "You could finish reading all the CRISPR literature in 2008 in one hour," he jokes.

Qi first used dCas9 as a roadblock that sits on DNA in front of a particular gene and prevents other proteins from turning the gene on. He dubbed the roadblock CRISPRi, for CRISPR interference. CRISPRa (CRISPR activation) involved strapping an "activator domain" from another protein to dCas9 to turn genes on. A third tool developed in Qi's lab at Stanford rearranges how DNA is packed in a cell's nucleus. Moving around big chunks of the genome with this "CRISPR-GO" tool (GO stands for genome organization) may help scientists better understand what goes wrong in cancer cells and how stem cells develop into mature cells, says Wendell Lim, a synthetic biologist at the University of California, San Francisco.

Researchers have requested Qi's dCas9 tools more than 6,500 times, he says. But he wants to know, "beyond the research community, can we really help anyone? That's the real test."

Qi is guiding his lab toward developing therapies to regulate gene activity to treat various diseases. He's already collaborating with neurologists to tackle diseases of the nervous system, such as devising schemes to one day restore dopamine production in the brains of people with Parkinson's disease.

Before Stanford, Qi was a faculty fellow at UC San Francisco. He recalls feeling as if he didn't quite fit with the medical school faculty, because he wasn't trained in biology or medicine. He took his concerns to Lim, who offered some advice that Qi has embraced: "You want to be close to biologists, but you probably don't want to become a biologist," Qi recalls. "Just be yourself." ■

Plants alter climate in neglected ways

By Susan Milius

There's a lot to love about 19th century electronics that spray sparks into the air.

When Abigail Swann was a high school student, building a modern version from scratch of what's called a Tesla coil struck her as a fine project to tackle with her engineer father in the garage. The underdog genius Nikola Tesla, who developed the voltage-amplifying device, "was really fun to learn about," she says.

For months, daughter and father poked around electronics surplus stores, custom-cut plastic pieces and repurposed old wine bottles — the family lived among the vineyards in California's Sonoma County.

The coil eventually sizzled into action, and Swann took it to school. "It made some pretty big sparks," she says — and it lit up a long fluorescent lighting tube she held nearby. She doesn't remember if her classmates were impressed. "It was more about making it, and making it work."

Abigail Swann, 38
ATMOSPHERIC SCIENTIST
UNIVERSITY OF WASHINGTON

FROM TOP: H. WANG *ET AL*; UNIV. OF WASHINGTON

Today, Swann, 38, builds whole planets, some of them very odd and all of them simulations inside a computer. An atmospheric scientist at the University of Washington in Seattle, she has turned her garage creativity to developing computer models for testing ideas about Earth's atmosphere. "I started very early on with experiments where I would do things like: What if the whole world were grass? And what if the whole world were an ocean? And why are they different?"

She focuses on an often-overlooked but essential factor for understanding the effects of climate change: how plants influence the atmosphere by transporting water. "Abby is extremely good at drilling down to the essence of a problem," says Charles Koven, who was an officemate in grad school and now works at Lawrence Berkeley National Laboratory in California. "She can propose model experiments that seem crazy at first." Yet these schemes "turn out to be perfect ways of identifying fundamental processes that show up in a wide variety of situations."

Swann sounds surprised to have ended up in a profession of staring at computer screens. "I love to be outside and actually make things with my hands," she says.

She was interested in physics back at Sonoma Valley High School, a "really ordinary" school, she says. A lot of the top students in her classes were women, so it "was kind of a shock" when she was one of only a few female students, sometimes the only one, in undergraduate physics classes at the University of California, Berkeley.

At Berkeley, Swann heard Inez Fung lecture about atmospheric physics. Fung "connected all kinds of real things that mattered," Swann says. After getting a master's from Columbia University in 2005, Swann returned to Berkeley, with Fung as her adviser, to finish a Ph.D. in 2010 on plant influences on the atmosphere.

Atmospheric scientists have long recognized that plants pull carbon dioxide, a major greenhouse gas, out of the air. Swann focuses instead on how plants affect Earth's atmosphere by drawing water from soil and leaking water vapor from leaves. Understanding plants' role "is absolutely essential," says Sonia Seneviratne, a climate scientist at ETH Zurich. The water effect "has been a bit of a neglected area."

Trees in one hemisphere could actually move rain belts in another hemisphere.

Untangling how plants impact precipitation could improve plans for fending off food shortages and saving biodiversity. Plants may, for example, change who gets rain and whose crops shrivel a hemisphere away. Trees in one hemisphere could actually move rain belts in another hemisphere from one place to another, Swann's modeling shows.

That insight comes from Swann's work on how forests in North America and Eurasia can have a global role. If forests expand, the tree canopy darkens the landscape. When that happens, the hemisphere absorbs more energy, which makes the circulation in the atmosphere rearrange a bit.

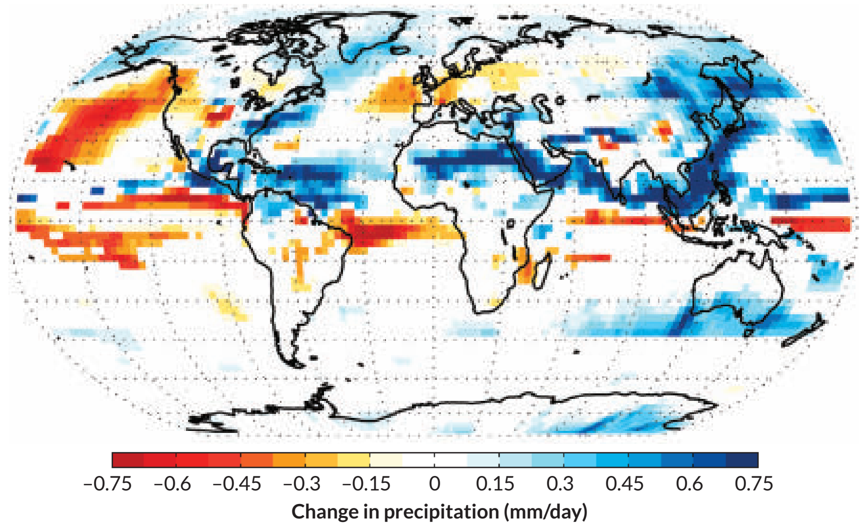
Then, air masses that drenched a swath of South America could nudge northward. The center of South America could get thirstier as rains increase toward the equator, Swann, Fung and John C.H. Chiang, also of UC Berkeley, wrote in 2012 in the *Proceedings of the National Academy of Sciences*.

Thirsty land has become one of the big worries of climate change, with research predicting more frequent and severe droughts across as much as 70 percent of Earth in the next century. Swann and colleagues took a new look at droughts, this time including more details about plant water use. In their analysis, only about 37 percent of the world's land would expect more severe droughts, the team reported in 2016, also in the *Proceedings of the National Academy of Sciences*.

That doesn't equal a uniform easing of risk, Swann says. Drought predictions for some places, such as southern North America, don't improve much. And when droughts happen, she points out, they can still be very bad.

Swann has taken on a different project this summer: the birth of her second son. She encourages working parents to talk candidly about the demands of families instead of trying to sustain the pretense of effortlessness (described on Twitter as #secretparenting). Her family might have some tinkering time and perhaps even another Tesla coil in their future. ■

The simulated effects of northern forest expansion on precipitation



Tree power To see what kind of effect plants might have on the atmosphere, Abigail Swann ran computer simulations that added a lot of trees in the middle latitudes of the Northern Hemisphere. Those hypothetical forests would lead to far-flung changes in precipitation patterns (shown), even in the opposite hemisphere. Some areas would get wetter (blue) and some would get drier (orange).

A.L.S. SWANN, I.Y. FUNG AND J.C.H. CHIANG/*PNAS* 2012

Understanding an ocean of changes

By Carolyn Gramling

Malin Pinsky had the first of two lightbulb moments while standing on the bridge of a research ship crossing the churning Drake Passage, which separates the tip of South America and Antarctica. It was 2003, and Pinsky was five months out of his undergraduate studies in biology and environmental science. He was scanning the sky for seabirds, part of his duties as a research technician on the cruise. But his eyes kept straying to the vast, mysterious ocean below, slate blue in every direction.

Malin Pinsky, 38
MARINE ECOLOGIST
RUTGERS UNIVERSITY

As the ship entered nutrient-rich Antarctic waters, the water temperature gauges on the bridge abruptly dropped. Whales suddenly surrounded the ship. "It was stunning," says Pinsky, 38, now a marine ecologist at Rutgers University in New Brunswick, N.J. "That moment helped me realize that, yes, the ocean looks featureless from the top, but there's so much going on underneath."

His second lightbulb moment came several months later, in a far less captivating locale. Pinsky, an intern for the Washington, D.C.–based conservation group Oceana, was making photocopies. A lot of photocopies.

It was about the time that two big reports on what policies might best preserve U.S. ocean resources came out, he says. "And I realized, wait a minute. We have all these laws and policies that determine how we as a society interact with the ocean, and they're far out of date compared with where the science is. And yet, we don't yet have the science to know what the new policy should be."

Now, the sprawling, busy Pinsky Lab — a cast of about 20 — leads the charge to collect data needed to shape ocean policy amid global temperature rise. "The overarching focus of the lab is to understand how marine ecosystems are changing, why they are changing and what choices we can make as a society to alter that course," Pinsky says.

One research area in particular garnered significant media attention over the last year: how warming ocean waters are reducing the sustainable catch of fish species around the globe (*SN: 3/30/19, p. 5*). And his team's work was incorporated into a high-profile international report suggesting that nearly 1 million species are threatened with extinction, in part because of human activities (*SN: 6/8/19, p. 5*).

Pinsky's team is also seeking to understand exactly how a changing climate, as well as overfishing and habitat destruction, might be driving changes in fish and other marine populations. For this, team members travel each year to coral reefs near the Philippines to carefully catalog populations of clown fish, collecting data on growth and mating, sex diversity and other factors. A staggering number of factors could affect clown fish populations, in fact; in a team meeting, a whiteboard of ideas to pursue looks like a mash-up between a flowchart and a crazy quilt.

Another focus is whether recent climate change is leading to rapid genetic changes among Atlantic cod and other marine fishes and resulting in, for instance, fish maturing at younger ages.

His rigorous, data-driven approach to studying how well species can tolerate temperature changes is "incredibly important at this point in time," says Kimberly Oremus, a fisheries economist at the University of Delaware in Newark. Pinsky's holistic approach to the problem — looking at species, their habitats and resource management — is setting the pace for other researchers, Oremus adds. "He's pushing the whole field to respond to his growing body of research."

Looking for the big picture has always been a trait of Pinsky's, says Stephen Palumbi, who advised Pinsky in his graduate studies at Stanford University. "He's always raring to do a thousand different things in a hundred different ways."

That seemingly boundless energy is legendary among Pinsky's colleagues. Michelle Stuart, a marine biologist who has worked in Pinsky's lab since 2013, recalls sitting on the team's boat, exhausted after a long day of fieldwork. "Someone was just below the surface, kicking towards the boat, and it was like one of those windup dolls that you put in the bathtub, you know, ch-ch-ch. And I was like, of course, that's Malin. Because after a long day of diving, he's still, like, 120 percent."

At times Pinsky has been more interested in "what's the big idea?" than in nurturing "little baby nascent ideas," says Rebecca Selden, a marine ecologist who joined the lab in 2015. (Pinsky concurs, noting that he once had a reputation as "Dr. No.") But over the last four years, she says, Pinsky's leadership style has evolved, and he now creates space where ideas have room to grow. It's a lesson that Selden, who in July left to start her own lab at Wellesley College in Massachusetts, plans to take with her. ■

A swarm of fish surrounds marine ecologist Malin Pinsky at a reef off the coast of Leyte island in the Philippines in 2017.

FROM TOP: JEFF HECKMAN, COURTESY OF RUTGERS UNIV.; M. STUART/RUTGERS UNIV.

Visit www.sciencenews.org/webinars to join an Oct. 22 chat with Malin Pinsky.

Monika Schleier-Smith, 36
PHYSICIST
STANFORD UNIVERSITY

Atom master drives quantum chatter

By Elizabeth Quill

"I like it if I can run uphill and be rewarded with a view of the bay," says Monika Schleier-Smith. She's talking about a favorite spot to exercise around Palo Alto, Calif., but the sentiment also applies to her scientific work. A physicist at Stanford, Schleier-Smith, 36, has a reputation for embracing the uphill climb. She'll push the smallest details of an experiment until she achieves what others thought near impossible.

Her reward? Seeing large ensembles of atoms do her bidding and interact over vast distances.

"She tends to persist," says Harvard physicist Susanne Yelin, who has been following Schleier-Smith's research.

Quantum physics describes a microworld where many possibilities reign. Unobserved atoms and particles don't have clearly defined locations, and information can be shared by widely spaced parts of a system. "We have equations that describe quantum mechanics well, but we can't solve them when we are dealing with more than a few particles," Schleier-Smith says.

That's a shame, because understanding how large numbers of these small entities interact is essential to figuring out how our world works at the most fundamental level. Getting atoms to behave in just the right ways also has some practical benefits. It could lead to the most precise clocks yet, a boon for precision measurement, and to quantum computers that can solve problems that are too hard for today's supercomputers.

Schleier-Smith's experimental setups use elaborate tabletop arrangements of mirrors, lasers, vacuum chambers and electronic parts to cool atoms, pin them in place and then manipulate them with light. It's a clutter of essential components, the construction of which requires an exacting understanding of the physics at play plus engineering know-how.

As a graduate student at MIT, Schleier-Smith worked with a small team that pushed the precision of an atomic clock beyond what's known as the "standard quantum limit," a result reported in 2010. Though people knew this was theoretically possible, many thought it was too hard to try to pull off. Schleier-Smith spent weeks optimizing and troubleshooting the control circuitry that kept the experiment's lasers at the right frequency, says Ian Leroux, a member of the MIT team now at Canada's National Research Council Metrology Research Centre in Ottawa. She has "that blend of care, dexterity, observation and attention to detail that lets her make an apparatus work better than it has any right to."

> Quantum physics describes a microworld where many possibilities reign.

In a more recent experimental feat, reported in January in *Physical Review Letters*, Schleier-Smith and Stanford colleagues used laser light to create long-distance interactions in a cloud of some 100,000 cold rubidium atoms. The atoms chatted up other atoms half a millimeter away — a great distance in the atomic realm. At Schleier-Smith's direction, an excitation in the atoms, in this case a flip in a property called spin, hopped from one side of the atom cloud to another, using a photon to bypass the atoms in between. What's more, the team found a way to image that hopping.

Schleier-Smith traces her interest in physics back to high school, when a chemistry teacher told her to think of an electron as "spread out like peanut butter." The idea fascinated her. She sensed that a deeper understanding meant studying quantum mechanics.

It's not an insight you'd expect from the average high schooler. But such clarity of vision has been a characteristic of Schleier-Smith's work. She quickly identifies ideas that are both interesting and experimentally feasible, says graduate student Emily Davis, who has worked in Schleier-Smith's lab since 2013. (About half of the current lab is female, atypical in such a male-dominated field.)

"I tend to be fairly intuitive," says Schleier-Smith. "I think it is a matter of how my brain works."

And she readily sees through other scientists' questionable assumptions, Leroux says. Her spin-hopping setup bucks a commonsense argument that you need to hold atoms in a very small space to get good control of their electromagnetic interactions.

That setup might also have value in studies of black holes. Attempts to unite quantum physics with Albert Einstein's theory of gravity make specific predictions about what happens to information that falls into black holes. It might get mixed up exponentially quickly through interactions analogous to those Schleier-Smith has demonstrated. "She has built an exceptionally powerful platform for exploring these phenomena in the lab," says theoretical physicist Stephen Shenker of Stanford.

Could pursuing connections to black holes reveal something interesting about how atoms interact, as well as how to control them? Schleier-Smith can't say for sure, but she sees the potential. ■

DAWN HARMER/SLAC NATIONAL ACCELERATOR LABORATORY

Numbers guy seeks education equality

By Sujata Gupta

Parag Pathak, 39
ECONOMIST
MIT

Every year, 70,000 New York City eighth-graders get sorted into about 400 high schools across the Big Apple. But until the early 2000s, more than a third of students wound up at schools they had not chosen.

School choice systems emerged in the 1960s and '70s after courts began ordering schools to desegregate to comply with federal law. The systems were meant to provide mostly poor, minority students zoned to underperforming schools with access to a better education. But many choice systems have still not met that goal, with parents in the know gaming the system to get their children into preferred schools while other kids end up back at their poor, neighborhood schools.

In 2003, researchers with expertise in game theory and market design overhauled New York's school choice system to make it fairer. Parag Pathak devoted much of his time as a doctoral student in economics at Harvard University to analyzing components of the system, such as how to break a tie between two students vying for a school's last seat.

Now an economist at MIT and cofounder of the School Effectiveness & Inequality Initiative, Pathak, 39, continues to apply economics to daily life. Economists "have a language to think about what improves welfare," Pathak says. His school choice work earned him a 2016 Social Choice and Welfare Prize and the 2018 John Bates Clark Medal, both for economists under 40 who have made significant contributions to the field.

By tackling the question of how to allocate resources in real-life settings, Pathak serves as "a model economist," says MIT colleague James Poterba, president of the National Bureau of Economic Research. "He's found ways to make the lives of people better."

The son of Nepalese immigrants, Pathak grew up in Corning, N.Y. A numbers guy at heart, he earned a bachelor's degree in applied math at Harvard. His economics courses piqued his interest, so he stayed to study under economist Alvin Roth. Roth, a 2012 Nobel laureate in economics now at Stanford, had already modified a well-known algorithm to match graduating medical students to residency programs. Among other improvements, the program helped couples end up in the same hospital or region for training. It was an early example of how an economist could engineer a social system.

> Economists "have a language to think about what improves welfare."
> PARAG PATHAK

That work led to a call from a representative at the New York City Department of Education who thought the approach could work for school matching. Roth roped in Pathak and economist Atila Abdulkadiroglu, now at Duke University.

Pathak soon realized that the existing system, in which students ranked their top five school choices, resembled the college admissions process. Star students received multiple offers and everyone else received none. Better-off families had learned the system's inner workings, such as which schools would consider only students who ranked that school first and which good schools were a safe bet. Families who didn't understand the system simply listed schools in order of preference.

So the team designed a system that provided no benefit to students who obscured their true preferences. Students could now list their top 12 schools, and schools could specify their priorities, such as test scores or geographic proximity (or even prioritize specific students). The algorithm then matched students to schools, with the process ending when schools were filled or schools on students' lists had been exhausted.

The system worked. From 2003 to 2004, the number of students who did not receive an offer from one of their chosen schools dropped from 30,000 to 3,000. Other cities have since adopted the algorithm, including Indianapolis, Washington, D.C., Denver, New Orleans, Boston and Newark, N.J. Pathak continues to work on the nitty-gritty details of the algorithm, while also explaining the system to families — outreach he sees as integral to this work.

There are still problems with equity, Pathak admits; no algorithm can increase the supply of good schools. But with data from districts that have adopted the algorithm, and permission to access student records, Pathak is now comparing students' academic performance to find out what makes for a good education. He and colleagues reported in *Econometrica* in 2014, for example, that kids who attended a selective school didn't perform better on standardized and Advanced Placement tests than kids who had just missed admission. "We call this the 'elite illusion,' " Pathak says.

Pathak also investigates other urban resources, such as housing, but education remains his passion. If he could be granted one wish, he says he would design a school system from scratch. How, he asks, would you set up that system to be as equitable as possible? ■

BRYCE VICKMARK

Biological tinkering without borders

By Laura Sanders

Seth Shipman is a magpie of biological innovation. He collects useful parts — from bacteria, nerve cells, reams of genetic data — and transforms them into tools that do amazing things.

One of his best creations so far is a collection of bacterial cells with DNA that carries an iconic movie of a running horse. Recording images, or any other information, in the genetic material of living cells isn't just for entertainment; it will give scientists views of processes that are usually hidden.

Imagine designing record-keeping cells capable of eavesdropping on the cellular destruction that precedes dementia in the brain. Or monitoring the genetic instructions that tell a brain cell how to develop. Or even seeing the exact moment when cellular missteps begin to create a disorder such as schizophrenia.

Seth Shipman, 36
BIOTECHNOLOGIST
UNIVERSITY OF CALIFORNIA, SAN FRANCISCO AND GLADSTONE INSTITUTES

Scientists can't do any of this yet. But Shipman, 36, is patient. "If you're worried about what you can do right now, it's hard to take a big step forward," says Shipman, a biotechnologist at the University of California, San Francisco and the Gladstone Institutes, a nonprofit research organization on the UC San Francisco campus. To move forward often requires a pause, a careful reckoning to examine your tools and look around a bit, he says.

His willingness to shift perspective and cross disciplines — neuroscience, microbiology, engineering and even art — is unusual, says neuroscientist Roger Nicoll, who oversaw Shipman's Ph.D. work at UC San Francisco. "I get really antsy when I get outside of my comfort zone," Nicoll says. "He has no comfort zone."

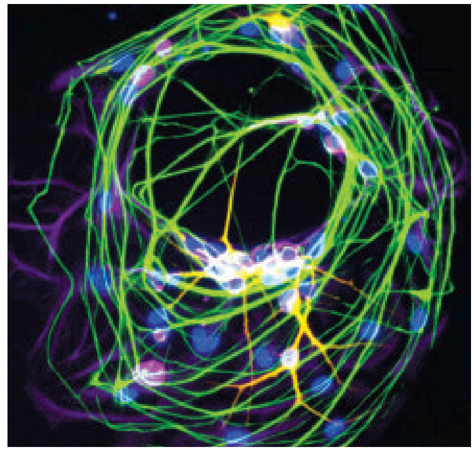
The bacterial movie feat came from Shipman's frustration with a lack of good tools. He wanted to monitor genes' behavior inside cells as time passes, but one of the only ways to track that behavior requires killing the cells. "That destruction is something that's really incompatible with something that happens over time," he says. So instead of hammering away with the wrong tools, he backed up and thought about what the ideal tool would look like.

The perfect system would unobtrusively monitor cellular events from the inside and provide a record of those activities. During a postdoc at Harvard, Shipman and colleagues figured out how to best use the gene-editing tool CRISPR to get bacterial DNA to accept foreign snippets, a technique described in 2016 in *Science*. Once that was achieved, "it was off to the races," he says.

After discussions with his Harvard benchmate, artist and biologist Joe Davis, Shipman decided to transfer instructions for the images of a running horse as a nod to the images' creator, early technologist Eadweard Muybridge. In the late 1800s, in part to settle a debate about whether running horses are ever fully airborne, with no feet touching the ground, Muybridge created a series of images that captured the motion.

The response to Shipman's work was big. "I've never had a reaction to a paper like that," he says. Scientists were enthralled with the prospects of the technology. Journalists were enchanted with the idea of a movie embedded in DNA. Even Muybridge historians got excited.

The ability to put external information into living cells, in the right order, described in 2017 in *Nature*, brought Shipman a step closer to his ultimate goal: to build a tool to record sophisticated cellular information inside the DNA of living cells and reveal biological processes that have remained mysterious. Now Shipman's team is working on coaxing the cells into recording information on their own.



Seth Shipman studies simple circuits of human nerve cells in lab dishes that might turn up clues to how more complex networks form. (Message-sending axons are green, message-receiving dendrites are orange, cell nuclei are blue and astrocytes are purple.)

"He's going to push the advancement of this field," says synthetic biologist Harris Wang of Columbia University.

When Shipman and Davis worked side by side at Harvard, they had wide-ranging, boundary-pushing talks. "I could float really crazy ideas," Davis says, "and he could float really crazy ideas." Davis mentions the "zen neuron," a single nerve cell that they grew alone in a dish. With no nearby neurons to send tendrils toward, this cell connected to itself.

In his own lab, Shipman is still cultivating neurons. Many scientists try to figure out how cells form their complex connections by scrambling those connections. "Instead of taking something that works and breaking it, we make something, and try to impose order on it," Shipman says. His pared-down system, made of one to five neurons growing on a single "island," offers a way to test the rules governing the shape of more elaborate networks in the brain.

Where Shipman's tinkering might lead next is anybody's guess. "There is no doubt that he will do very well, but you have no idea where it's going to go," Nicoll says, "which is great." ■

FROM TOP: S. SHIPMAN; LAUREN BAYLESS/GLADSTONE INSTITUTES

Watch the movie encoded in cellular DNA at **bit.ly/SN_RunningHorse**

Some concepts of the multiverse suggest that each universe is contained in a cosmic bubble.

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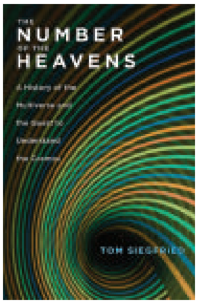


The Number of the Heavens
Tom Siegfried
HARVARD UNIV., $29.95

INTERVIEW

Multiverse science through time

There is no bigger question than whether the universe is all there is.

Scientists are juggling several ideas for what a multiverse, if one exists, might be like. Our universe could be one bubble in a vast cosmic fizz. Or one of many 3-D domains stacked, like pages of a book, in higher dimensional space. Or one series of events that continually branches off from other histories in a tree of alternate realities. All these possibilities, while tantalizing, remain unconfirmed.

The prospect of many universes has intrigued scholars for millennia — and has evolved to mean different things, as humankind's concept of the universe has zoomed out from a single solar system to a galaxy to a great cosmic web.

"The multiverse debate is like a long-running TV series with new characters replacing the old ones," science journalist Tom Siegfried, a former editor in chief of *Science News* and current contributing correspondent, writes in *The Number of the Heavens*. His new book is a recap of that age-old discourse.

Each rendition of the multiverse debate has revisited common themes, including whether science has any business speculating about unobservable realms. Each iteration has had its believers and its naysayers. But those curious minds have been united in their common fascination with one of the most profound mysteries of all time: What is the entirety of existence?

Science News spoke with Siegfried about what we can learn from past generations of multiverse debates and how scientists might determine whether a multiverse exists. The following conversation has been edited for length and clarity. *— Maria Temming*

Are there ways to test any of the modern views of the multiverse?

They might be long shots, but it's not impossible. If there are other [bubble universes] out there, it is conceivable that one of those bubbles could collide with our bubble and imprint on the cosmic microwave background radiation in space to reveal that.

But the main point that people overlook is, the multiverse is not a theory. The multiverse is a prediction of other theories [such as superstring theory] that can be tested in other ways. If you have a theory that makes many testable predictions that turn out to be right, that implies the existence of other things the theory predicts. [After the ancient Greeks proposed the existence of atoms, they] could not be observed directly for [about] 2,500 years. But they were nevertheless inferred to exist by things that could be observed. The multiverse could be the same way.

In 1277, the bishop of Paris declared it heresy to teach the Aristotelian view that God couldn't make multiple worlds, granting scholars freedom to contemplate the multiverse. Have there been paradigm-shifting moments for the multiverse question in the modern era?

The underlying belief among physicists for a long time has been that there is a theory out there that could specify everything there is to specify about the universe. In 1998, when the discovery of the acceleration of the expansion of the universe was announced, that changed the game. Now you had this apparent force called dark energy driving the universe to expand faster and faster, which had to be of a magnitude that the fundamental physical theories we had could not explain.

That freed up physicists to explore issues outside the prevailing view that there was one specification for all the forces and properties of the universe. It led to this idea that there could be multiple universes, and that dark energy is the amount that it is in our universe because that amount produces a universe that's hospitable for life.

What can people contemplating the multiverse learn from people who have asked similar questions in the past?

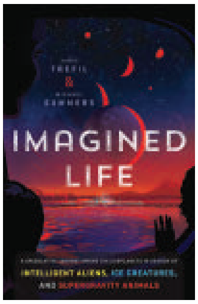
Two things. One is, every time this issue has come up, of whether there's one universe — as was conceived at that time — or many, the answer has always been many. That doesn't mean that it's going to be the case this time for sure. But it is an instructive point. Second is that history shows that [contemplating the multiverse] is a scientific question. It is not a metaphysical question or a meaningless question. It is a legitimate scientific question that warrants further investigation — and scientific research might someday provide the answer.

You write that you believe "it makes much more sense for a multiverse to exist than not." What would you bet that we live in a multiverse?

[Laughs.] I would not wager on this, because I only bet on sure things. I like the idea. It's got great explanatory power, and I find it pleasing. But that doesn't translate, in my mind, to mean it has to be true. I have to just wait as the evidence comes in, and the evidence hasn't definitely answered the question yet. ■

BOOKSHELF

What life on other planets might look like



Imagined Life
James Trefil and Michael Summers
SMITHSONIAN BOOKS, $29.95

An organism is shaped by the environment in which it dwells. Considering the rampant diversity of species on Earth, just imagine the oddities that could evolve on radically different sorts of planets — perhaps black-leafed "plants" that thrive in dim light or even creatures made of metal rather than carbon.

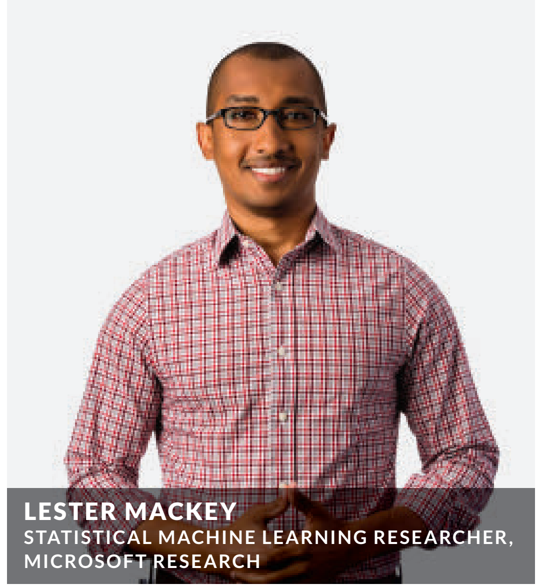
In *Imagined Life*, physicist James Trefil and planetary scientist Michael Summers set out on a safari through the cosmos, conjuring up the menagerie that might inhabit some of the thousands of exoplanets discovered thus far. Many of the book's chapters explore potential life on various types of worlds, each vastly unlike Earth. Though fanciful and fun, the pair's efforts are grounded in science and adhere to two main principles: that a small number of general rules govern the physical universe, and that Earth's laws of physics, including thermodynamics and electricity and magnetism, apply everywhere else in the cosmos. Trefil and Summers also propose that in all but a few scenarios, natural selection drives evolution on other planets.

No matter the environment, life needs a source of energy. But that energy doesn't have to come from a star's radiation, the authors note. An ice-smothered world or even a rogue planet floating in interstellar space could, like Earth, have oceans with seafloor hydrothermal vents driven by heat from the decay of radioactive elements in the planet's core or from heat left over from when the planet coalesced. Whether such oceans are ice-covered or not, life in these oceans would probably evolve to take advantage of the energy-rich chemicals spewing from those vents and need to be mobile, as vents can spring into being and just as quickly fade away. Vent creatures might either resemble those living in similar ecosystems on Earth or be completely unrecognizable.

On other types of worlds, life-forms could be even stranger. On a planet that has one side permanently facing its star, the most hospitable temperatures for life as we know it would exist in a thin north-south halo around the planet, where the sun always sits on the horizon. Supersonic winds would buffet the surface, scientists have suggested, so species would have to be low-slung and streamlined to minimize air resistance, the authors argue. On a rocky planet much larger than Earth, land organisms would have to deal with stronger gravity and would thus be short, squat and have strong bones or exoskeletons.

Imagined Life is an amazingly fun read. While musing about how life — and even technological civilizations — might evolve and thrive on other worlds, Trefil and Summers slip in tons of info about how life on Earth came to be. — *Sid Perkins*

CONVERSATIONS WITH MAYA



LESTER MACKEY
STATISTICAL MACHINE LEARNING RESEARCHER, MICROSOFT RESEARCH

DANA J QUIGLEY

Maya Ajmera, President & CEO of Society for Science & the Public and Publisher of *Science News*, sat down to chat with Lester Mackey, a statistical machine learning researcher at Microsoft Research Labs New England. Mackey is an alumnus of the Science Talent Search (STS) and the International Science and Engineering Fair (ISEF), both science competitions of the Society. We are thrilled to share an edited summary of the conversation.

You're an STS 2003 and ISEF 2003 alum. How did the competitions affect your life?

When I was a college freshman at Princeton, an Intel researcher reached out to me and asked if I wanted to intern in their Strategic CAD Labs. The lab was made up entirely of Ph.D.s and hadn't taken on interns before. The researcher knew of me because of my participation in ISEF and STS, and if it hadn't been for my science fair participation, I wouldn't have had the opportunity to work there.

Long story short, I loved the experience. I liked the freedom that I had, the opportunity that I had to productively deploy creativity at every turn. And I came away from that experience determined to get a Ph.D. What's more, my Intel mentor knew Maria Klawe, who was dean of Princeton University's School of Engineering and Applied Science at the time, and recommended that she recruit me for a research project. That kicked off my research career.

Do you have any memorable experiences from the competitions to share?

My ISEF project was awarded an Operation Cherry Blossom Award, which included an all-expense-paid trip to Japan. This took me on an incredible adventure: We went to Tokyo and Yokohama and the ancient capitals of Nara and Kyoto. Part of the trip involved meeting a Japanese princess.

You taught at Stanford before moving to Microsoft. Can you describe how being at Microsoft has been different than a purely academic environment and how that's helped you in your career?

In many ways my lab, Microsoft Research Labs New England (MSR), is very much like a university. The researchers here work on whatever they want. We publish everything. We're evaluated based on our contributions to our academic communities and to the world.

The main difference is in the extra degree of freedom that we have at MSR. If you want to spend 100 percent of your time doing research, you can do that. If you want to teach courses at neighboring universities, you can do that too. You have the freedom to choose how you want to spend your day, and I think that freedom is very valuable.

I've also noticed that the researchers here tend to be very hands-on with their projects and very collaborative. I find myself working not just with my students, interns and postdocs, but also with my talented and experienced labmates. That's been a big positive for me. Our lab is somewhat unique in that it was created as a research lab for both computer scientists and social scientists. Some of my colleagues are scholars in economics, communication or anthropology. The lab fits on a single floor, and that proximity breeds collaboration. I find myself working on problems that I hadn't even considered before coming to MSR.

How do you recommend students start studying and getting involved in machine learning?

I tell all students to try a data science competition. My first encounter with machine learning was through a competition that Netflix ran when I was a senior in college. Netflix wanted to improve its movie recommendation system, so they released a dataset of 100 million ratings that users had given to various movies. Competitors were challenged to predict how the users would rate other movies in the future. My philosophy is that these public competitions provide a great sandbox for people who are just starting out in machine learning because you get to work with real data on a real problem that someone really cares about. By the end, you'll understand both the methods and the problem, and you'll have fun doing it.

There's been a lot of talk about artificial intelligence and its influence on humankind. Why do you think students or the public should care about AI?

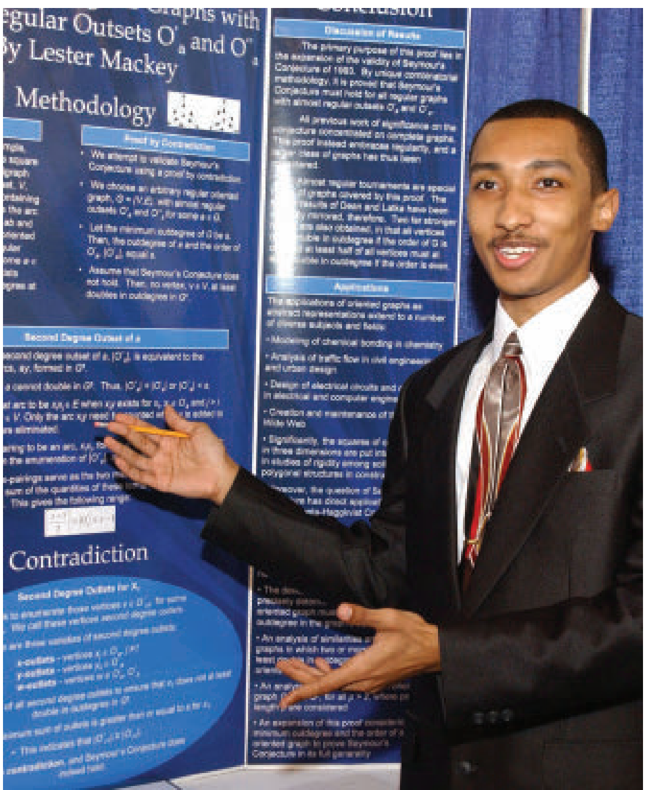
I think we have to be aware of these technologies so that we can hold them accountable to our standards of fairness and safety. AI is becoming much more pervasive, and it's increasingly being incorporated into technologies that impact our everyday lives: self-driving cars, résumé-screening tools and algorithmic risk-assessment tools that inform bail-release and criminal-sentencing decisions.

I also think that AI holds the potential to help us address some of our biggest challenges like poverty, food scarcity and climate change. What I love most about my field is that these tools have the potential to do real good. I think that's something that will excite many students and the public more generally.

Using AI to solve issues like poverty is interesting to think about. I would love to hear more about how this technology can be employed to solve these types of problems.

Take the example of GiveDirectly, a nonprofit that gives unconditional cash transfers to the poorest people in the poorest communities. They're finding that this leads to sustained increases in assets. However, the on-the-ground process the organization goes through to identify transfer candidates is quite laborious and expensive.

So they've been working with experts in machine learning, statistics and data science to automate more of that process. Early work transforms satellite images into predicted poverty heat maps to guide the search of field-workers, and I think we've just scratched the surface of what is possible.



Lester Mackey presents his poster at the Science Talent Search 2003 competition. He came in sixth out of 40 finalists.

SSP

What do you feel are the most interesting problems that could be addressed within your field of research?

I'd love to see the field direct more of its attention and resources to social problems like poverty, hunger and homelessness. There are many open questions in this space. What specific problems could actually benefit from machine learning intervention? How can machine learners work with experts and policy makers to actually affect meaningful change? How do we incentivize our talented students and professional machine learners to work on these problems?

A second, different sort of challenge is responsible deployment. We see that AI is being used already to inform important decisions in society, such as screening résumés or determining when people should be released on bail. How do we ensure that those decisions are fair and reflect our societal values? This is an increasingly active area of research in the field.

As a person of color in machine learning, what are your thoughts on bringing more young people of color into this field?

There have been some developments in this direction that I'm particularly excited about. There's a "Black in AI" movement now. It's bringing people of African ancestry together in this field. Although we might be sparse and distributed, we have a big presence. It's been excellent for networking and for encouraging younger people to get involved in machine learning and stay involved. You can learn more about it at blackinai.github.io or by searching online for Black in AI.

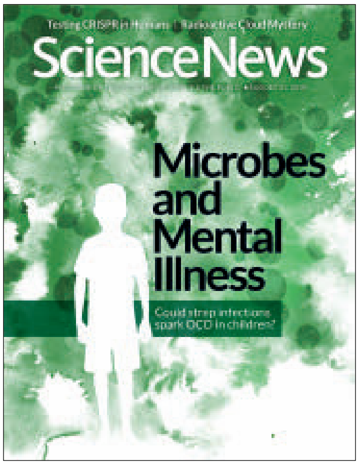
What books are you reading now? And what books inspired you when you were younger?

I just finished reading *Astrophysics for People in a Hurry* by Neil deGrasse Tyson, and now I'm in the middle of *American Nations* by Colin Woodard.

When I was younger, my three favorite books were Brian Greene's *The Fabric of the Cosmos*, Matt Ridley's *The Red Queen* and Neil Gaiman's *American Gods*.

The world faces so many challenges today. What keeps you up at night?

I would say poverty. I can't comprehend how there can be so much wealth in my field, my community and this country, and yet half a million people in the United States are homeless on any given night. One in nine people are malnourished in the world. That just doesn't make sense to me. ◆



AUGUST 31, 2019

The award goes to ...

Tina Hesman Saey, *Science News'* molecular biology writer, has won a National Academies of Sciences, Engineering and Medicine 2019 Communications Award for her series "Genetic testing goes mainstream" (*SN: 5/26/18, p. 20*). Judges called it a "timely, informative and eminently readable series on the uses and limitations of DNA testing for both medical and ancestry purposes." The prize recognizes excellence in reporting and communicating science, engineering and medicine to the public. **Saey** will be honored October 16 at a ceremony in Washington, D.C.

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Under a macroscope

A theoretical dark matter particle called a macro would have to be about 1 square micrometer in size traveling at hypersonic speed to kill a person, ***Lisa Grossman*** *reported in "Dark matter particles can't be so big, or they'd kill us"* (SN: 8/31/19, p. 4).

A macro that size would deposit as much energy as a metal bullet and vaporize tissue, researchers theorize. If a macro "were to deposit energy in tissue, it would do likewise in any other kind of matter, such as the atmosphere, no?" reader **Clay Naff** asked. "We'd expect a superheated atmosphere rather than riddled bodies, wouldn't we?"

If macros exist, then they could interact with the atmosphere as they fall to Earth, says physicist **Glenn Starkman** of Case Western Reserve University in Cleveland. The amount of energy that macros release into the atmosphere would depend on the particles' size, which is still an unknown. Micrometer-sized macros would hold on to most of their energy, contributing little heat to the atmosphere, whereas larger macros would release most of their energy. Either way, macro strikes would be too few and far between to superheat the atmosphere — or kill millions of people, **Starkman** says. Cosmic ray detectors may be able to pick up macros falling to Earth, **Starkman** suggests. "The point is that the rare events are detectable — one person killed (or not), a cosmic ray detector alerted (or not)."

Spin zone

Researchers are using ancient spinning and weaving tools to unravel how people made textiles long ago, ***Amber Dance*** *reported in "Threads of time"* (SN: 8/31/19, p. 16).

Reader **Duren Thompson** was disappointed that the article didn't mention other spinning wheels used before the wheel called the spinning jenny, invented in 1764 in England. **Thompson** noted that the story ignores "the early medieval Asian and Middle Eastern (and later medieval European) engineering innovations that laid the foundation for the spinning jenny."

Thompson is correct that the spinning jenny came after other thread-spinning wheels, says **Eva Andersson Strand**, director of the Centre for Textile Research at the University of Copenhagen. The first spinning wheel likely originated in Asia around the 11th century. Over the next few centuries, the technology spread to other parts of the world. Some notable wheels that came before the spinning jenny are the great wheel and the treadle wheel. But the spinning jenny was a key innovation in industrial weaving.

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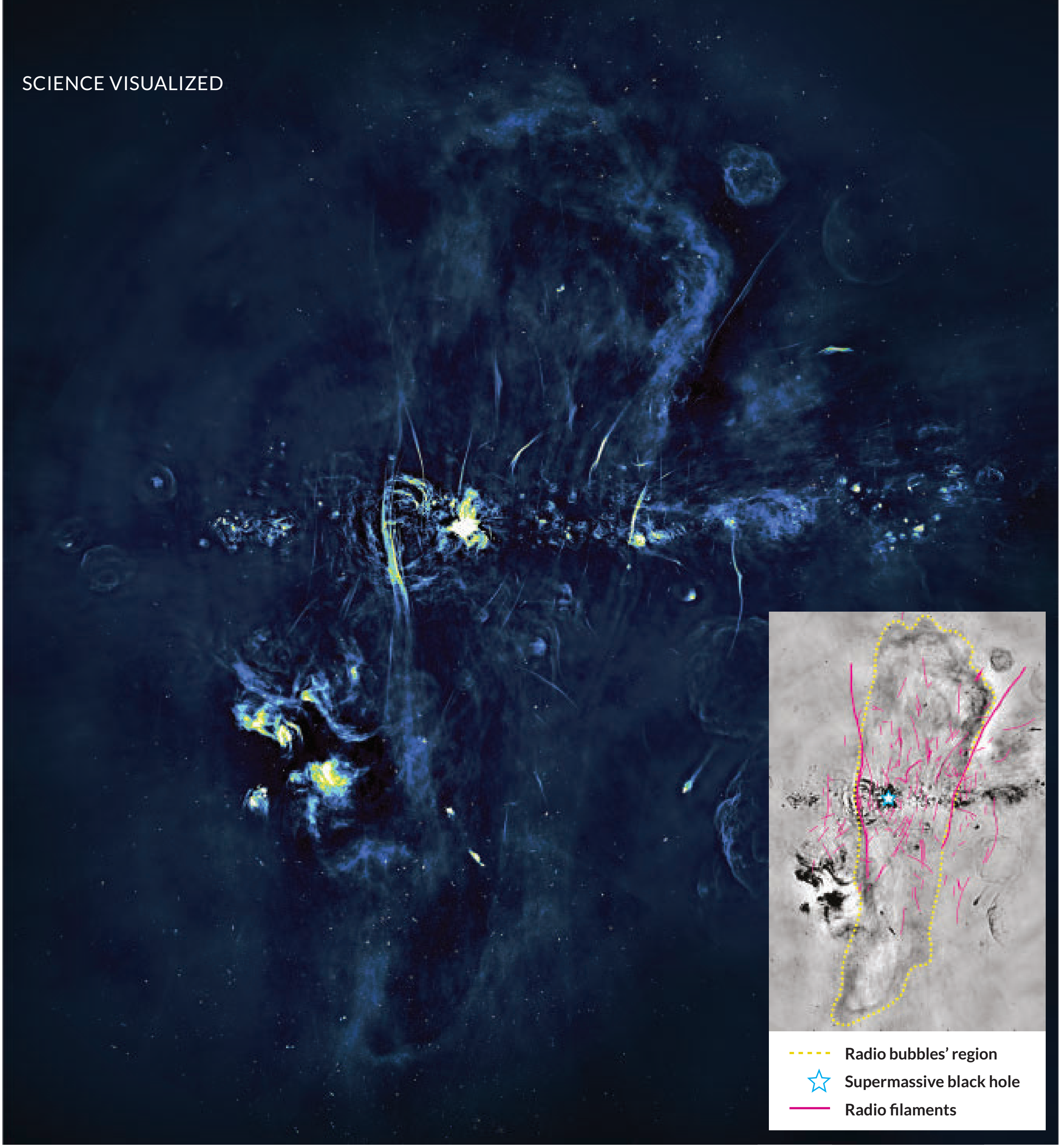

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The heart of the Milky Way spews giant radio bubbles

Colossal bubbles emanate from the Milky Way's center, spitting out radio waves detected with the MeerKAT radio telescope in South Africa.

The structures are a sign of a long-ago burst of activity from the region around the now relatively sleepy supermassive black hole at the galaxy's center, researchers report in the Sept. 12 *Nature*. These two bubbles (shown in the colored radio image, with their region outlined in yellow in the grayscale radio image) extend hundreds of light-years above and below the plane of the Milky Way. And they point to "something extraordinary that had happened in the galactic center," says astrophysicist Ian Heywood of the University of Oxford.

Heywood and colleagues estimate that an event involving vast amounts of energy — equivalent to the explosions of roughly 100 stars — sent matter streaming out of the region around the black hole a few million years ago. Speedy, electrically charged particles produced in that event, accelerated by magnetic fields, create the bubbles' radio waves, the team suggests. The bubbles join previously discovered radio filaments and bright spots that also are sources of radio waves, such as clouds of gas and dust.

A temporary black hole feeding frenzy could have spawned the bubbles, the researchers propose, as the behemoth gulped down matter and discarded the excess. *— Emily Conover*

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