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SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
OCTOBER 14, 2017

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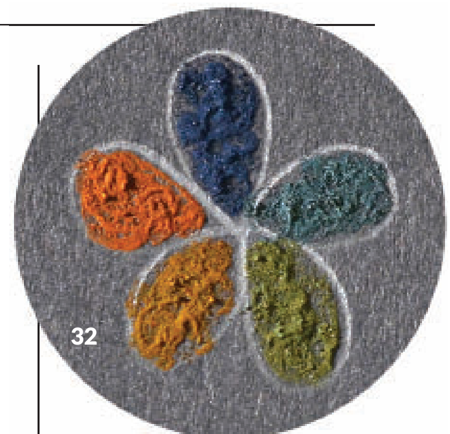
ScienceNews

Feature

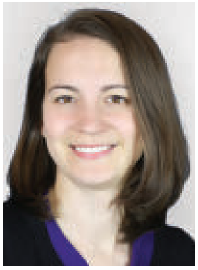
News



Departments

COVER *Science News'* SN 10 spotlights scientists exploring vast worlds, from outer space to the inner realms of the mind. *Sam Falconer*

SN 10, CLOCKWISE FROM TOP LEFT: MASSIMO PISTORE; TIMOTHY ARCHIBALD; UNIV. OF OKLAHOMA; J. ADAM FENSTER/UNIV. OF ROCHESTER; PENNY JENNINGS/UCLA CHEMISTRY & BIOCHEMISTRY; PICOWER INSTITUTE; TIMOTHY ARCHIBALD; EMILY KIPPING; ROBIN KEMPSTER; EGENESIS; BOTTOM, FROM LEFT: STEVEN SAFFI; M. XIAO *ET AL/SCIENCE ADVANCES* 2017



Success in science depends on luck, plus much more

Like anything else in life, there is a lot of luck in scientific success. Astronomers searching for new worlds have to pick the right sections of sky. Biologists cross their fingers that their cell lines will survive long enough for an experiment. Two paleontologists are excavating at a field site in Montana — both skilled, both committed. One turns up a *T. rex* skeleton; the other, nothing but dirt. In the end, it's the luck of the dig.

A fruitful career in science can also depend on the luck of birth. Early exposure to the wonders of discovery, access to a good education and the wisdom of an academic mentor are all matters often outside of a future scientist's control. As is the historical context in which a scientist lives. It's impossible to know, but what if Albert Einstein had been born a century earlier, or a century later? Would his mind, brilliant as it was, still have been suited to solve the puzzles of the day? Would his insights have been ignored? Or would his ideas have arrived too late, with someone else making his biggest discoveries? More than one Nobel laureate has credited success, at least in part, to being in the right place at the right time.

In the 1920s, two sociologists explored the idea of "the right time" by asking the question: Are inventions inevitable? William Ogburn of Columbia University and his student Dorothy Thomas studied the phenomenon of simultaneous discovery — the fact that multiple people often hit on the same idea at the same time. The duo compiled a list of 148 "inventions and discoveries made independently by two or more persons." Included were the discovery of Neptune (1840s), the branch of mathematics known as calculus (1670s) and the function of the pancreas (1830s). Ogburn and Thomas went on to ask a number of lofty questions, including: "Are inventions independent of mental ability?"

My answer? Most definitely not. Yes, advances are often a product of their times. One step forward requires previous steps, the bubbling and building of data and ideas; even Isaac Newton stood on the shoulders of giants. But the individual is absolutely essential. It's the individual brain, often in collaboration with other individual brains, that takes the work that has come before and figures out how to add to it. It's that unique contribution that makes for scientific progress. Such progress might come from a spark of insight, a moment of creativity or a steady pound, pounding on a problem. It might come from the drive required to go big, say by putting 1,600 tubs of ultrapure water at the foot of the Andes to detect cosmic rays (see Page 7). Individuals have to take some initiative to do something great with what they've got.

Often the most game-changing discoveries come from the boldness to imagine that existing paradigms might be wrong. That's a theme repeated in this special issue. For the third year, *Science News* is spotlighting 10 early- and mid-career scientists who are — through their own special mixes of personal attributes — leaving a mark on their fields (see Page 16). It's a rare (for us) celebration of the individual. And it demonstrates that luck is not enough. Not nearly. — *Elizabeth Quill, Acting Editor in Chief*

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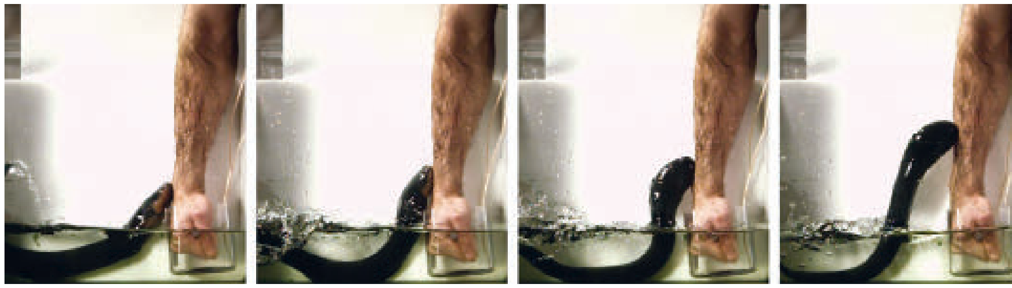
Excerpt from the October 14, 1967 issue of *Science News*

50 YEARS AGO

The earthy moon

Space scientists have been intrigued for years with the possibility of finding usable oxygen on the moon — not in the lunar atmosphere, since there essentially is none, but in the rocks. As long ago as 1962 ... [NASA researchers] predicted vast lunar processing plants turning out 4,000 pounds of liquid oxygen per month, both for breathing and as an oxidizer for rocket fuel.... Now the Surveyor 5 spacecraft ... reveals it is standing directly over just the kind of rock that would do the job.

UPDATE: The moon is not yet dotted with lunar oxygen factories, but scientists are still devising ways to pull oxygen from moon rocks. One technique, proposed by NASA scientists in 2010, isolates oxygen by heating lunar rocks to over 1650° Celsius and exposing them to methane. Chemical reactions would produce carbon monoxide and hydrogen, which then react to create water. Passing an electric current through the water would separate oxygen from hydrogen, allowing the desired gas to be captured.



This electric eel may be small as eels go, but the pain from its shock made a researcher jerk his hand away after every zap.

BOTH: K. CATANIA/*CURRENT BIOLOGY* 2017

THE SCIENCE LIFE

Researcher goes all in to study eel electricity

Kenneth Catania knows just how much it hurts to be zapped by an electric eel. The biologist at Vanderbilt University in Nashville has measured the strength of an eel attack on a real-life potential predator: himself. Though many people have felt an eel's sting, Catania is the first to measure the strength of the shock on a human.

The researcher placed his arm in a tank with a 40-centimeter-long electric eel (small as eels go) and calculated the strength of the electric current that flowed into him when the eel reached out of the water and attacked. At its peak, the current in his arm reached 40 to 50 milliamperes, he reports online September 14 in *Current Biology.* This zap was painful enough to cause him to jerk his hand from the tank in each of about 10 trials. "If you've ever been on a farm and touched an electric fence, it's pretty similar to that," he says.

Catania got hooked on eels in 2014 while researching the slippery creatures to write a book chapter. "I got to do some photography and video to get to know them before I wrote about them, and I started making discoveries," he says. He has since developed a body of research analyzing the eels' intricate behaviors (*SN: 11/28/15, p. 5*).

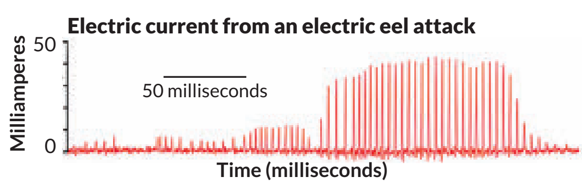
Catania didn't dive headfirst into using his own limbs. First, he tested the lunge attacks on a plastic alligator head (it lit up when zapped), a fake arm and metal plates. But he eventually needed to know the power of a shock on a living thing. When he divulged his plan to use his own arm for the measurements, a few eager students volunteered theirs as well; he declined their help.

"I don't think it would go over very well [with the university] if I were bringing in students to do that," he laughs. "Plus, I don't think that many would come back to my lab."

Before Catania's work, descriptions of the way the eels use their electric current had been fairly primitive, says biologist Jason Gallant, who heads the Michigan State University Electric Fish Lab in East Lansing. Catania has revealed that the electric eel uses its electric ability "to its absolute advantage in a very sophisticated, deliberate way," Gallant says.

The eels use electric current to navigate, communicate and zap small prey. Once the prey are stunned and immobilized, the eel goes in for the kill. When faced with large land-based predators, as Catania showed in 2016, an eel launches itself from the water and electrifies the animal with a touch of the head (*SN Online: 6/9/16*).

Based on his latest observations, Catania estimates that a human struck on the trunk by a more typical, 1.8-meter-long electric eel might endure a zap about 8½ times as powerful as that from a typical law-enforcement TASER gun. *— Mariah Quintanilla*

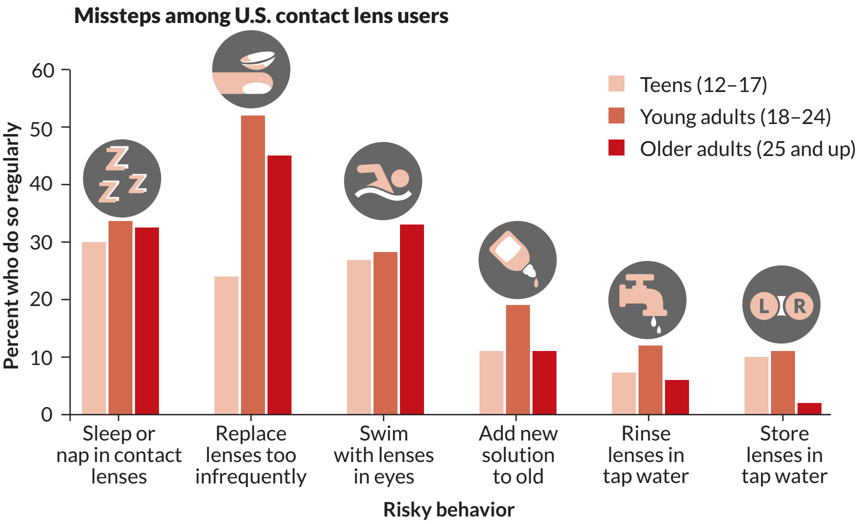


Power leap The current an electric eel released into the arm of a researcher got stronger as the animal reached out of the water to attack. The highest bars in the graph correspond to the third and fourth panels above.

FOR DAILY USE

Risky behaviors among contact lens wearers

People in the United States who wear contact lenses share an eye-opening characteristic. Roughly 85 percent report regularly taking at least one risk when wearing or cleaning their lenses. In the Aug. 18 *Morbidity and Mortality Weekly Report*, researchers at the U.S. Centers for Disease Control and Prevention describe results from a 2016 national survey of more than 6,000 people. Contrary to previous studies, teens did better in some categories than adults. The no-no's below can lead to serious eye infections, mainly by introducing microorganisms into the eye. Even water that's safe to drink or swim in can bug up lenses. *— Aimee Cunningham*



TEASER

Courteous robot gets around

A new robot has the mobility of R2-D2 and the manners of C-3PO. This knee-high, self-driving bot abides by social protocols as it weaves through foot traffic: keep right, pass left, respect others' personal space. The machine, presented at the IEEE/RSJ International Conference on Intelligent Robots and Systems in Vancouver on September 25, paves the way for robots that could one day navigate sidewalks to make deliveries or transport people through hospital hallways.

Programming a polite mobile bot is different from designing a self-driving car, says Michael Everett, a mechanical engineer at MIT. Unlike the rigid rules of the road, "the rules that humans follow when they're walking around are pretty loose." Building a bot that's light on its wheels among individuals with highly unpredictable paths is "a totally different ball game," he says.

Everett and colleagues decked out their rover with webcams and a depth sensor, then taught the bot how to behave by running it through thousands of simulated scenarios. After several hours of training, the robot could cruise at walking speed down a busy hallway without tripping up anyone nearby. *— Maria Temming*

This careful robot avoids obstacles and oncoming pedestrians.

In 2014, a Phoenicid meteor shower (streak, at arrow) appeared for the first time since 1956 (the bright spot is the moon).

MYSTERY SOLVED

The case of the vanishing comet

The reappearance of a long-lost meteor shower has finally explained what happened to a missing comet named 289P/Blanpain.

That comet was spotted only once in 1819 and never again, unusual for a body orbiting the sun. But in 2003, astronomers found a small asteroid moving along the Blanpain orbit, suggesting the space rock might be the comet (or a piece of it) after it ejected much of its cometary dust.

Some of that dust may have been what Japanese researchers saw in 1956 when they observed a meteor shower from the constellation Phoenix. Meteor showers occur when dust left behind by a comet burns up as it hits Earth's atmosphere. Those "Phoenicid" meteors hadn't been seen before — or since.

Astronomer Jun-ichi Watanabe of the National Astronomical Observatory of Japan in Tokyo and colleagues traced the meteors to where the comet's dust trail should have been. In 2010, the group predicted that the remaining dust would create another shower in 2014.

Team members traveled to North Carolina and Spain's Canary Islands to test their prediction, and on the first two days of December, 2014, they saw Phoenicids streak across the sky. But there were about 90 percent fewer meteors than expected; Blanpain may have lost its dust more quickly than previously thought, the team reports in the Sept. 1 *Planetary and Space Science*. The astronomers will get a second chance to check — another shower is expected in 2019. *— Lisa Grossman*

FROM TOP: HIROYUKI TODA/NAOJ; T. TIBBITTS; MIT

Watch a robot maneuver busy hallways at **bit.ly/SN_SociallyAwareRobots**

HUMANS & SOCIETY

Skeleton ignites Viking warrior debate

DNA identifies individual buried with full battle gear as female

BY BRUCE BOWER

Viking warriors have a historical reputation as tough guys, with an emphasis on testosterone. But scientists now say that DNA has unveiled a Viking warrior woman who was previously found in a roughly 1,000-year-old grave in Sweden. Until now, many researchers assumed that "she" was a "he" buried with a set of weapons and related paraphernalia worthy of a high-ranking military officer.

If the woman was in fact a warrior, a team led by archaeologist Charlotte Hedenstierna-Jonson of Uppsala University in Sweden has identified the first known female Viking to have participated in what's been considered a male pursuit.

But the findings, published online September 8 in the *American Journal of Physical Anthropology*, have drawn criticism from some researchers. All that's known for sure, they say, is that the skeleton assessed in the new report belonged to a woman who moved to the town where she was interred after spending her youth elsewhere.

"Have we found the Mulan of Sweden, or a woman buried with the rank symbols of a husband who died abroad?" asks archaeologist Søren Sindbæk of Aarhus University in Denmark. There's no way to know what meanings Vikings attached to weapons placed in the grave, he says.

Though the paper dubs the woman "a high-ranking female Viking warrior," other interpretations of her identity are possible, Hedenstierna-Jonson acknowledges. But she notes that the woman "was an exception in a sphere dominated by men, either if she was an active warrior or if she was 'only' buried in full warrior dress with a complete set of weapons."

Excavations in the late 1800s at Birka, a trading center from the eighth century to around 1000 (*SN: 4/18/15, p. 8*), uncovered the woman's grave. About 1,100 of more than 3,000 graves known to encircle Birka, on an island about 30 kilometers west of Stockholm, have been unearthed.

Excavators noted that the body lay among a warrior's gear, including an ax, a spear, arrows, a large knife, two shields and two horses. Playing pieces, apparently for a board game, suggest the woman may have been a high-ranking officer with knowledge of military tactics, Hedenstierna-Jonson's team speculates.

Researchers have usually assumed that Viking-era graves with weapons contain male warriors. Yet many skeletons in these graves, including the Birka woman, show no battle injuries.

Anna Kjellström, a study coauthor and biological anthropologist at Stockholm University, reported in 2013 that the Birka individual was a woman, based on pelvic shape and bone sizes. DNA from the skeleton now confirms it and reveals genetic similarities to modern northern Europeans.

A comparison of two forms of radioactive strontium in teeth from the Birka woman, 15 other individuals excavated at Birka and pre–Viking age people from elsewhere in Sweden indicates that the woman moved to the trading center as a teenager or young woman. Humans absorb strontium from local rock formations through water and plant foods, leaving a chemical signature in teeth that roughly maps where these people grew up. The researchers estimate the woman was at least 30 years old at death.

The new paper doesn't demonstrate that the woman was a warrior, Judith Jesch of the University of Nottingham in England writes September 9 on her *Norse and Viking Ramblings* blog. Perhaps all alleged warriors in Viking-era graves who lack serious wounds didn't actually fight, writes Jesch, a specialist in Viking-era languages and literature who has long collaborated with archaeologists. The researchers offer no evidence that the bones show signs of strenuous physical activity expected from a warrior adept enough to avoid injury, Jesch writes.

"A certain amount of confusion" surrounds the original locations of bones excavated at Birka, Jesch adds. Sloppy excavation practices more than 100 years ago accidentally lumped together bones from different graves, she says in her post.

Whether or not the Birka woman fought, women could have been warriors during the Viking age, says archaeologist Marianne Moen of the University of Oslo. Viking women were landowners, farmers, merchants, traders and participants in legal proceedings. Graves of two other Viking-era women, both in Norway, contain numerous weapons.

What's important is not to hold women to a different standard than men when assessing comparable weapons placed in their graves, Moen asserts. The Birka find "was a warrior grave until it was sexed as female," she says. "Now a lot of people would like to call it something else. That is where the danger lies here." ■

A 10th century woman buried with horses, weapons and other artifacts (illustration of excavation, left; grave reconstruction, right) may have been a Viking warrior.

FROM LEFT: EVALD HANSEN, C. HEDENSTIERNA-JONSON *ET AL*/*AM. J. PHYS. ANTHROPOL.* 2017; ÞÓRHALLUR ÞRÁINSSON (© NEIL PRICE)

STEVEN SAFFI

Large tanks of water (one shown above) at the Pierre Auger Observatory in Argentina have helped astronomers track the direction of incoming ultrahigh energy cosmic rays.

ATOM & COSMOS

Cosmic rays raid the Milky Way

Ultrahigh energy particles come from other galaxies

BY LISA GROSSMAN

The largest study yet of the most energetic particles to slam into Earth provides the first solid clues to where the particles come from. Using a giant array of tubs of water, scientists found that these ultrahigh energy cosmic rays originate outside of the Milky Way.

An international team of researchers analyzed about 12 years of data to show that particles with energies above 8 billion billion electron volts generally come from a particular direction in the sky, and it's not the galaxy's center. The team reports the finding in the Sept. 22 *Science*.

"It's the first clear experimental indication that the sources of these high-energy particles are located outside of our own galaxy, probably somewhere in the nearby universe," says particle astrophysicist Karl-Heinz Kampert of the University of Wuppertal in Germany, a spokesperson for the Pierre Auger Collaboration, which made the discovery.

Ultrahigh energy cosmic rays are atomic nuclei that zip through space at some of the highest energies observed in nature. Some unknown engine accelerates the particles to energies many million times as high as that of protons in the Large Hadron Collider, the largest particle accelerator on Earth.

Previous hints suggested that cosmic rays could be boosted to such high speeds by starbursts (*SN: 12/5/09, p. 8*), supernovas (*SN: 3/23/13, p. 16*) and supermassive black holes in the centers of galaxies — possibly including the black hole in the middle of the Milky Way (*SN: 11/10/07, p. 291*). But the charged particles are difficult to track back to their homes because magnetic fields in space scatter the rays. To overcome that uncertainty, researchers need lots of particles.

> "It's a very hard problem to attack, maybe the hardest problem in high-energy astrophysics."
> VASILIKI PAVLIDOU

"It's a very hard problem to attack, maybe the hardest problem in high-energy astrophysics," says Vasiliki Pavlidou, an astroparticle physicist at the University of Crete in Heraklion, Greece, who was not involved in the new analysis.

The Pierre Auger Observatory in Argentina finds the particles using a collection of 1,600 tubs of ultrapure water arranged over 3,000 square kilometers. That spread gives the observatory a better chance of detecting ultrahigh energy cosmic rays, which are so rare that an average of about one particle per square kilometer hits Earth per year.

Luckily, the tubs don't need to detect individual cosmic rays directly. Instead, the structures catch the cascade of particles that cosmic rays produce when they slam into Earth's atmosphere, called an air shower. When the electrons, protons and other subatomic particles of the air shower run through the tubs of water, the particles give off a little burst of light known as Cherenkov radiation. The speed, direction and arrival time of that light can help identify where the cosmic ray originated.

The observatory caught evidence of 30,000 ultrahigh energy cosmic rays between January 1, 2004, and August 31, 2016. The team found that, compared with the average density of particle strikes across the whole sky, about 6 percent fewer particles came from the center of the Milky Way. Slightly more particles came from a direction about 125 degrees away from the galactic center.

Intriguingly, the excess points in the direction of the nearest cluster of galaxies to the Milky Way, located between 300 million and 900 million light-years from Earth. That finding suggests these cosmic rays are produced in some galaxies, Kampert says — just not ours.

Trying to identify which galaxies produce cosmic rays, and seeing if there is any pattern linking the galaxies, are the next steps. That research could help narrow down the processes that can accelerate cosmic rays. "What we would like to understand is, not only what kind of sources they are, but also how these sources work," Kampert says.

The result is "the most exciting thing that has happened in this field for a very long time," Pavlidou says. "I definitely think the first experiment that will establish where these particles are coming from will get the Nobel Prize. But it's very hard. I think we have a decade still to go." ■

See a simulated cosmic ray's journey to Earth at **bit.ly/SN_cosmicray**

GENES & CELLS

Edited embryos reveal gene's function

In a first, CRISPR/Cas9 aids study of early human development

BY TINA HESMAN SAEY

For the first time, researchers have disabled a gene in human embryos to learn about its role in development.

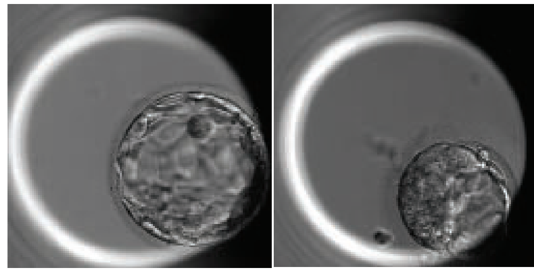
Using molecular scissors called CRISPR/Cas9, researchers made crippling cuts in the *OCT4* gene, Kathy Niakan and colleagues report online September 20 in *Nature*. The edits revealed a surprising role for the gene in the development of the placenta.

Until now, directly studying human development genes has not been possible, says developmental biologist Dieter Egli of Columbia University. "What we know about human development is largely inferred from studies of mice, frogs and other model organisms."

Other scientists have used CRISPR/Cas9 to repair mutated genes in human embryos (*SN: 9/2/17, p. 6*). That work aims to prevent genetic diseases, but it has no direct clinical applications yet.

Niakan, a developmental biologist at the Francis Crick Institute in London, and colleagues focused on a gene called *OCT4* (also known as *POU5F1*), a master regulator of gene activity important in mouse embryo development. This gene is also known to help human embryonic stem cells stay flexible enough to become any type of body cell. But researchers didn't know precisely how *OCT4* operates during human development. Niakan already had clues that it works at slightly different times in human embryos than it does in mice.

In the experiment, human embryos lacking *OCT4* had difficulty reaching the blastocyst stage: Only 19 percent of edited embryos formed blastocysts, while 47 percent of unedited embryos did. Blastocysts are balls of about 200 cells that form a few days after fertilization. The ball's outer layer of cells gives rise to the placenta. Inside the blastocyst, one type of embryonic stem cell, known as epiblast progenitor cells, will give rise to all the cells in the body.



A 5-day-old human embryo, called a blastocyst, is usually a hollow ball of about 200 cells (left). Embryos edited to remove the *OCT4* gene (right) fail to develop into normal blastocysts.

"Knocking out" *OCT4* disrupted epiblast development, as Niakan's group had predicted. What the researchers hadn't expected is that *OCT4* also affects development of the placenta precursor cells on the outside of the blastocyst.

"That's not predicted anywhere in the literature," Niakan says. "We'll be spending quite a lot of time on this in the future to uncover exactly what this role might be." ■

BODY & BRAIN

Antibodies defeat HIV by ganging up

Two new approaches stopped infections in rhesus monkeys

BY AIMEE CUNNINGHAM

For certain HIV antibodies, having a buddy or two makes a big difference in the fight against the virus.

Combining the antibodies, called broadly neutralizing antibodies, may stop more strains of HIV than any single one can, two new studies suggest. A "triple-threat" antibody can bind to three spots on the virus, researchers report online September 20 in *Science*. In the second study, a separate team describes a cocktail of two single antibodies that each target a different region of HIV. Both methods prevented infection from multiple strains of an HIV-like virus in monkeys.

Broadly neutralizing antibodies can bind to multiple strains of HIV, stopping the virus from infecting cells. Using more than one of these antibodies "is the most promising approach" to stopping HIV in humans because it offers more coverage, says Nancy Haigwood, a molecular biologist at the Oregon Health & Science University in Portland.

This extra coverage is needed because HIV is a master of mutation. "It's really adopted every bit of what I would call molecular trickery to outwit our immune system," says Gary Nabel, a coauthor of the study in *Science* and chief scientific officer of the pharmaceutical company Sanofi in Cambridge, Mass. The immune system keeps trying to recognize parts of the virus, but mutations in the virus can alter those sites.

No single antibody can block all strains, says virologist Dan Barouch of Beth Israel Deaconess Medical Center in Boston. Barouch and colleagues tackled the issue by mixing two antibodies together. None of five rhesus monkeys given the cocktail became infected after exposure to a mix of two simian-human immunodeficiency virus, or SHIV, strains. (SHIV and HIV share an outer protein where antibodies bind.) Fifteen other monkeys given either one antibody or no antibodies got infected, the researchers report in the Sept. 20 *Science Translational Medicine*.

Nabel's team took a different tack by developing a molecule that combines the binding talents of three antibodies. None of eight rhesus monkeys given the trio antibody and exposed to a mix of SHIV strains developed infections; 11 of 16 monkeys given just one antibody did.

David Margolis, a virologist at the University of North Carolina School of Medicine in Chapel Hill, notes that both approaches most likely have preventive potential, but they also may be therapeutic. The next step is to test the combination antibodies in people. ■

BOTH: K. NIAKAN, *NATURE*

EARTH & ENVIRONMENT

Algae speed up melting of glacial snow

Surface reddening from microbes boosts sunlight absorption

BY LAUREL HAMERS

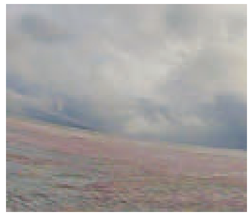
Microbes are pushing glacial snow into the red.

An alga species that grows on glaciers gives snow a crimson hue, which increases the amount of sunlight that the snow soaks up and makes it melt faster, new measurements confirm. On Alaska's Harding Icefield, these microbes are responsible for about a sixth of the snowmelt in algae-tinged areas, researchers report September 18 in *Nature Geoscience*. The finding suggests that future climate simulations should account for the effects of these algae when making predictions about glacial melt.

The pink "watermelon" snow, as it's known, is caused by *Chlamydomonas nivalis* algae and related species. *C. nivalis* thrives in cold water, and "snowfields and glaciers are, in some sense, an aquatic environment," says study coauthor Roman Dial, a biologist at Alaska Pacific University in Anchorage. Blooms pop up in the spring and summer, and algae can come back year after year. Recent work has suggested that darkening by algae or other microbes might make snow melt faster, and that melt might spur more algal growth, starting a feedback loop of accelerated melting. But this is the first time the effect of algae-darkening on snowmelt has been directly tested.

"We used everything from microscopes to satellites," Dial says.

Glaciers naturally contain nutrients like nitrogen and phosphorus. At high enough levels, those nutrients might spur algal growth. So Dial and colleagues added either extra water or nutrient-rich fertilizer to different patches of snow on Harding Icefield, a 1,900-square-kilometer frozen expanse in southern Alaska. Extra water led to about a 50 percent increase in the algal growth compared with growth in untouched regions. Adding fertilizer nearly quadrupled algal growth.



Algae turn the snow pink and red on parts of Alaska's Harding Icefield. Pink snow melts faster than clean snow, experiments show.

In other test sites, the researchers added algae to some areas by dousing spots in fertilizer and removed algae from other sites using bleach. During 100 days of study, zones with extra algae melted much faster than areas where algae had been stripped away and were three times as likely to melt down to slush or exposed ice by the end of the test. Exposing ice could amplify the algae's melting effects because ice reflects less (and absorbs more) sunlight than clean snow.

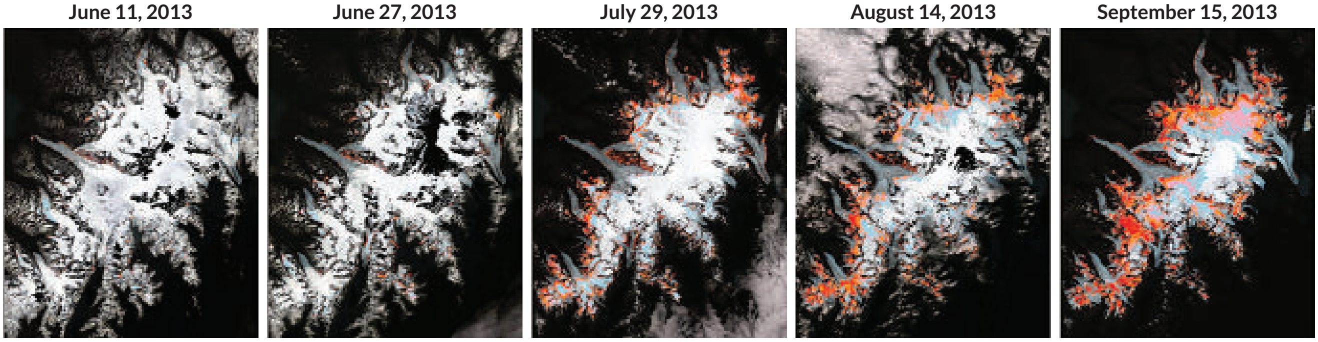
Using satellite imagery and remote sensing equipment, the team estimated algae grew on over a third of the Harding Icefield in the summer of 2013. In that area, reddened snow was responsible for about 17 percent of the melt, the team concluded. Most of the rest of the melting was caused by high temperatures.

"There's a growing push to understand the impact of microorganisms on glaciers and ice sheets," says microbiologist Christopher Williamson of the University of Bristol in England. Scientists often rely on long-term observations, Williamson says, but this research manipulates the environment to show a direct connection between algal growth and snowmelt.

The effect probably isn't limited to Alaska. A different team sampled red snow from across the Arctic and found that its presence decreased snow reflectivity by 13 percent, as reported in *Nature Communications* last year. Lower reflectivity probably increases the snow's melt rate because more sunlight gets absorbed, though that wasn't directly measured. And if rising Arctic temperatures increase the area of snow just below freezing, algae's preferred habitat, the algae might expand their range.

Other microbes might also hasten glacial melt. Williamson is investigating the impact of ice algae and bacteria on the Greenland ice sheet. He and colleagues want to figure out whether the dark tinge from those microbial residents helps explain why the ice sheet is melting faster than expected from warming alone. ■

June 11, 2013 | June 27, 2013 | July 29, 2013 | August 14, 2013 | September 15, 2013



Microbe melt The estimated abundance of snow algae across Alaska's Harding Icefield increased over the summer of 2013. Snow-darkening algae grew on over a third of the glacial area, scientists say.

ALL: GERARD GANEY

MATTER & ENERGY

Traveler in a vacuum might heat up

Classical analog matches predictions of Unruh effect

BY EMILY CONOVER

Empty space might feel hot to a traveler zipping through at a rapidly increasing clip — or so some physicists predict. A new study hints that they might be right.

That idea, known as the Unruh effect, seems to be supported by an analogous effect: Patterns in water waves re-create the expected signature of the Unruh effect, researchers argue September 7 at arXiv.org. If it holds up to scrutiny, the result would be the first time a version of the effect has been spotted.

It's a counterintuitive concept: To an observer moving at a constant velocity, a perfect vacuum would be frigid. But someone accelerating through that empty space might work up quite a sweat. "The Unruh effect is basically saying that if you are accelerated enough in the vacuum, you can burn to death," says theoretical physicist George Matsas of São Paulo State University in Brazil.

Dreamed up in the 1970s, the Unruh effect — named after physicist William Unruh — hinges on the fact that space is never truly empty in quantum physics. Chaotic swirls of particles and antiparticles are constantly created and annihilated. For anyone moving at a constant velocity, the particles are transient. They appear to briefly violate conservation of energy — possible thanks to Heisenberg's uncertainty principle. But for an accelerating observer, the particles have well-defined energies and produce a temperature that increases with greater acceleration.

No one has confirmed the Unruh effect because it's so hard to measure. A temperature of 1 kelvin (1 degree Celsius above absolute zero) would require an acceleration about 10 billion billion times that generated by gravity on Earth's surface.

Ulf Leonhardt of the Weizmann Institute of Science in Rehovot, Israel, and colleagues set out to observe an analogous effect — one without quantum mechanics — that wouldn't need extreme acceleration. By vibrating a channel of water, the scientists made waves reminiscent of the frothing vacuum that begets particles and antiparticles. The team traced the waves' height along the trajectory an accelerating observer would take, which produced a pattern analogous to a temperature. When the ripples were broken up by frequency, the distribution matched that of the frequencies of radiation that would be associated with the Unruh effect's predicted temperature.

"Quite convincing," Matsas says of the work. Other physicists are more cautious. Silke Weinfurtner of the University of Nottingham in England notes that the researchers didn't accelerate the observer. They just deduced what a hypothetical observer would detect. ■

LIFE & EVOLUTION

Ancient fossils feature tube feet

Sea star relatives probably used tentacles to grab food

BY LAUREL HAMERS

Sea stars and their kin eat, breathe and scuttle around the seafloor with tiny tube feet. Now scientists have gotten their first look at similar tentacle-like structures in an extinct group of echinoderms.

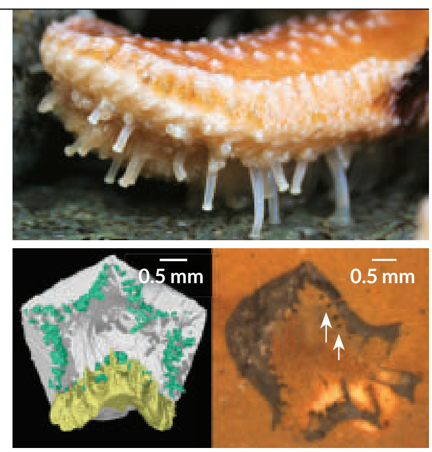
Scientists had suspected that the ancient marine invertebrates, called edrioasteroids, had tube feet. But a set of well-preserved fossils found in England that date to about 430 million years ago, described in the Sept. 13 *Proceedings of the Royal Society B,* provides proof.

Usually, when an echinoderm dies, "the tube feet are the first things that go," says Colin Sumrall, a paleobiologist at the University of Tennessee in Knoxville who wasn't part of the study. "The thing that's so stunning is that they didn't rot away."

The edrioasteroids were probably buried alive by volcanic ash, entrapped before their soft tissues could break down, says Derek Briggs, a paleontologist at Yale University.

Briggs' group slowly ground three fossils down, taking layer-by-layer images to build a 3-D view. The fossils belong to a new genus, the analysis reveals. Unlike mostly flat sea stars, the species — dubbed *Heropyrgus disterminus* — had a conical body less than 3 centimeters long. Its narrower end anchored in the seabed. The other end sported five plates partially covering dozens of tube feet arranged in a pentagonal ring.

Today's echinoderms use hydraulic pressure in a vascular system to extend and retract their tube feet, which serve a variety of roles. The feet help animals pull in particles of food, filter water or gases and even inch along the seafloor. The placement of *H. disterminus*' tube feet suggests that the animal probably used the appendages mostly for feeding and gas exchange.



Modern echinoderms such as sea stars have tentacle-like tube feet (top). Three-dimensional imaging of fossils (one at bottom right) reveal ancient echinoderms had these structures too (arrows in fossil; green dots in 3-D rendering).

SEA STAR: DAN BAGUR/SHUTTERSTOCK; FOSSILS: D.E.G. BRIGGS *ET AL/PROC. R. SOC. LOND. B, BIOL. SCI.* 2017

Sumrall says he isn't surprised that this edrioasteroid had tube feet. But *H. disterminus* does have some surprises: It had five-point symmetry in its fleshy top part like most other echinoderms, but the animal switched to eight-point symmetry in its long, columnar body. ■

GENES & CELLS

Alzheimer's-linked gene is triple threat

In addition to plaques, *APOE4* spurs tangles, brain inflammation

BY TINA HESMAN SAEY

A genetic risk factor for Alzheimer's disease is a double, make that triple, whammy.

In addition to speeding up the development of brain plaques associated with Alzheimer's, a gene variant known as *APOE4* also worsens tau tangles, another signature of the disease, researchers report online September 20 in *Nature*. The APOE4 protein also ramps up brain inflammation that kills brain cells, David Holtzman, a neuroscientist at Washington University School of Medicine in St. Louis, and colleagues have discovered.

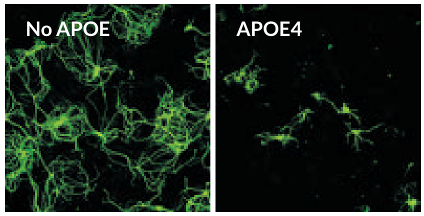
"This paper is a tour de force," says Robert Vassar, a neuroscientist at Northwestern University Feinberg School of Medicine in Chicago. "It's a seminal study that's going to be a landmark in the field" of Alzheimer's research, Vassar predicts.

People with the E4 version of the *APOE* gene are at increased risk of developing Alzheimer's. A version of the gene called *APOE3* has no effect on Alzheimer's risk, whereas the *APOE2* version reduces the risk of the disease. How APOE protein, which helps clear cholesterol from the body, affects brain cells is not understood.

But Holtzman and others previously demonstrated that plaques of amyloid-beta protein build up faster in the brains of *APOE4* carriers (*SN: 7/30/11, p. 9*). Having plaques isn't enough to cause the disease, Holtzman says. Tangles of another protein called tau are also required. Once tau tangles accumulate, brain cells die and people develop dementia. In a set of experiments, Holtzman and colleagues now show, for the first time, a link between *APOE4* and tau tangles.

In one experiment, mice with no A-beta in their brains developed more tau tangles if they carried the human version of *APOE4* than if they had the human *APOE3*. That finding indicates *APOE4* affects tau independently of A-beta.

Brains of people who died from various diseases caused by tangled tau had more dead and damaged cells if the people carried *APOE4*. The researchers also tracked 592 people who had low levels of A-beta in their cerebral spinal fluid — a clue that plaques have formed in the brain — and who showed symptoms of Alzheimer's. Over a five- to 10-year period, the disease progressed 14 percent faster in people with one copy of *APOE4* and 23 percent faster in people with two copies than in people who didn't have that version of the gene. Those worsening symptoms are presumed to be caused by more rapid buildup of tangles in the *APOE4* carriers.



Mouse brain nerve cells (green) making a disease-causing version of the tau protein were killed off when grown in lab dishes with glial cells that made the APOE4 protein.

Y. SHI ET AL/*NATURE* 2017

The APOE4 protein also seems to make Alzheimer's worse by causing inflammation. In a lab dish, the team grew two kinds of mouse glial brain cells with brain nerve cells, or neurons, that make disease-causing forms of tau. Mouse neurons grown with glia that made no APOE grew well, even though the neurons were making abnormal tau. But neurons grown with glia making APOE4 often died. APOE4 provoked inflammation responses in the normally friendly glia, leading those cells to kill neurons. Such inflammation can make brain degeneration worse.

The data linking *APOE4* to tau tangles and brain inflammation is "super tight," says molecular neurobiologist Sangram Sisodia of the University of Chicago. But much more work is needed to uncover which molecules the APOE4 protein interacts with, so researchers can devise ways to counteract its negative effects. ■

NEWS IN BRIEF

EARTH & ENVIRONMENT

Earlier start for plate tectonics

Most estimates put the onset of plate tectonics at around 3 billion years ago. But a new study in the Sept. 22 *Science* asserts that the large plates that make up Earth's outer crust began shifting 500 million years earlier.

Nicolas Greber of the University of Geneva and colleagues say previous studies got it wrong because scientists looked at silicon dioxide in shales, which bear the detritus of continental rocks. These rocks' silicon dioxide composition hints at when continental rocks began diverging in makeup from oceanic rocks due to plate tectonics.

But weathering wreaks havoc on the silicon dioxide in shale. So, Greber's team turned to titanium. The proportion of titanium isotopes in shale is a useful stand-in for silicon dioxide concentrations because titanium isn't as easily altered by weathering. Those data helped the team estimate that plate tectonics was already going strong by 3.5 billion years ago.
— Carolyn Gramling

BODY & BRAIN

Microbes hobble chemo drug

Certain bacteria make an enzyme that inactivates the common chemotherapy drug gemcitabine, a team reports in the Sept. 15 *Science*. Gemcitabine treats pancreatic, lung, breast and bladder cancers.

Bacteria that produce the enzyme cytidine deaminase converted the drug to an inactive form. That allowed tumor cells to survive gemcitabine treatment in lab dishes and mouse studies, Leore Geller of the Weizmann Institute of Science in Rehovot, Israel, and colleagues found. In 113 pancreatic tumors sampled from human patients, 86 contained gemcitabine-inactivating bacteria.

Combinations of gemcitabine and antibiotics might make chemo more effective for some patients, the researchers say. *— Tina Hesman Saey*


ENGINEERING
SUCCESS

FEATURE

The SN 10

Scientists TO WATCH

Introducing 10 innovators transforming their fields

MASSIMO PISTORE

Earlier this year, General Electric asked a brilliant question: What if scientist Mildred Dresselhaus was treated like a celebrity? The idea, aired as a TV commercial, had many of us smiling at the possibility. In the ad, fans stop the nanoscience pioneer in the street to take selfies, a young girl receives a Dresselhaus doll as a birthday gift and a student sends a Millie emoji after acing a physics exam. The ad debuted in February during the Academy Awards telecast, just weeks before Dresselhaus passed away at age 86.

She lived an accomplished life. It's nice to know the public got to hear about her, even if so late in her life. In reality, few women or, for that matter, men in science are well known outside of their own research circles — and certainly not well enough to appear on billboards or celebrity talk shows.

In the spirit of introducing the world to more innovators, and doing it early in their careers (maybe even in preparation for the next Oscar-worthy commercial), *Science News* presents its SN 10 for 2017. For the third year, we are spotlighting the work of 10 early and mid-career scientists, age 40 and under, who stand out to mentors and peers as people who will make a difference.

Some of the researchers profiled here, nominated by Nobel laureates and recently elected members of the National Academy of Sciences, are motivated by the desire to ease the human condition. They want to feed the growing world population, boost our reliance on renewable energy or reduce the burden of global disease. One molecular anthropologist is revisiting the past, while an astronomer has his eyes pointed skyward, to find habitable worlds outside the solar system.

These scientists have been called creative, curious and fearless. They share a willingness to question existing knowledge and forge new paths that is reminiscent of Dresselhaus' approach to research. Sounds like a winning strategy. — *Cori Vanchieri*

Parasites fight for nutrients

By Aimee Cunningham

Lena Pernas, 30
PARASITOLOGIST
UNIVERSITY OF PADOVA

As a 9-year-old, Lena Pernas was plagued by many virtual infections. A favorite pastime was playing *The Amazon Trail*, an educational computer game. Players could encounter malaria near the river, and "I got malaria a lot," Pernas says. This predicament inspired her to learn about the disease, caused by *Plasmodium* parasites. Since then, parasites have been "a singular obsession," she says.

Her parasite of choice eventually became *Toxoplasma gondii*, which infects an estimated one-third of people. The parasite causes toxoplasmosis, not a terribly bothersome disease for people with healthy immune systems. But it can be serious, damaging the eyes and brain in those with weakened immune systems and in fetuses. (Pregnant women are warned not to handle kitty litter because the parasite can be found in cat feces.)

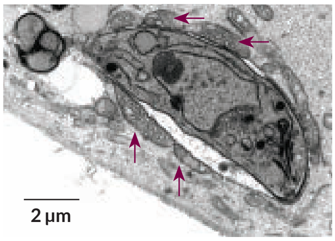
Pernas, now 30 and a postdoctoral fellow at the University of Padova in Italy, has upended thinking about how this parasite interacts with its host, specifically host mitochondria. Known as the cell's energy producers, these organelles are also involved in immunity and cell death. By studying how mitochondria respond to a parasitic infection, Pernas has begun to probe the ways access to nutrients in the cell — necessary for both the cell and the parasite — shapes an infection.

Studying this food fight "will teach us really interesting biology about how the cell senses the presence of a parasite metabolically, and how the cell is able to metabolically respond," Pernas says. Her discoveries are at the forefront of a new focus in microbiology: viewing the host-pathogen relationship as a "competition for nutrients," says cell biologist Navdeep Chandel of Northwestern University.

Inside a mammalian cell, *Toxoplasma* wraps itself in a sac, or vacuole, made from part of the cell's membrane. Early imaging showed a ring of the cell's mitochondria surrounding the parasite's vacuole. Why the mitochondria were there wasn't clear.

As a graduate student in the lab of John Boothroyd, a microbiologist at Stanford University School of Medicine, Pernas questioned two existing assumptions: that all three main strains of *Toxoplasma* interact with mitochondria in the same way, and that the key protein underpinning this relationship had already been found. She was right to ask. In 2014 in *PLOS Biology*, Pernas, Boothroyd and colleagues reported that when a type I or type III *Toxoplasma* invades a cell, the mitochondria circle the vacuole. But when the type II parasite enters, the mitochondria don't gather around.

With this knowledge, Pernas and colleagues identified the correct parasitic protein that tethers the organelles to the vacuole. All three *Toxoplasma* types have the gene for this protein, called MAF1, but only type I and III make the protein, the researchers found.



Mitochondria (arrows) surround a vacuole containing a *Toxoplasma* parasite. New work suggests mitochondria and invader fight for fuel.

FROM TOP: L. PERNAS; TIMOTHY ARCHIBALD

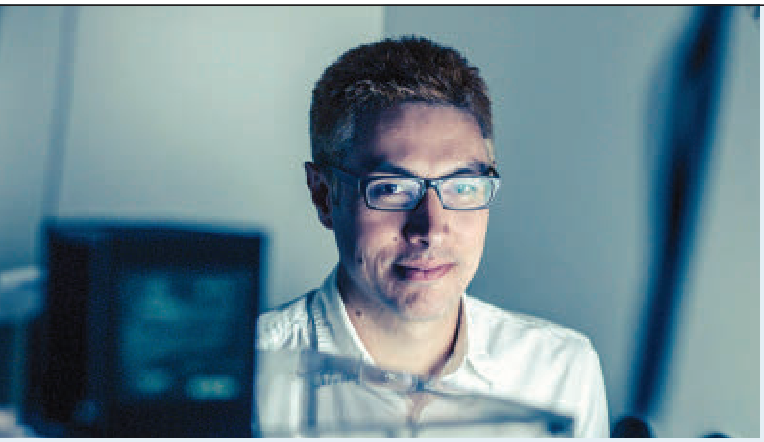
Pernas "completely countered the dogma of the field," Boothroyd says. "Where she excels is having that instinct of saying, 'This one doesn't smell right.' " The finding indicates that *Toxoplasma*, rather than the host cell, drives the interaction with mitochondria, and it is probably something the parasite does to survive in some subset of hosts, he says.

At Padova, Pernas is beginning to uncover how the interaction between mitochondria and the parasite affects the invader's survival. She's investigating what she calls "the rules that govern the hunger games between the host and parasite."

Toxoplasma, which needs nutrients from its host cell, is a "prolific scavenger" of fatty acids, Pernas explains. Mitochondria also use fatty acids, breaking them down for energy. When a type I or III *Toxoplasma* infects a cell, the mitochondria somehow sense the parasite's presence and move to surround the vacuole, Pernas says. (Why this doesn't happen with type II parasites is unclear.) Next comes a "fight for fatty acids," she says.

She has found, in unpublished work, that the invading parasite starts gobbling up fatty acids. The mitochondria circling the vacuole actually fuse together to more efficiently use nutrients. This limits the fatty acids that the parasite can get. The parasite sends out the MAF1 protein to tether the mitochondria to the vacuole, which seems to break them up, giving the parasite the greater share of fatty acids. This fighting for nutrients might be "a widespread phenomenon," Chandel says.

Understanding the battle could lead to new therapies for infection. Pernas would also like to study how malnutrition might change the course of an infection. "My dream would be to take the biological research to the global level," she says. ■



Bacteria's physical playbook

By Tina Hesman Saey

KC Huang, 38
PHYSICIST
STANFORD UNIVERSITY

Physicists often ponder small things, but probably not what's on Kerwyn Casey "KC" Huang's mind. He wants to know what it's like to be a bacterium: "My motivating questions are about understanding the physical challenges bacterial cells face."

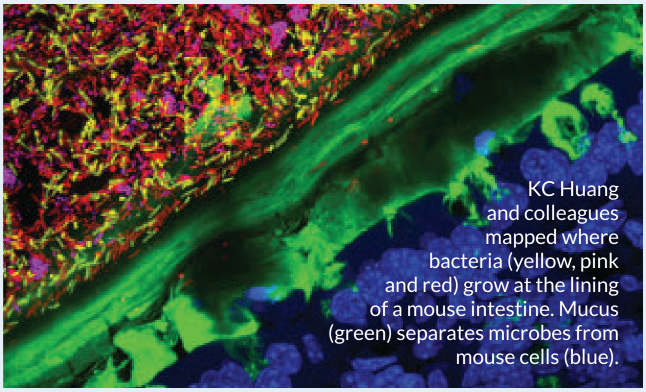
Bacteria are the dominant life-forms on Earth. They affect the health of plants and animals, including humans, for good and bad. Yet scientists know very little about the rules the microbes live by. Even questions as basic as how bacteria determine their shape are still up in the air, says Huang, of Stanford University.

Huang, 38, is out to change that. He and colleagues have determined what gives cholera bacteria their curved shape and whether it matters (a polymer protein, and the curve makes it easier for cholera to cause disease), how different wavelengths of light affect movement of photosynthetic bacteria (red and green wavelengths encourage movement; blue light stops the microbes in their tracks), and how photosynthetic bacteria's growth changes in light and dark. All three of these findings and more were published in just the first three months of this year.

Huang also looks for ways to use the tools and techniques his team develops to solve problems unrelated to bacteria. Computer programs that measure changes in bacterial cell shape can also track cells in plant roots and in developing zebrafish embryos. And he's helped determine how a protein's activity and stability contribute to a human genetic disease.

A physicist by training, Huang delves into biology, biochemistry, microbial ecology, genetics, engineering, computer science and more, partnering with a variety of scientists from across those fields. He's even teamed up with his statistician sister. He's an "all-in-one scientist," says longtime collaborator Ned Wingreen, a biophysicist at Princeton University.

When Huang started his lab at Stanford in 2008, after a Ph.D. at MIT and a postdoc at Princeton, his background was purely theoretical. Huang designed and ran computer simulations and his collaborators carried out the experiments. But he wanted to do hands-on research too, to learn why cells are the way they are.



KC Huang and colleagues mapped where bacteria (yellow, pink and red) grow at the lining of a mouse intestine. Mucus (green) separates microbes from mouse cells (blue).

Such a leap "is not trivial," says Christine Jacobs-Wagner, a microbiologist at Yale University who also studies bacterial cell shape. But Huang is a superb experimentalist, she says. "More than once he has come up with a new trick to address a tough question."

Jacobs-Wagner was particularly impressed with a microfluidics experiment testing a truism about how bacteria grow. Researchers used to think that turgor pressure — water pressure inside a cell that pushes the outer membrane against the cell wall — controlled bacterial growth, as it does in plants. But abolishing turgor pressure didn't change *E. coli*'s growth rate, Huang and colleagues reported in 2014 in *Proceedings of the National Academy of Sciences*. The finding "blew my mind away" and "crumbled the foundation" of what was thought about bacterial growth, Jacobs-Wagner says.

Sometimes Huang's tricks require breaking things. That was the case with a study of how rigid sugar strands and flexible proteins, like a chain link fence held together by rubber bands, are oriented in a bacterial cell wall. Huang and Wingreen reasoned that a bacterium put under pressure would split like a hot dog on a grill if the flexible links ran the length of the cell but would open like a Slinky if they circled the cell. The team reported the results — opened like a Slinky — in 2008.

Huang has worked with Justin Sonnenburg of Stanford on another basic question: When and where do gut bacteria grow? "How can we not know that?" Huang asks. "It's totally fundamental."

It's also crucial for understanding, for example, how antibiotics affect gut microbes. The researchers discovered that stripping fiber from a mouse's diet not only changes the mix of gut microbes, it also alters where in the intestines the microbes grow. Bacteria deprived of fiber's complex sugars began to munch on the protective mucus lining the intestines, bumping against the lining and sparking inflammation, a team including Huang and Sonnenburg reported in 2015 in *Cell Host & Microbe*.

Huang's breadth of research — from deciphering the nanoscale twists of proteins to mapping whole microbial communities — is sure to lead to many more discoveries. "He's capable of making contributions to any field," Jacobs-Wagner says, "or any research question that he's interested in." ■

Ancient tales from teeth

By Helen Thompson

Christina Warinner, 37
MOLECULAR ANTHROPOLOGIST
MAX PLANCK INSTITUTE FOR THE SCIENCE OF HUMAN HISTORY AND UNIVERSITY OF OKLAHOMA

In a pitch-black rainforest with fluttering moths and crawling centipedes, Christina Warinner dug up her first skeleton. Well, technically it was a full skeleton plus two headless ones, all draped in jewelry. To deter looters, she excavated through the night while one teammate held up a light and another killed as many bugs as possible.

As Warinner worked, unanswerable questions flew through her mind. "There's only so much you can learn by looking with your own eyes at a skeleton," she says. "I became increasingly interested in all the things that I could not see — all the stories that these skeletons had to tell that weren't immediately accessible, but could be accessible through science."

At age 21, Warinner cut her teeth on that incredible burial, left behind by the Maya in a Belize rainforest. Today, at 37, the molecular anthropologist scrapes at not-so-pearly whites to investigate similar questions, splitting her time between the University of Oklahoma in Norman and the Max Planck Institute for the Science of Human History in Jena, Germany.

In 2014, she and colleagues reported a finding that generated enough buzz to renew interest in an archaeological resource many had written off decades ago: fossilized dental plaque, or calculus. Ancient DNA and proteins in the plaque belong to microbes that could spill the secrets of the humans they once inhabited — what the people ate, what ailed them, perhaps even what they did for a living. Bacteria form plaque that mineralizes into calculus throughout a person's life. "It's the only part of your body that fossilizes while you're still alive," notes Warinner. "It's also the last thing to decay."

Though plaque is prolific in the archaeological record, most researchers viewed calculus as "the crap you scraped off your tooth in order to study it," says Amanda Henry, an archaeologist at Leiden University in the Netherlands. With some exceptions, molecular biologists saw calculus as a shoddy source of ancient DNA.

But a few researchers, including Henry, had been looking at calculus for clues to ancient diets. Inspired by Henry's images of starch grains preserved in calculus, Warinner wondered if the plaque might yield dead bacterial structures, perhaps even bacteria's genetic blueprints. Her timing couldn't have been better. Warinner began her graduate studies at Harvard University in 2004, just after the sequencing of the human

FROM LEFT: KRISTEN EARLE, GABRIEL BILLINGS, KC HUANG AND J. SONNENBURG; UNIV. OF OKLAHOMA genome was completed, and by the time she left in 2010, efforts to survey the human microbiome were in full swing. As a postdoc at the University of Zurich, Warinner decided to attempt to extract DNA from the dental grime preserved on the teeth of four medieval skeletons from Germany.

At first, the results were dismal. But she kept at it. "Tina has a very interested, curious and driven personality," Henry notes.

Warinner ultimately revealed that the calculus was chock-full of genetic material. "It was sitting there in almost every skeletal collection untouched, unanalyzed," Warinner says.

To interpret the data, Warinner mustered an army of colleagues from fields ranging from immunology to metagenomics. Her team found a slew of proteins and DNA snippets from bacteria, viruses and fungi, including dozens of oral pathogens, plus the full genetic blueprint of an ancient strain of *Tannerella forsythia*, which still infects gums today. The group revealed the miniature microbial world in 2014 in *Nature Genetics*.

Later in 2014, her team found the first direct DNA-based evidence of milk consumption in the plaque of Bronze Age skeletons from 3000 B.C. That same study linked milk proteins preserved in other ancient human skeletons to specific animals.

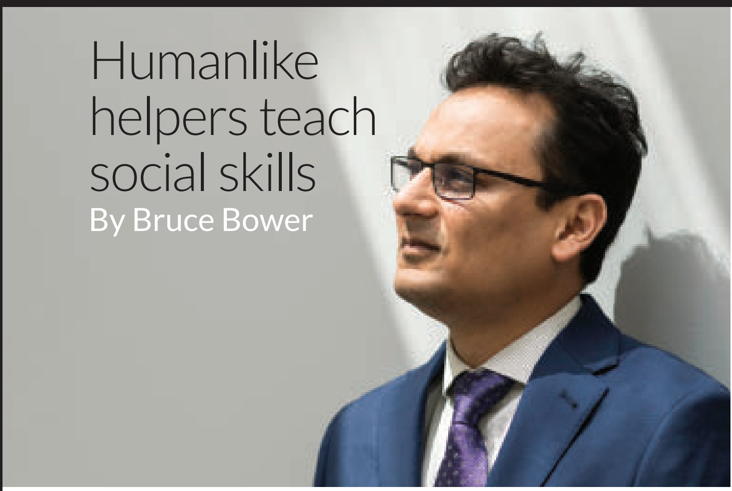
Fossilized plaque on the teeth of a skeleton from a medieval German monastery revealed plenty of microbial material.

"The fact that you can tell the difference between, say, goat milk and cow milk, that's kind of mind-blowing," says microbiologist Laura Weyrich of the University of Adelaide in Australia.

Since then, Warinner has found all sorts of odds and ends lurking on archaic chompers, from poppy seeds to paint pigments. Warinner is also branching out to the other end of the digestive spectrum: paleofeces, which is exactly what it sounds like. This desiccated or semi-fossilized poop doesn't stay as fresh as plaque in the archaeological record, but she's managed to find some sites with well-preserved samples. By examining the microbes that lived in the excrement and plaque of past humans and their relatives, Warinner hopes to characterize how our microbial communities have changed through time, and how they've changed us.

It's all part of what Warinner calls "the archaeology of the unseen." ■

FROM TOP: C. WARINNER *ET AL*/*NATURE GENETICS* 2014; J. ADAM FENSTER/UNIV. OF ROCHESTER



Humanlike helpers teach social skills

By Bruce Bower

M. Ehsan Hoque, 35
COMPUTER SCIENTIST
UNIVERSITY OF ROCHESTER

A growing band of digital characters that converse, read faces and track body language is helping people communicate better. While virtual helpers are becoming ubiquitous in commerce, computer scientist M. Ehsan Hoque is at the forefront of a more emotionally savvy movement. He and his team at the University of Rochester in New York create software for digital agents that recognize when a person is succeeding or failing in certain social interactions. Data from face-to-face conversations and feedback from professional counselors and interviewers with relevant expertise inform this breed of computer advisers.

One of Hoque's digital helpers grooms people to be better public speakers. With words on a screen, this attentive app notes, for example, how many times in a practice talk a person says "um," gestures inappropriately or awkwardly shifts vocal tone. With the help of Google Glass, the app even offers useful reminders during actual speeches. Another computerized helper, this one in the form of an avatar, helps people hone their job interviewing skills, flagging long-winded responses or inconsistent eye contact in practice interviews. In the works are computerized conversation coaches that can improve speech and communication skills among people with developmental conditions such as autism. And with financial support from the U.S. Department of Defense and the U.S. Army, Hoque is developing digital observers that monitor body language to detect when people are lying.

"There has been some progress in artificial intelligence, but not much in developing emotional aspects of AI," Hoque says. "We're just cracking through the surface at this point."

This is heady stuff for a 35-year-old who earned a doctoral degree just four years ago. Hoque, who immigrated to the United States as a teenager from Bangladesh, did his graduate work with the MIT Media Lab's Affective Computing research group. Hoque's approach puts a service spin on affective computing, which focuses on the study and development of computers and robots that recognize, interpret and simulate human emotions.

As a graduate student, he developed MACH, short for My Automated Conversation coacH. This system simulates face-to-face conversations with a computer-generated, 3-D man or woman that sees, hears and makes decisions while conversing with a real-life partner. Digital analyses of a human partner's speech and nonverbal behavior inform the avatar's responses during a session. A simulated coach may, for instance, let a user know if smiles during an interview look forced or are mistimed.

First, Hoque analyzed smiles and other behaviors that either helped or hurt the impressions MIT undergraduates left on experienced counselors during mock job interviews. Then his team developed an automated system that recognized impression-enhancing behaviors during simulated interviews. In testing, women, but not men, trained by MACH displayed substantial improvement in follow-up interviews. MACH trainees who watched interview videos but got no feedback showed minimal improvement. Testing with larger groups of men and women is under way.

As he developed MACH, Hoque consulted MIT sociologist and clinical psychologist Sherry Turkle. That was a bold move, since Turkle has warned for 30 years that, despite its pluses, digital culture discourages person-to-person connections. Social robots, in particular, represent a way for people to escape the challenges of forging authentic relationships, she says.

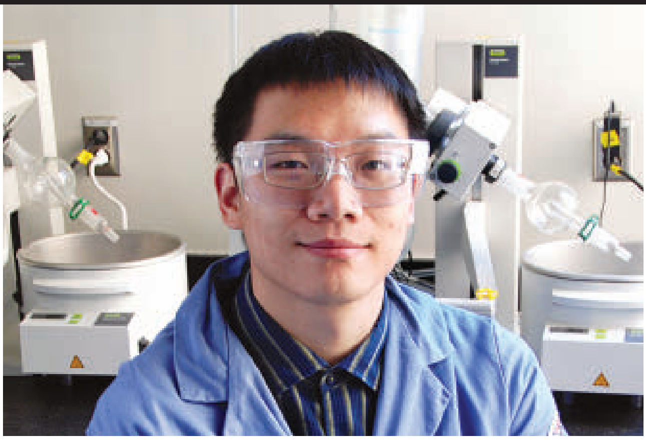
But Turkle came away impressed with Hoque, whose goals she calls refreshingly modest and transparent. "His avatars will be helpers and facilitators," she says, "not companions, friends, therapists and pretend people."

Hoque's approach grew out of personal experience. He is the primary caregiver for his 16-year-old brother, Eshteher, who has Down syndrome and does not speak. "I've spent a lot of time with him and can read what he's experiencing, like when he's frustrated or repentant," Hoque says.

His next-generation MACH, dubbed LISSA (Live Interactive Social Skill Assistance), is an avatar that conducts flexible, "getting acquainted" conversations while providing feedback on users' eye contact, speaking volume, smiling and body movements via flashing icons. LISSA has shown promise in preliminary tests aimed at improving the conversational chops of college students and individuals with autism spectrum disorders. Hoque plans to expand this technology for use with people suffering from social phobia and post-traumatic stress disorder.

Hoque's work on emotionally perceptive avatars may eventually transform the young industry of digital assistants, currently limited to voices-in-a-box such as Apple's Siri, says cognitive scientist Mary Czerwinski of Microsoft Research Lab in Redmond, Wash. Hoque agrees.

"In the future, we'll all have digital, personalized assistants," he says. If he gets his way, emotionally attuned helpers will make us more social and less isolated. That's something to applaud — if we can manage to put down our smartphones. ■



PENNY JENNINGS/UCLA CHEMISTRY & BIOCHEMISTRY

Photosynthesis reinvented

By Laurel Hamers

Chong Liu, 30
INORGANIC CHEMIST
UCLA

As a student, Chong Liu bet he could create a contraption that photosynthesizes like a leaf on a tree — but better. For the 30-year-old chemist, the gamble is paying off.

"He opened up a new field," says Peidong Yang, a chemist at the University of California, Berkeley who was Liu's Ph.D. adviser. Liu was among the first to combine bacteria with metals or other inorganic materials to replicate the energy-generating chemical reactions of photosynthesis, Yang says. Liu's approach to artificial photosynthesis may one day be especially useful in places without extensive energy infrastructure.

Liu first became interested in chemistry during high school, and majored in the subject at Fudan University in Shanghai. He recalls feeling frustrated in school when he would ask questions and be told that the answer was beyond the scope of what he needed to know. Research was a chance to seek out answers on his own. And the problem of artificial photosynthesis seemed like something substantial to throw himself into. It was challenging enough that he "wouldn't be jobless in 10 or 15 years," he jokes.

Photosynthesis is a simple but powerful process: Sunlight helps transform carbon dioxide and water into chemical energy stored in the chemical bonds of sugar molecules. But in nature, the process isn't particularly efficient, converting just 1 percent of solar energy into chemical energy. Liu thought he could do better with a hybrid system.

The efficiency of natural photosynthesis is limited by light-absorbing pigments in plants or bacteria, he says. People have designed materials that absorb light far more efficiently. But when it comes to transforming that light energy into fuel, bacteria shine.

Liu's early inspiration was an Apollo-era attempt at a life-support system for manned space missions. The idea was to use inorganic materials with specialized bacteria to turn astronauts' exhaled carbon dioxide into food. But early attempts never went anywhere.

"The efficiency was terribly low, way worse than you'd expect from plants," Liu says. And the bacteria kept dying — probably because other parts of the system were producing molecules that were toxic to the bacteria.

As a graduate student, Liu decided to build a system that would work with the bacteria, not against them. He first designed a system that uses nanowires coated with bacteria. The nanowires collect sunlight, much like the light-absorbing layer on a solar panel, and the bacteria use the energy from that sunlight to carry out chemical reactions that turn carbon dioxide into a liquid fuel such as isopropanol.

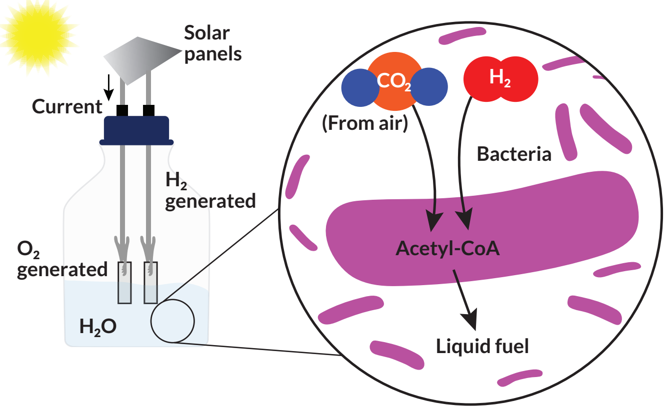
As a postdoctoral fellow in the lab of Harvard University chemist Daniel Nocera, Liu collaborated on a different approach. Nocera had been working on a "bionic leaf" in which solar panels provide the energy to split water into hydrogen and oxygen gases. Then, *Ralstonia eutropha* bacteria consume the hydrogen gas and pull in carbon dioxide from the air. The microbes are genetically engineered to transform the ingredients into isopropanol or another liquid fuel. But the project faced the same problems as other bacteria-based artificial photosynthesis attempts: low efficiency and lots of dead bacteria.

"Chong figured out how to make the system extremely efficient," Nocera says. "He invented biocompatible catalysts" that jump-start the chemical reactions inside the system without killing off the bacteria. Liu replaced the original system's problem catalysts, which made a microbe-killing, highly reactive type of oxygen molecule, with cobalt-phosphorus, which didn't bother the bacteria.

The device was about 10 times as efficient as plants at removing carbon dioxide from the air, the team reported in *Science* in 2016. With 1 kilowatt-hour of energy powering the system, Liu calculated, it could recycle all the carbon dioxide in more than 85,000 liters of air into other molecules that could be turned into fuel. Using different bacteria but the same overall setup, the researchers later turned nitrogen gas into ammonia for fertilizer, which could offer a more sustainable approach to the energy-guzzling method used to produce fertilizer today.

Now at UCLA, Liu is launching his own lab to study how the inorganic components of soil influence bacteria's ability to run these and other important chemical reactions. He wants to understand the relationship between soil and microbes. Liu is ready to place a new bet — this time on re-creating the reactions in soil the same way he's mimicked the reactions in a leaf. ■

Fake it Artificial "leaves" by Chong Liu and colleagues collect solar energy to generate electric current. The current splits water molecules into oxygen and hydrogen, and bacteria in the water transform carbon dioxide and hydrogen into fuels or other useful chemicals.



FROM TOP: PICOWER INSTITUTE: C. LIU, HARVARD UNIV.

Improvisation helps reveal our inner lives

By Laura Sanders

Kay Tye, 36
NEUROSCIENTIST
MIT

Here are some of the things Kay Tye relishes: break dancing, rock-climbing, snowboarding, poker, raising her young daughter and son. These adrenaline-fueled activities all require basic skills. But true mastery — and the joy Tye finds in them — comes from improvisation. She boldly steps into a void, a realm where she has to riff, and trusts that a flash of insight will lead the way out.

As a 36-year-old neuroscientist studying how the brain creates experiences, Tye brings this mix of fearlessness and creativity to her lab, where it's a key ingredient to her success. "Kay always finds this interesting twist," says Leslie Vosshall, a molecular neurobiologist at Rockefeller University in New York City. Tye's group at MIT investigates scientific questions in innovative ways, often with powerful results.

The goal, Tye says, is ambitious: to identify — in neuroscientific terms — the core of what makes us individuals. We all live in the same world, but have vastly different experiences of it. Our private emotions and motivations are crucial for driving our behavior. But just how our inner mental lives are created, she says, is a mystery: "How do we actually ground the mind in the brain?"

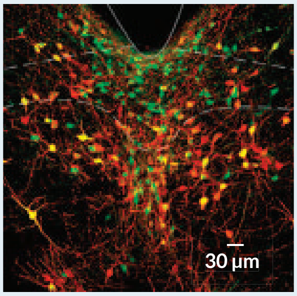
So far, Tye's findings, which come in large part from tweaking nerve cells and behaviors in lab animals, have led to a deeper understanding of the neural forces shaping experiences. Many of those forces may operate similarly in people, she believes.

One insight came unexpectedly. After a series of experiments on how certain nerve cells respond to cocaine, the data were in shambles. But Tye and postdoctoral researcher Gillian Matthews didn't shy away from the project. Instead, they ventured into the void, hunting for inventive ways to explain the puzzling results. It turns out that these nerve cells, buried in a part of the mouse brain called the dorsal raphe nucleus, weren't responding to cocaine at all. They were reacting to a mouse version of loneliness.

During the experiments, some of the mice were isolated. In mice reintroduced to companions after a period of solitude, dorsal raphe nerve cells grew very active, Tye's team reported in 2016 in *Cell*. Using a technique called optogenetics (*SN: 1/30/10, p. 18*), developed in Karl Deisseroth's lab at Stanford, where Tye was a postdoc, the researchers turned these same cells on artificially with a laser.

Though the mice didn't seem to like the sensation, avoiding a place where the stimulation happened, the artificial kick made the mice more social. Tye suspects that these cells play a role in creating a sensation similar to loneliness or alleviating it by promoting social interactions. The results offer a handhold to explore how these nerve cells might work together to create the mind.

"We threw away what we originally thought, completely," Tye says. "The word *cocaine* doesn't appear in the paper. It was really fun to go on that journey ... because where we ended up was not where we thought we were going to go."



Nestled in the dorsal raphe nucleus of a mouse brain, nerve cells (green, red and yellow) that make dopamine may have a role in social isolation.

In another experiment using optogenetics in rats, Tye and colleagues pitted the sensations of reward and punishment against each other. Published in June in *Nature Neuroscience*, the results describe the neural pathways that help an animal decide whether to risk a shock for a sweet treat. Looking at reward and punishment simultaneously in this way is not something other researchers had done.

These insights into motivated behaviors come from blending state-of-the-art techniques with clever experimental design, says neuroscientist Joseph LeDoux of New York University. The question of how the brain decides on a behavior is a classic one, and Tye is "taking it to a new level of neurobiological sophistication," he says.

She's not doing it alone. At MIT, where Tye also did her undergraduate work, she heads a lab full of people Vosshall describes as "fiercely loyal and incredibly hardworking."

Helping her students find their scientific footing is one of Tye's favorite parts of the job, a task she likens to the dynamic role of being a mother. "It takes my breath away quite frequently," Tye says, "to see someone blossom and grow and develop and get stronger and get more capable and more confident."

That nurturing no doubt provides opportunities to go off script. In science and her personal life, Tye delights in the unexpected, as evident from her poker game. Some poker players "grind it out," playing a "very careful, tight game," she says. "The hands I like being in the most are where anything can happen." ■

Seeking unexpected worlds

By Lisa Grossman

David Kipping, 33
ASTRONOMER
COLUMBIA UNIVERSITY

By early next spring, David Kipping hopes to know if the object he's spent his early career searching for is really there.

An astronomer at Columbia University, Kipping is perhaps most known for a project sifting through data from the Kepler space telescope on more than a thousand planets orbiting distant stars. But he's more interested in their moons. A moon could be home to alien life even if its planet is inhospitable (*SN: 2/9/13, p. 5*). A moon could also make its host planet more likely to harbor life. Some simulations suggest that the presence of our moon might have helped make Earth a nice place to live. The same could be true for other moon-planet partnerships.

So Kipping's search, dubbed the Hunt for Exomoons with Kepler, gets at the fundamental nature of our place in the universe: Are we alone?

In late October, Kipping and colleagues will use the Hubble Space Telescope to find out if they've caught their first quarry. The possible candidate is a Neptune-sized object orbiting the planet Kepler 1625b (*SN: 8/19/17, p. 15*). If the candidate turns out to be a genuine exomoon — Kipping is quick to point out that similar hints have fizzled before — he will no doubt solidify his reputation as "the moon guy."

But he dabbles in a lot of things. "I write a lot of failed papers," he admits. He arrived at exomoons by following a simple philosophy: No idea is too crazy.

"His signature projects are quite risky, but with obvious large payback," says Dimitar Sasselov, director of the Harvard Origins of Life Initiative, who worked with Kipping in his postdoctoral research at Harvard University.

Kipping, now 33, grew up in a small town in England. He loved *Star Trek*, wanted to be an astronaut and memorized the names and masses of all the planets in the solar system — and their moons.

Teachers encouraged him to pursue a career in physics at a time when exoplanet research was just starting to be taken seriously. By 2003, during his undergraduate years at the University of Cambridge, there were just a few dozen known exoplanets. "It felt like there was a huge wave of discovery waiting to happen," Kipping says.

Six years later, NASA launched Kepler, and by 2014, the

FROM TOP: G.A. MATTHEWS *ET AL*/*CELL* 2016; EMILY KIPPING number of known exoplanets ballooned to well over 1,000.

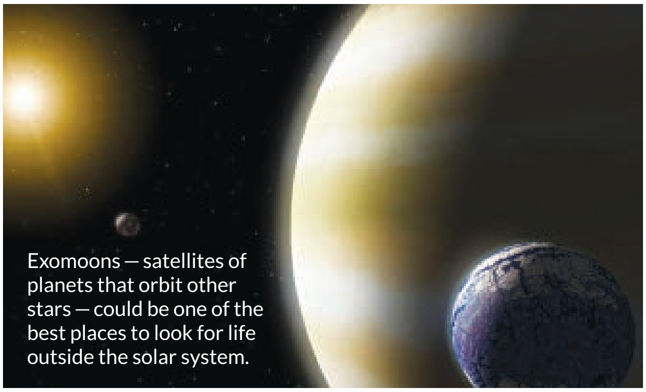
All the planets Kepler has picked up made themselves known by blocking their star's light as they crossed, or transited, in front of the star. Those transits produce a characteristic U-shape in graphs of starlight over time. As a graduate student at University College London, Kipping considered what the U-shaped graphs might reveal about the planets. Researchers already knew that deeper U's mean larger planets, for example.

While staring at the stars on a hiking trip in the Himalayas, Kipping thought of something else that could change the U: A large enough moon would create an occasional extra dip in the light. "It was just obvious to me," he says.

In the early days of the exoplanet boom, looking for such dips in the Kepler data was an audacious notion. But Kipping jumped in anyway. "I assumed it would be a tiny effect, but it turned out to be detectable," he says. His paper, published in 2009 in *Monthly Notices of the Royal Astronomical Society,* pointed out that Kepler could be used to search for exomoons, too.

To pursue the search in earnest, Kipping taught himself new data processing techniques. The problem proved so computationally intensive that he turned to crowdfunding to buy a supercomputer while a postdoc at Harvard. His hunt caught on in the popular press, with write-ups in *Time* magazine and *Wired*. Other scientists joined the chase, with several more groups announcing competing searches in the last few years.

There's a reason Kipping's team has found only one exomoon candidate so far: There aren't many out there big enough for Kepler to see, according to his statistical work. "Because he's doing such a careful job, it probably means something," Sasselov adds. The systems the team has checked that show no moons most likely aren't hiding any.


Exomoons — satellites of planets that orbit other stars — could be one of the best places to look for life outside the solar system.

Kipping's latest experiment is a YouTube channel aimed at nonscientists. It has already led to success. While preparing a video about the Breakthrough Starshot initiative, which aims to send tiny spacecraft at 20 percent the speed of light to visit the nearest star to the sun (*SN: 9/2/17, p. 4*), Kipping realized there was an error in one of the Breakthrough team's calculations. The error was in a calculation of the photon pressure needed to propel the craft. Kipping's paper discussing the error — which connected back to Albert Einstein's 1905 paper about special relativity and came from some assumptions made for simplicity that wouldn't hold in real life — was published in June in the *Astronomical Journal*.

"I would never have written a paper about special relativity if I hadn't been doing outreach about Starshot," he says. His philosophy makes more sense every year: Let all the crazy in. You never know where it will lead. ■

FROM TOP: JPL-CALTECH/NASA; TIMOTHY ARCHIBALD

Visionary wrangles light

By Emily Conover

Jennifer Dionne, 35
MATERIALS SCIENTIST
STANFORD UNIVERSITY

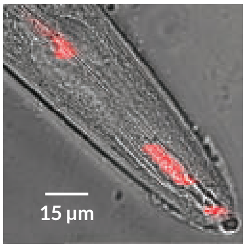
When choosing her research goals, Jennifer Dionne envisions conversations with future, hypothetical grandchildren. What would she want to tell them she had accomplished? Then, "I work backward to figure out what are the milestones en route," she says.

That long-term vision has led the 35-year-old materials scientist on a quest to wrangle light and convince it to do her bidding in interactions with nanoparticles and various materials. Already, Dionne has created nanomaterials that steer light in ways that are impossible with natural substances. Her latest projects could eventually lead to light-based technologies to improve drugs or to find cancerous cells. Her work even has applications for renewable energy, such as materials that help solar cells absorb more light.

But the route to a scientific vision may not always be clear, so Dionne makes time for diversions. "A lot of the really amazing discoveries that we enjoy today came from just playing in the lab," she says. Dionne encourages her team to let creativity be a guide, melding a serious sense of purpose with play.

"She's an extremely deep and rigorous thinker," says Paul Alivisatos, the vice chancellor for research at the University of California, Berkeley, who mentored Dionne when she was a postdoc there.

Dionne, now at Stanford University, studies nanophotonics, the way that light interacts with matter on very small scales. Her interest in light and materials began in childhood, she recalls, when she was fascinated by the blue morpho butterfly. The insect's wings sport an azure hue that comes not from pigments, like most colors found in living things, but from tiny nanostructures on the wings' surfaces (*SN: 6/7/08, p. 26*). When light reflects off the structures, blue wavelengths are amplified, while wavelengths corresponding to other colors are canceled out.



Nanoparticles fed to this roundworm glow when illuminated with infrared light. Their color changes as they are squeezed in the digestive tract.

That early interest led Dionne to begin wielding light as a tool during graduate school at Caltech and then a postdoc at UC Berkeley. Then and now, says Alivisatos, "she has consistently done very beautiful work."

At Caltech, Dionne and colleagues created a bizarre optical material in which light bends backward. As light passes from one material to another — say, from air to water — the rays are deflected due to a property called the index of refraction. (That's why a straw in a drinking glass appears to be broken at the water's surface.) In natural materials, light always bends in the same direction. But that rule gets flipped around in oddball nanomaterials with a negative index of refraction.

Dionne's material, reported in *Science* in 2007, was the first that worked with visible light (*SN: 3/24/07, p. 180*). Because they can steer light around objects to hide the objects from view, such materials could one day be used to create rudimentary versions of invisibility cloaks.

Another focal point of Dionne's research is harnessing light to separate mixtures of mirror-image molecules. Right- and left-handed versions of these molecules are perfect reflections of each other, like a person's right and left hands. The two types are so similar that scientists struggle to separate them, which can cause problems for drugmakers. In drugs, one version might relieve pain, while the other causes unwanted side effects.

To separate molecules and their mirror images, Dionne is developing techniques that use circularly polarized light, in which the light's wiggling electromagnetic waves rotate over time. Such light can interact differently with the handed molecules, for example, breaking apart one version while leaving the other unscathed. In a theoretical study published in *ACS Photonics* last December, Dionne and colleagues showed that adding nanoparticles to the mix could enhance the process.

She and colleagues have also created nanoparticles that, when illuminated with infrared light, emit visible light. The color of that light changes depending on how tightly the nanoparticle is squeezed, the team reported in June in *Nano Letters*. Dionne and colleagues fed these nanoparticles to *Caenorhabditis elegans* roundworms to study the forces exerted as a transparent worm squeezed a meal through its digestive tract. Dionne plans to use the technique to reveal more sinister squeezing: cancer cells exerting forces on their environment. And in collaboration with other researchers, she hopes to marshal her color-changing nanoparticles to understand how jellyfish move and how plants take a drink.

"She's done amazing work," says materials scientist Prineha Narang of Harvard University, who heard chatter about Dionne as a graduate student at Caltech. "The legend of Jen Dionne was definitely all over," Narang says. So Dionne has made a start at establishing her scientific legacy — even before that chat with her future grandchildren. ■

How plants hunt water

By Susan Milius

José Dinneny, 39
PLANT STRESS BIOLOGIST
CARNEGIE INSTITUTION FOR SCIENCE

José Dinneny wants us to see plants as stranger things.

"They're able to integrate information and make coherent decisions without a nervous system, without a brain," he points out. Plus, plants find water without sight or touch. For too many of us, however, we've become blind to how exotic they are.

"We're out searching the solar system and the galaxy for extraterrestrial life," says Dinneny, 39, "and we have aliens on our own planet."

FROM TOP: ALICE LAY/DIONNE LAB; ROBIN KEMPSTER

The thrill of discovering plants' alien ways drives Dinneny to explore how roots search for water. His research group, at the Carnegie Institution for Science labs in Stanford, Calif., "runs on curiosity," he says.

His work could have practical food security and geopolitical consequences. Dinneny is passionate about the molecular whys and hows of regulating plant growth. From a background in basic plant development, he moved to questions of environmental stress. These questions are important in "this huge crisis we face as a species," says Jonathan Lynch, a root biologist at Penn State and the University of Nottingham in England. Knowing how to grow plants in environments degraded by climate change will be crucial to feeding an exploding human population.

Lynch calls Dinneny "one of these transitional characters, very important in science." He builds bridges between the pure molecular biologists and the more agricultural plant biologists, "people like me who think about specific plants," Lynch says. The two groups rarely mingle and focus on different goals and priorities, Lynch says. He remembers a 2015 workshop on plant development and drought stress that Dinneny helped organize: "People were standing up and shouting."

To add a touch more agricultural realism to molecular root research, Dinneny and colleagues developed an alternative to the typical seedlings in petri dishes. The system, called GLO-Roots, makes roots in soil easier to watch. Plant roots induced to glow spread in slim sandwiches of soil between two clear plates, weaving among air pockets, micro rivers and clots of dirt. Computer analysis of images tracks where root tissues luminesce as various genes turn on in the twinkling underground observatory, giving researchers clues to how roots detect and respond to their environment.

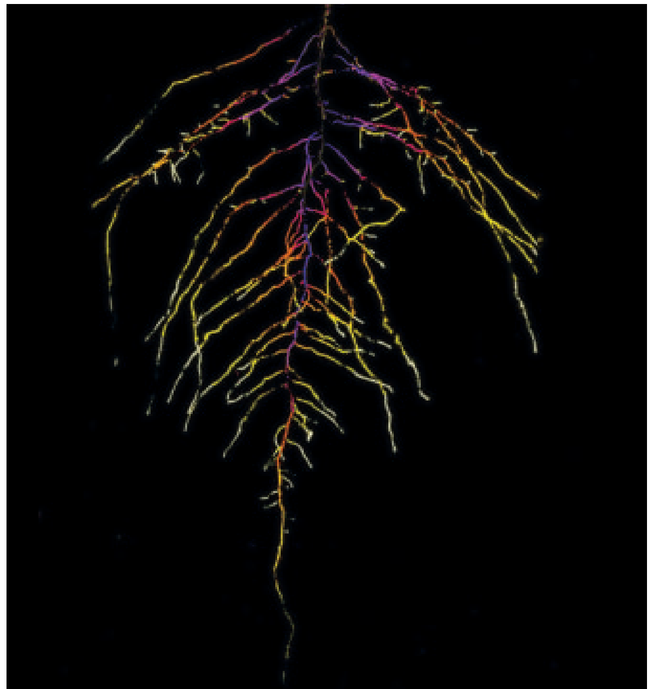
Thrusting out a side branch to find water is a local matter on a root, Dinneny and colleagues found using micro-CT scans of roots in soil. Analyzing hormones showed that tissues can sense water differences on a scale of mere micrometers. The team described the basic development of what Dinneny calls "hydropatterning" in 2014.

Plants are very different from vertebrates, which develop while shielded in wombs or eggs. Root branching responds to outside triggers, heading toward life-sustaining reservoirs.

"Myself and many other people had studied lateral roots for many years," says Malcolm Bennett of the University of Nottingham, a study collaborator. It was familiar to see seedlings forming roots mostly on the wet side. But Dinneny thought to ask how something so obvious was actually happening.

Dinneny and colleagues are now probing deeper into the cellular machinery at work. Individual cells in the root need to be expanding to detect water, he and Carnegie colleague Neil E. Robbins II proposed online at bioRxiv.org in January.

Dinneny spent much of his childhood in California's San Fernando Valley. "I wasn't tracked to do anything excellent at all," he says of his school years. "I was placed in classes that weren't particularly challenging." In 10th grade, though, he took an Advanced Placement biology class and still remembers a pivotal moment when his teacher asked about a chemical bond in DNA. "I was the only person who raised his hand." The answer: a phosphodiester bond. "Everyone looked around the room sort of wondering who could possibly have known that factoid," he says.



José Dinneny's GLO-Roots system reveals how the roots of a seedling explore soil. The view above combines daily images, starting 11 days after sowing of a cress seed. The closer to white, the more recently the little rootlets formed.

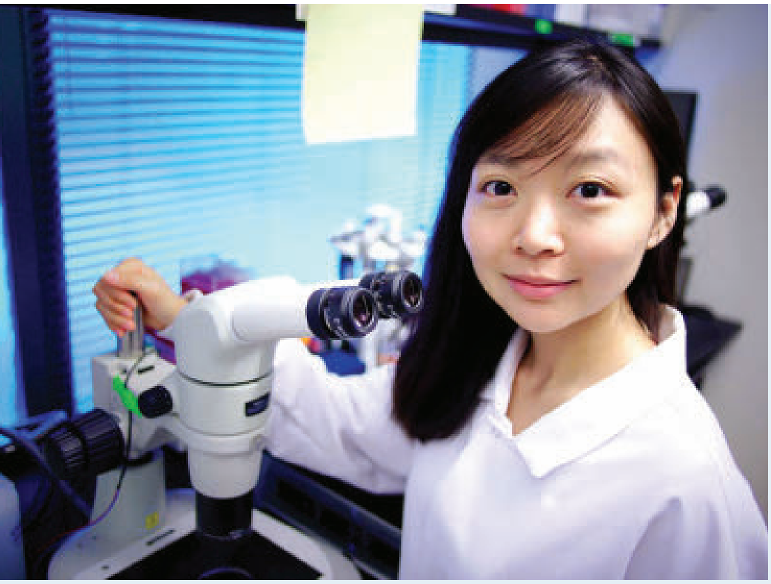
RUBÉN RELLÁN ÁLVAREZ

He was surprised to realize he had a talent for understanding biology. He lobbied hard to transfer to advanced classes and began to apply himself to studying. He didn't come from an academic family, but he had fine examples of working hard, including his single mother, a government accountant, and his grandfather, whose good cooking in Acapulco, Mexico, earned him an invitation to the United States and chef jobs in Los Angeles. (Dinneny himself enjoys the nightly challenge of preparing a meal his three children will "find edible.")

"Often we kind of cubbyhole ourselves: 'OK, I'm good at this,' or 'I'm not good at that,' " he says. "There is a magical relationship between effort and success." Not every goal gets met, but "you're going to do better than you ever thought."

Dinneny graduated with straight A's and headed to the University of California, Berkeley, where a holistic approach to plant science captivated him. For his Ph.D., at the University of California, San Diego, he studied the genetics of plant development, then moved to studying plants under environmental stress.

Deep-sea creatures and ocean exploring captivated Dinneny for much of his childhood. But plants have turned out to be strange enough. ■



Engineering better organs

By Alexandra Witze

Luhan Yang, 31
BIOLOGIST
EGENESIS

Luhan Yang dreams of pig organs that will one day fly — into people.

If she has her way, animal farms will raise bioengineered pigs, designed to produce kidneys, livers and other organs that could be transplanted into humans. Animal parts would slip seamlessly into people, easing their suffering.

"There are millions of patients worldwide waiting for organ transplants," says Yang, chief scientific officer of eGenesis, a biotech start-up in Cambridge, Mass. "It's such a huge unmet need."

Researchers have long dreamed of using animal organs to alleviate the shortage of human ones, a field known as xenotransplantation. So far those efforts have ended in failure, usually with the person's immune system rejecting the transplanted animal organ. But Yang has both the tools and the drive to change that. She is pioneering the direct editing of mammals' genetic instruction books, or genomes, working to tweak DNA to make pig organs more acceptable inside humans. All before her 32nd birthday.

"Luhan is exceptionally bold, yet careful," says George Church of Harvard University, who oversaw Yang's Ph.D. work and then cofounded eGenesis with her. "She is unstoppable."

Yang grew up in Sichuan province in southwestern China, at the base of a mountain that inspired a fascination with nature. In high school, she developed biology skills thanks in part to a teacher who took classes into the woods to learn about plants and animals. She passed a rigorous set of exams and was chosen for China's team for the International Biology Olympiad, where she won a gold medal in 2004.

At Peking University in Beijing, she studied not only life science but also added a second major, psychology. "The human brain and thinking are the most mysterious part to me," she says. That background later served her well in navigating the fast-paced management of biotech start-ups.

In 2008, Yang moved to the United States to explore options for her Ph.D. work. She rotated through laboratories in cardiology and cardiovascular disease before settling on Church's group, a good match for her desire to look at biological problems holistically. This was, after all, the lab that tasked itself to engineer an embryo of a woolly mammoth.

Language difficulties nearly derailed Yang at first. But she persevered to improve her English while beginning to rack up achievements. A choice to take on risky projects turned out well thanks to the game-changing CRISPR/Cas9. With this gene-editing technique, which was just beginning to take off, biologists could precisely and permanently modify genes in living organisms. Yang dove right in to push the technology in new directions. In 2013 in *Science*, a team led by her and bioengineer Prashant Mali, now at the University of California, San Diego, stunned the scientific world by reporting CRISPR gene editing in human stem cells. And in 2015, Yang reported a way around one of the biggest problems in pig-organ transplants.

Pig cells contain retroviruses that may infect human cells when transplanted. In 2015 in *Science*, Yang, Church and others described a method, using CRISPR in cell lines, to eliminate 62 retrovirus genes from pigs at once (*SN: 11/14/15, p. 6*). It was the most genetic modifications anyone had ever made to a mammalian genome.

With her Ph.D. in hand, Yang cofounded eGenesis. Her next goal is to create what she calls "Pig 2.0," which will be not only free of the harmful retroviruses but also incorporate additional genetic tweaks to get around immune rejection. In August, her team reported another step toward that goal: raising 15 live piglets in which problematic retroviruses had been eliminated (*SN: 9/2/17, p. 15*). "This will be an important foundation for building a better pig for transplantation," says Philip O'Connell, a transplant specialist at the University of Sydney in Westmead, Australia. "They have made the prospect of xenotransplantation a lot safer."

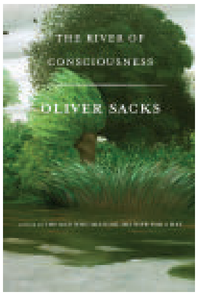
Yang continues to work on ambitious side projects, such as an effort to synthesize human genomes from scratch. In her limited spare time she plays badminton, runs and hikes — but most of all she reads. Each year she chooses a theme for her books: One year it was Western art history, and another it was detective novels. For 2017, she is focusing on books about leadership, to better handle the management decisions that come with heading a driven, 14-person team. (She recommends *True North*, from Bill George, a former Medtronic CEO.)

For Yang, there is no slowing down at the top. "We strive to create a world where there is no organ shortage," she says. "We understand it is a very audacious vision. We get up every day to work on that." ■

EGENESIS

BOOKSHELF

Essays offer peek into the mind of Oliver Sacks



The River of Consciousness
Oliver Sacks
KNOPF, $27

The experience of reading the essays that make up *The River of Consciousness* is very much like peering into an ever-changing stream. Pebbles shift as the water courses by, revealing unexpected facets below.

The essays, by neurologist Oliver Sacks and arranged into an anthology two weeks before his death in 2015, meander through such topics as evolution, memory and scientific progress. Most have been published before. But by bringing these quirky, personal and curious essays together, Sacks invites readers into his mind where they can experience the world from his unusually insightful perspective.

Some essays are long, some short. Some take a biographical bent, while others focus more on scientific principles. Many explore lesser-known fascinations of scientific luminaries: Charles Darwin's intense study of flowers, the reader learns, provided some of the best evidence for his theory of evolution.

And then, of course, there are Sacks' own observations. As his death neared, he wrote of his fading hearing, perceiving a story about a big-time publicist diagnosed with amyotrophic lateral sclerosis as a story about a "cuttlefish." He began keeping a notebook of these mishearings, recording what he heard, what was actually said and people's reactions.

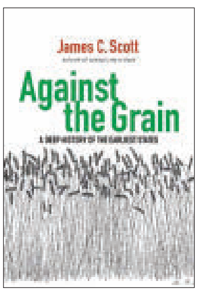
Other bodily sensations set his curiosity loose, such as when he hurt his leg in an accident. Nerve injuries and immobilization temporarily turned his leg into a stranger, no longer part of his body. Dismissed by his surgeon, Sacks turned to historical literature to find examples of this "alien" limb sensation.

Some of the most compelling stories arise when Sacks scrutinizes his own mind. He has a detailed memory of a bomb dropping in his London backyard during World War II. At the time, though, he was at boarding school. Sacks had co-opted the memory from a letter from his brother, who had written a vivid account of the incident. "We, as human beings, are landed with memories which have fallibilities, frailties, and imperfections — but also great flexibility and creativity," he writes.

The same could be said for the scientific endeavor as a whole, Sacks argues. Like ever-evolving flowers, malleable memories and fluid perceptions, ideas are not fixed, he writes: "Ideas, like living creatures, may arise and flourish, going in all directions, or abort and become extinct, in completely unpredictable ways." *— Laura Sanders*

BOOKSHELF

Rise of civilization came at a big cost, book claims



Against the Grain
James C. Scott
YALE UNIV., $26

Contrary to popular opinion, humans didn't shed a harsh existence as hunter-gatherers and herders for the good life of stay-in-place farming. Year-round farming villages and early agricultural states, such as those that cropped up in Mesopotamia, exchanged mobile groups' healthy lifestyles for the back-breaking drudgery of cultivating crops, exposure to infectious diseases, inadequate diets, taxes and conscription into armies.

In *Against the Grain,* political anthropologist James C. Scott offers a disturbing but enlightening defense of that position. He draws on past and recent archaeological studies indicating that the emergence of state-run societies around 6,000 years ago represented a cultural step backward in some important ways. Scott has previously written about modern states' failed social engineering projects and the evasion of state control by present-day mountain peoples in Southeast Asia. Exploring the roots of state-building was a logical next step.

Neither agriculture nor large settlements, on their own, stimulated state formation, Scott argues. Middle Eastern foragers cultivated grains thousands of years before year-round villages appeared. Large, permanent settlements depending substantially on wild plants and marine food materialized in Mesopotamia well before agricultural states formed there.

Scott proposes that early states represented a shotgun marriage of farming and huge communities presided over by a new class of hyperambitious rulers. State-building began in wetland areas, such as the Fertile Crescent, with huge expanses of fertile soil. There, grain farming squeezed enough people and storable food into a small enough space to enable state control and tax collection.

Fledgling states were fragile, often breaking into smaller entities or falling apart entirely. Researchers have tended to overlook the possibility that apparent state "collapses" in the archaeological record involved intentional flights of subjects fed up with war, taxes, epidemics and crop failures, Scott says.

He ends with a look at how herding groups both raided and abetted early agricultural states in Asia. Nomads deftly robbed stores of food and goods from their neighbors, then negotiated steep bribes in exchange for not attacking. Mobile pastoralists eventually became trading partners, bringing sedentary societies copper, horses and slaves, to name a few. Herders were also mercenaries, catching runaway slaves and repressing revolts. Ironically, Scott writes, "barbarians" helped states become the dominant political players they are today.

Scott writes in a straightforward style largely free of scientific jargon. He doesn't portray foraging and mobile lifestyles as utopian systems, but a closer look at their cons as well as their pros would have painted a fuller picture of these people. Still, Scott's depiction of early centralized states' problems rings true in a modern world of nation-states. *— Bruce Bower*

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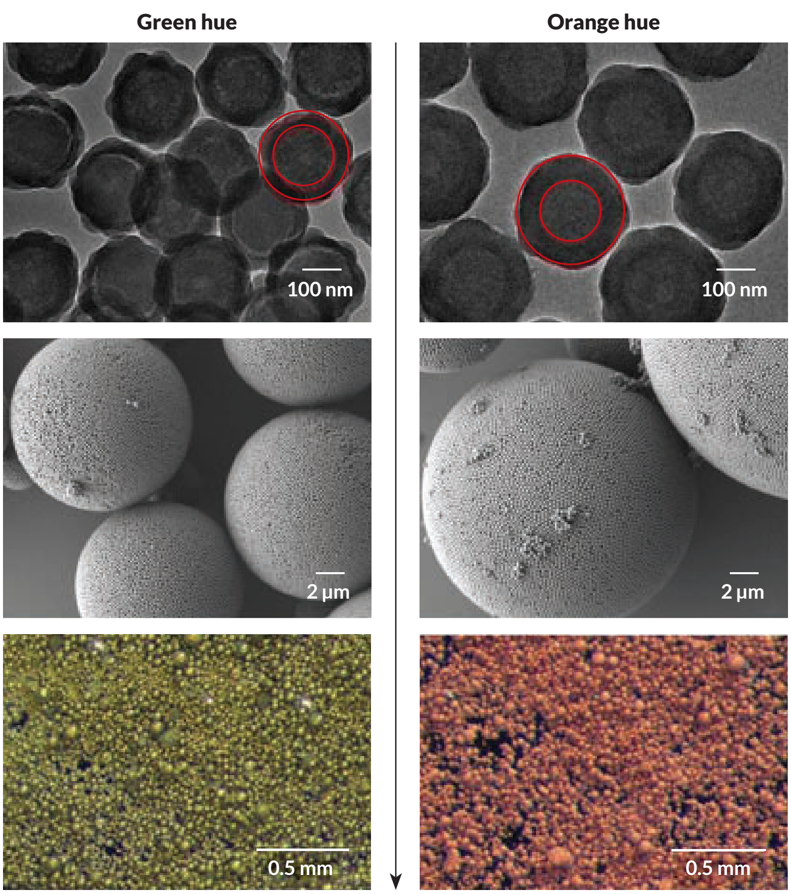

A whole new (tiny) ball game for color

Itty-bitty orbs of melanin could someday paint the rainbow. They're one of the key ingredients in a new way to craft a palette of structural colors (seen in the examples at top left).

Structural colors — created when light interacts with special nanostructures — are a longer-lasting alternative to a chemical pigment, which loses all pizzazz when it breaks down. Such durable hues abound in nature. Many bird feathers and butterfly wings, for instance, get their colors in part from nanoscale texturing (*SN: 6/11/16, p. 32*). But finding a simple, scalable way to generate complex structural colors has been tricky.

In the new study, researchers made nano-sized balls of melanin aggregate into clusters called supraballs. Melanin, the pigment that darkens skin, appears black in the individual nanoparticles. But altering the spacing of the particles in the ball affects how the minute orbs scatter light, generating an array of structural colors, says study coauthor Ali Dhinojwala, a polymer scientist at the University of Akron in Ohio.

He and colleagues added a thin silica coating to the outside of the melanin nanoparticles. The coating acts like a bumper, limiting how close the particles can pack together.

Varying the melanin core's diameter and the silica shell's thickness produces supraballs in a range of colors, the researchers report September 15 in *Science Advances*. The images at left show two examples, with the red circles highlighting the thickness of the silica layers (top). Though the corresponding supraballs (below) look similar under a microscope, they result in different hues (bottom).

This recipe is simpler than other ways of making structural colors in the lab, Dhinojwala says. The nanoparticles cluster into supraballs at room temperature in a water-and-alcohol mixture and are easy to extract as a powder. Plus, particles with different dimensions can be mixed in one supraball to create any shade imaginable. *— Laurel Hamers*

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