Holding Out Hope for Lost Plants | Superconducting Warms Up

ScienceNews

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Going SUPERNOVA

Scientists re-create stellar explosions in the lab

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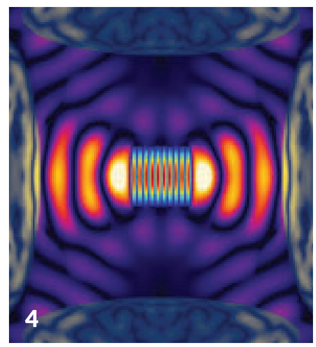
Science News

Features

News



Departments

COVER A mosaic of Hubble pictures shows part of the Veil Nebula, an 8,000-year-old supernova remnant. *NASA, ESA, Hubble Heritage Team*

FROM TOP: CALIFORNIA ACADEMY OF SCIENCES; R. SINGH AND T. PURDY/*PHYSICAL REVIEW LETTERS* 2020; JAY FLEMING

In praise of serendipity — and scientific obsession

Two fields of science seem to stand as far apart as possible — botany and astrophysics.

In one field, scientists may amble through bosky glens seeking elusive, rare vegetation. In the other, teams may use massive, multimillion-dollar machines to blast targets into smithereens and study some of the most dramatic events in the known universe, including how stars are born and die. Yet both species of scientist are driven by a desire to discover, and a refusal to quit despite the difficulty of a quest that can take decades and promises no sure rewards.

In this issue, we delve into the world of botanists trying to save the last plants of their kind from extinction (Page 14). This is native soil for life sciences writer Susan Milius. In thinking about what makes the plant partisans tick, "what struck me was that a practice of observation, or maybe a passion for observation, favors serendipity," Milius told me. She notes that Norma Etta Pfeiffer, who discovered the rare *Thismia americana* in 1912, was on her hands and knees in a prairie looking for liverworts. Her patient, intent gaze spied that *Thismia*, a plant with a flower no bigger than a pinkie nail.

The same goes for Dan Gluesenkamp, a plant ecologist who discovered a manzanita long thought extinct while commuting along a California freeway. "He says he notices stuff," Milius said. "He once found a valuable painting in a dumpster because out of the corner of his eye, something just caught his attention." But finding that manzanita while zipping by was the find of a lifetime.

Physics writer Emily Conover introduces us to Hye-Sook Park, a physicist who blows stuff up (Page 20). Park is trying to re-create the massive forces generated by the exploding stars called supernovas. She hopes to understand the impacts of the phenomenal energy the explosions release, and what that can tell us about the workings of the universe.

Park had a serendipitous encounter with a supernova as a graduate student in the 1980s, while working on an experiment in a salt mine 600 meters under Lake Erie. A supernova exploded, and the experiment detected neutrinos the blast launched earthward. "Yes, serendipity was important in the initial discovery of the neutrinos from the supernova," Conover told me. Park's more recent work, Conover said, requires years of effort and planning. Park is now working with some of the world's most powerful lasers in an effort to re-create the shock waves generated in the aftermath of supernovas, at minuscule scale.

By describing Park's work, Conover opens a door into a mysterious world that most of us will never experience. I'm more familiar with the plant people, and was delighted to find a shout-out in Milius' story to the Morton Arboretum in Lisle, Ill. I grew up not far away; my brothers worked there as students, pulling weeds as part of a prairie restoration project. I remember being included in a "slide-in," where scientists shared slideshows and enthusiastically debated plant taxonomy. It didn't turn me into a botanist, but I learned to appreciate the passion and dedication it takes to continue the hunt for a last surviving plant, or plumb mysteries of the universe in miniature.
— Nancy Shute, Editor in Chief

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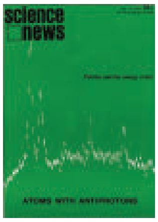


Excerpt from the November 14, 1970 issue of *Science News*

50 YEARS AGO

Clouds may be ecosystems

Clouds in the sky may contain living microbial ecosystems.... [Research] determined that metabolic activity, in the form of CO_2 uptake into organic material, occurred in [airborne] dust over a 24-hour period, whereas it did not occur in sterilized control dust.

UPDATE: The atmosphere is rich in microbial life. One census documented some 28,000 bacterial species in samples of water from clouds above a mountain in France, scientists reported in 2017. Research building over the last decade or so has supported the claim that some bacteria may indeed be metabolically active within their hazy abodes. One species of *Bacillus*, for example, eats sugar floating in the atmosphere to build a coating — perhaps to shield itself from ultraviolet radiation and low temperatures (*SN: 2/7/15, p. 5*). Some scientists suspect cloud bacteria contribute to Earth's carbon and nitrogen cycles, and even influence weather (*SN: 6/18/11, p. 12*). The microbes can spur ice crystals to form, triggering rain and snow — and a ride back to Earth's surface.

Translating visual telescope data, such as that shown in this composite image of the center of the Milky Way, into sound can benefit astronomy fans and scientists.

THE SCIENCE LIFE

How music can amplify astronomy

Put into music, telescope observations of the center of the Milky Way create a tranquil tune, glittering with xylophone and piano notes. The iconic Pillars of Creation in the Eagle Nebula sound like an eerie sci-fi score. And the supernova remnant Cassiopeia A is a sweeping symphony.

These musical renditions, or sonifications, were released September 22 by NASA's Chandra X-ray Center at its A Universe of Sound website. Such efforts can make cosmic wonders more accessible to people with blindness or visual impairments, and complement images for sighted learners.

Christine Malec, an astronomy enthusiast not involved in the project, recalls that the first sonification she ever heard — a rendering of the TRAPPIST-1 planetary system — gave her goose bumps. "I felt like I was getting a faint impression of what it's like to perceive the night sky," says Malec, who is blind. Music affords data "a spatial quality that astronomical phenomena have, but that words can't quite convey."

The new renditions combine data from telescopes that are tuned to different types of light. The sonification of the galactic center, for instance, includes observations of superhot gas filaments from the Chandra X-ray Observatory, optical images of stellar nurseries from the Hubble Space Telescope and infrared observations of gas and dust clouds from the Spitzer Space Telescope. Users can listen to data from each telescope alone or the trio in harmony.

The audio plays over the image from which it was composed. As a cursor (white line, above) pans across the image, light sources near the top play at higher pitches. Brighter objects play louder. The song crescendos where glowing gas and dust shroud the galaxy's giant black hole. Layering the sonified data "was done in a harmonious way — it was not discordant," Malec says.

That was on purpose. "We wanted to create an output that was not just scientifically accurate, but also hopefully nice to listen to," says visualization scientist Kimberly Arcand of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass.

But discordant sounds can be educational. Malec points to the new sonification of Cassiopeia A, in which notes played on stringed instruments represent chemical elements. Those notes can be difficult to tell apart, she says. Perhaps a violin paired with a trumpet or an organ would have made it easier for the ear to follow.

Sonification is valuable for getting the public interested in astronomy, and it holds promise for research, says Wanda Díaz-Merced, also of the Harvard-Smithsonian Center for Astrophysics but who was not involved in the project. Astronomers including Díaz-Merced, who is blind, have used sonifications to study stars, solar wind and cosmic rays. But efforts to sonify datasets for research have been rare. Making it a standard practice would break down barriers in the field and may lead to many new discoveries, she says. *— Maria Temming*

X-RAY: CXC/NASA, SAO, OPTICAL: NASA, STSCI, INFRARED: JPL-CALTECH, SPITZER NASA, SONIFICATION: CXC/NASA, SAO, K. ARCAND, MATT RUSSO, ANDREW SANTAGUIDA

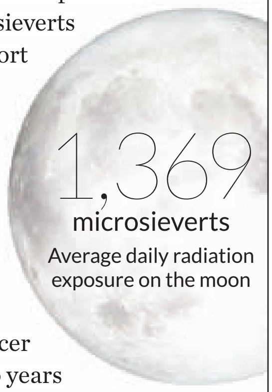
Listen to sonifications of the cosmos at **bit.ly/UniverseOfSound**

SCIENCE STATS

Radiation measurement could help guide lengthy lunar missions

A two-month stint on the moon would expose astronauts to roughly the same amount of cosmic radiation as they would get living on the International Space Station for five months, new lunar surface measurements suggest.

China's lunar lander Chang'e-4 measured radiation from galactic cosmic rays at the moon's surface in early January 2019 — just after landing on the farside — and again the next month. An astronaut would be exposed to an average daily dose of 1,369 microsieverts of cosmic radiation, researchers report in the September *Science Advances*. That's about 2.6 times as high as the average daily exposure recorded inside the space station and about 1.5 million times as high as the average daily exposure on Earth.

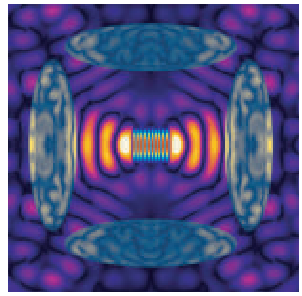


It's unclear how prolonged exposure on the moon might impact health. Potential effects, such as cancer and cardiac problems, may show up years later, says radiation biologist Marjan Boerma of the University of Arkansas for Medical Sciences in Little Rock. The findings come at a time when the United States and other nations are planning crewed missions to the moon. NASA intends to land the first U.S. woman and a man on the surface in 2024. *— Aayushi Pratap*

TEASER

This thermometer is a good listener

A new device eavesdrops on objects to take their temperatures.



A new thermometer (shown in a simulation) uses a silicon nitride sheet (center) to sense sounds that hot objects (ovals around the sheet) give off.

Hot objects not only glow, but also softly hum. The hum is generated by the rapid jitters of atoms that make up the hot object. If human ears could hear this noise, "it would sound like radio static," says Tom Purdy of the University of Pittsburgh. "The hotter [an object] gets, the louder it gets."

Purdy and Robinjeet Singh of the University of Maryland in College Park created an acoustic thermometer that senses the intensity of heat-generated sound coming from nearby objects. Described in the Sept. 18 *Physical Review Letters*, the device's heart is a sheet of silicon nitride. That sheet is suspended in the center of a silicon chip, which transmits sound waves better than air.

In experiments, the physicists deposited blobs of epoxy on the chip's surface around the sheet. When heated with a laser, each blob gave off sound waves that rippled through the chip to the sheet, causing the sheet to vibrate. Tracking the sheet's motion with another laser let the team determine the temperatures of the blobs. Purdy imagines this thermometer could find use in quantum computers, which must operate at low temperatures. *— Maria Temming*

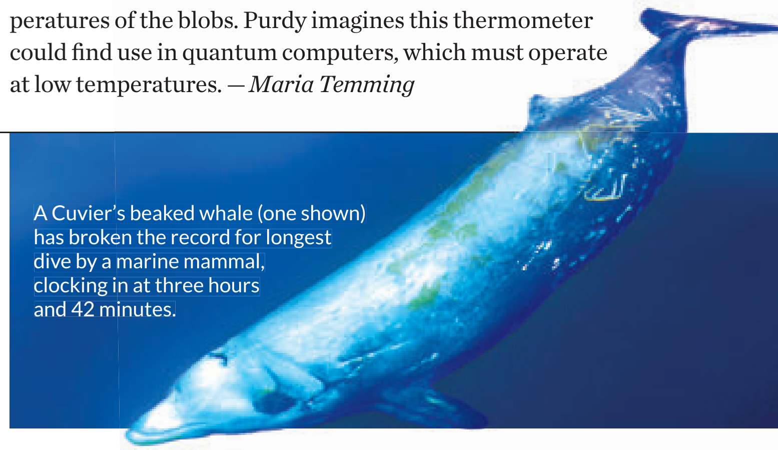
THE –EST

Whale's breathtaking dive impresses

To break the record for longest dive by a marine mammal, take a deep breath and jump in the water. Then don't breathe in again for almost four hours.

Cuvier's beaked whales (*Ziphius cavirostris*) are master divers. The creatures not only hold the record for deepest plunge by a marine mammal, measuring nearly 3,000 meters, but also for the longest dives. In 2014, scientists documented one record-setting dive that lasted just over two hours at 137.5 minutes. Another Cuvier's beaked whale has now shattered that record, going 222 minutes, or three hours and 42 minutes, without coming up for air, researchers report online September 23 in the *Journal of Experimental Biology*.

To last so long underwater, the mammals may rely on large stores of oxygen and a slow metabolism. Once oxygen runs out, the animals might have the ability to tolerate lactic acid building up in their muscles from anaerobic respiration — a way of generating energy that doesn't rely on oxygen. "These guys blow our expectations," says animal behaviorist Nicola Quick of the Duke University Marine Lab in Beaufort, N.C.



A Cuvier's beaked whale (one shown) has broken the record for longest dive by a marine mammal, clocking in at three hours and 42 minutes.

Calculations based on a seal's oxygen stores and limits on diving time hinted that the whales should last about half an hour before running out of oxygen. Seals can exceed their limit about 5 percent of the time. Quick's team analyzed 3,680 dives by 23 whales. While most dives lasted around an hour, 5 percent exceeded about 78 minutes. That finding suggests it takes more than twice as long as thought for the whales to switch to anaerobic respiration.

The researchers expected to find that the whales spend more time at the surface recovering after long dives, but there wasn't a clear pattern. "We know very little about [the whales] at all," Quick says, "which is interesting and frustrating at once." *— Erin Garcia de Jesus*

FROM TOP: R. SINGH AND T. PURDY/*PHYSICAL REVIEW LETTERS* 2020; NASA; ANDREA IZZOTTI/ALAMY STOCK PHOTO

News

When squeezed to high pressure between two diamonds (shown), a material made of carbon, sulfur and hydrogen can transmit electricity without resistance at room temperature.

ADAM FENSTER

MATTER & ENERGY

Superconductivity breaks big barrier

At room temperature, current flows with no energy loss

BY EMILY CONOVER

Scientists have reported the discovery of the first room-temperature superconductor, after more than a century of waiting. But there's a caveat: The material requires extreme pressure.

The discovery evokes daydreams of futuristic technologies that could reshape electronics and transportation. Superconductors transmit electricity without resistance, allowing current to flow with no any energy loss. But all previously known superconductors must be cooled, many of them to very low temperatures, making them impractical for most uses.

Now, scientists have found the first superconductor that operates at room temperature — at least given a fairly chilly room. The material is superconducting below temperatures of about 15° Celsius (59° Fahrenheit), Ranga Dias, a physicist at the University of Rochester in New York, and colleagues report in the Oct. 15 *Nature*.

The team's results "are nothing short of beautiful," says materials chemist Russell Hemley of the University of Illinois at Chicago.

However, the need for extreme pressure limits the superconductor's utility.

Dias and colleagues formed the superconductor by squeezing carbon, hydrogen and sulfur between the tips of two diamonds and hitting the material with laser light to induce chemical reactions. At a pressure about 2.6 million times that of Earth's atmosphere, and at temperatures of 14.55° C or below, the electrical resistance vanished.

14.55°
Celsius
Highest temperature recorded for a superconductor

That alone wasn't enough to convince Dias. "I didn't believe it the first time," he says. So the team studied additional samples of the material and investigated its magnetic properties.

Superconductors and magnetic fields are known to clash — strong magnetic fields inhibit superconductivity. Sure enough, when the material was placed in a magnetic field, lower temperatures were needed to make it superconducting. The team also applied an oscillating magnetic field to the material and showed that, when the material became a superconductor, it expelled that magnetic field from its interior, another sign of superconductivity.

The scientists were not able to determine the exact composition of the material or how its atoms are arranged, making it difficult to explain how it can be superconducting at such relatively high temperatures. Future work will focus on describing the material more completely, Dias says.

When superconductivity was discovered in 1911, it was found only at temperatures close to absolute zero (–273.15° C). But since then, researchers have steadily uncovered materials that superconduct at higher temperatures. In recent years, scientists have accelerated that progress by focusing on hydrogen-rich materials at high pressure.

In 2015, physicist Mikhail Eremets of the Max Planck Institute for Chemistry in Mainz, Germany, and colleagues squeezed hydrogen and sulfur to create a superconductor at temperatures up to –70° C (*SN: 12/26/15, p. 25*). A few years later, two groups, one led by Eremets and another involving Hemley and physicist Maddury Somayazulu, studied high-pressure compounds of lanthanum and hydrogen. The two teams found evidence of superconductivity at even higher temperatures of –23° C and –13° C, respectively, and in some samples possibly as high as 7° C (*SN: 10/13/18, p. 6*).

The discovery of a room-temperature superconductor isn't a surprise. "We've been obviously heading toward this," says theoretical chemist Eva Zurek of the University at Buffalo in New York, who was not involved with the research. But breaking the symbolic room-temperature barrier is "a really big deal."

If a room-temperature superconductor could be used at atmospheric pressure, it could save vast amounts of energy lost to resistance in the electrical grid. And it could improve current technologies, from MRI machines to quantum computers to magnetically levitated trains. Dias envisions that humankind could become a "superconducting society."

But so far scientists have created only tiny specks of the material at high pressure, so practical applications are still a long way off.

Still, "the temperature is not a limit anymore," says Somayazulu, of Argonne National Laboratory in Lemont, Ill. Instead, physicists now have a new aim: to create a room-temperature superconductor that works without putting on the squeeze, Somayazulu says. "That's the next big step." ■

BODY & BRAIN

COVID-19 vaccine efficacy, explained

Many factors affect how well a shot would work in the real world

BY AIMEE CUNNINGHAM

With several vaccines against COVID-19 in late-phase testing, the business of measuring efficacy is front and center.

Determining the efficacy, or how well a vaccine works in a randomized, controlled trial, gives a sense of how much a vaccine could help alleviate the suffering caused by COVID-19. The U.S. Food and Drug Administration recommends that vaccines tested against COVID-19 reach an efficacy of 50 percent, at minimum. That means at least a 50 percent reduction in symptomatic cases of COVID-19 in those who are vaccinated compared with those who receive a placebo.

Johnson & Johnson, Moderna, Pfizer and AstraZeneca have each begun phase III trials of their vaccines in the United States. These trials, which will each assess safety and efficacy in tens of thousands of people, randomly assign some people to receive vaccinations and others a placebo. The companies and the U.S. government have set a goal of having initial vaccine doses available by January 2021 (*SN: 8/1/20, p. 6*). It won't be clear how well any vaccine works until the companies report full trial results.

The FDA setting a minimum recommendation for efficacy doesn't mean vaccines couldn't perform better. The benchmark is also a reminder that COVID-19 vaccine development is in its early days. If the first available vaccines meet only the minimum, they may be replaced by others that prove to be more effective. But with more than 1 million deaths from COVID-19 worldwide — and U.S. deaths surpassing 219,000 — the urgency in finding a vaccine that helps at least some people is at the forefront.

"You want to set the bar [for efficacy] high enough so that it is clinically and epidemiologically significant, but low enough that a 'good enough' vaccine can be licensed until something better comes along," says Kawsar Talaat, a vaccine researcher at the Johns Hopkins Bloomberg School of Public Health.

Efficacy applies to how a vaccine works in a clinical trial. For the four vaccine candidates now in U.S. phase III trials, the primary goal is not necessarily to stop an infection but to prevent a person from experiencing symptoms or, in Johnson & Johnson's case, to guard against moderate to severe illness. Researchers will count cases of symptomatic COVID-19 in the vaccinated groups and in the placebo groups (who get injections of saline, for example) and calculate how much of a reduction there was with vaccination.

"At least with the first generation of vaccines," Talaat says, "what we're really trying to do is prevent severe disease and hospitalization and death."

A vaccine that prevents symptoms may not stop people from becoming infected and passing the virus to others. If such a vaccine gets approved, what the vaccine does and doesn't do would need to be communicated very clearly, says Maria Bottazzi, a vaccinologist at the Baylor College of Medicine in Houston. People would still need to wear masks and practice social distancing to help keep the virus from spreading, she says.

The efficacy results won't be the final word on how effective the vaccine is in the real world. Studies of other vaccines in which a trial took place in different locations have reported different results based on the incidence of disease in those areas; some vaccines haven't worked as well in populations where the risk of exposure is higher.

In this pandemic, Black and Latino Americans are disproportionately represented in the essential jobs that can't be done at home, putting these groups at risk for more exposures to the virus.

That's one reason "why it's always a good idea to have a more diverse population in your trials," says Saad Omer, a vaccine researcher at Yale University. That way, researchers can gather data on how the vaccine works for different people in a variety of scenarios.

Age also affects how well a vaccine works. Our immune system "ages as we age too," Bottazzi says. When older adults get the basic flu vaccine, for example, the shot doesn't elicit as strong an immune response as it does in younger adults.

For the COVID-19 trials, the FDA has encouraged "enrollment of populations most affected by COVID-19, specifically racial and ethnic minorities." The agency also states that the phase III trials should include enough older adults and people with certain underlying medical conditions, two groups at increased risk for COVID-19, to be able to evaluate efficacy for them. How well the first vaccines work, and for whom, will influence who is initially recommended to get the vaccine.

There are other COVID-19 vaccines in development and testing; some aren't very far behind the front-runners. Even if one or more of the vaccines now in phase III trials gets the green light, "the story wouldn't be over," Omer says. "It would be the end of the beginning." ■

Vaccine matchup The U.S. Food and Drug Administration recommends that COVID-19 vaccines have an efficacy of at least 50 percent — measured by the reduction in symptomatic cases among those vaccinated versus those not. Here's how such a vaccine compares with some common vaccines. SOURCES: CDC, FDA, H. LAL *ET AL/NEJM* 2015, A.L. CUNNINGHAM *ET AL/NEJM* 2016

Vaccine	Disease	How well it works
COVID-19 vaccine	COVID-19	FDA recommends a minimum of 50 percent efficacy; could be higher
Shingrix vaccine	Shingles	97 percent overall efficacy in adults 50 and older; 90 percent efficacy for those 70 and older
Seasonal flu vaccine	Flu	Typically 30 to 60 percent effective, depending on the year and how well it matches with circulating flu viruses
Inactivated polio vaccine	Polio	At least 90 percent effective with two doses; 99 to 100 percent effective with three doses

ATOM & COSMOS

Black hole's ring is caught wobbling

Event Horizon Telescope data reveal changes over time

BY MARIA TEMMING

Astrophysicists have gotten their first direct view of a supermassive black hole's appearance changing over time.

The black hole at the center of galaxy M87, about 55 million light-years from Earth, was the first black hole to get its picture taken (*SN: 4/27/19, p. 6*). That image, created with Event Horizon Telescope data from 2017, showed a lopsided ring of light: the black hole's shadow on the accretion disk of hot, glowing plasma swirling into the black hole. Comparing that image with earlier data reveals that the ring's brightest spot changes location, due to turbulence in the eddy of material around the black hole, researchers report in the Sept. 20 *Astrophysical Journal*.

"It's a very exciting result," says astrophysicist Clifford Will of the University of Florida in Gainesville. "The first image that they produced was just a snapshot. What we would really like to do is understand more of the dynamics of what's going on at the center of that galaxy."

The Event Horizon Telescope, or EHT, is a network of radio telescopes that together make much higher-resolution observations than any observatory could alone. An early version of the EHT began observing M87's black hole, M87*, in 2009, with three observatories. A fourth one joined in 2013. But the network didn't have enough telescopes to create a complete image until 2017, when the EHT peered at M87* with seven observatories.

Using the 2017 image as a starting point, along with preliminary data from 2009 to 2013 to fill in some details, the EHT team got a rough idea of what M87* looked like during the EHT's early years.

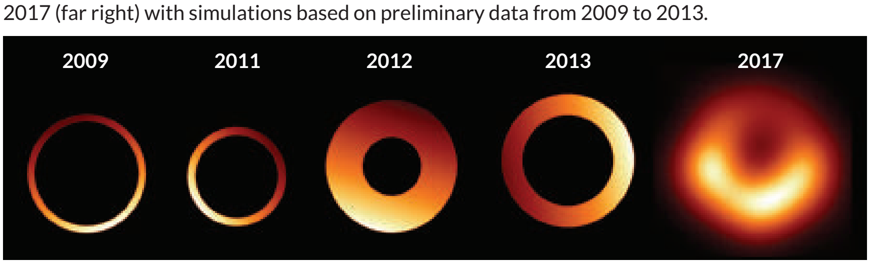
The black hole's diameter remained the same, but the brightest spot on the ring swiveled. The ring's right side was brightest in 2013, while the bottom was brightest in 2017. The ring's uneven glimmer arises from the tumultuous flow of superhot plasma around the black hole.

This turbulence in the accretion disk is expected to depend on factors like how fast the black hole is spinning, the tilt of its rotation and the strength of its magnetic fields, says Yale University astrophysicist Priyamvada Natarajan. So monitoring changes in M87*'s appearance may reveal new information about the nature of the black hole.

The results show the promise of using the EHT to probe the tempest around M87*, says Harvard University astrophysicist Avi Loeb. But the rough sketches do not contain enough information to draw firm conclusions, he says.

For that, scientists will need more full images of M87*. The EHT team is analyzing 2018 data, including observations from a newcomer to the network, the Greenland Telescope. The EHT did not observe in 2019 or 2020, but "we will be observing in 2021, COVID permitting," says team member Geoffrey Bower of the Academia Sinica Institute of Astronomy and Astrophysics in Hilo, Hawaii. "We expect to have incredible imaging quality out of those 2021 data." By then, the EHT will have two more observatories. ■

The ring of light around the black hole at the center of galaxy M87 shifts over time, an analysis of Event Horizon Telescope data shows. Scientists compared the image of M87's black hole from 2017 (far right) with simulations based on preliminary data from 2009 to 2013.



ATOM & COSMOS

Mars 'lake' may have company

More evidence points to liquid water beneath the planet's ice

BY CHRISTOPHER CROCKETT

Fresh intel from Mars has stirred debate about whether liquid water lurks beneath the planet's polar ice.

Data from a probe orbiting Mars appear to bolster a claim from 2018 that a lake sits about 1.5 kilometers beneath ice near the south pole (*SN: 8/18/18 & 9/1/18, p. 6*). The new work, reported September 28 in *Nature Astronomy*, also hints at more pools encircling the main reservoir.

If it exists, the main lake spans roughly 600 square kilometers. To keep from freezing, the water would likely have to be very salty, possibly making it similar to subglacial lakes in Antarctica. "This area is the closest thing to 'habitable' on Mars that has been found so far," says planetary scientist Roberto Orosei of the National Institute for Astrophysics in Bologna, Italy, who led the team that made the 2018 claim.

Ali Bramson, a planetary scientist at Purdue University in West Lafayette, Ind., agrees that "something funky is going on." But "there are some limitations to the instrument and the data.... I don't know if it's totally a slam dunk yet."

Orosei and colleagues probed the ice using radar on board the European Space Agency's Mars Express orbiter. Short bursts of radio waves reflect off the ice, but some penetrate deeper and bounce off the bottom of the ice, sending back a second echo. The brightness and sharpness of that second reflection can reveal details about the terrain under the ice.

The possible lake was found using data collected from 2012 to 2015. Now, in data from 2010 to 2019, the team once again found regions beneath the ice that are highly reflective and very flat. Those findings not only confirm earlier hints of the buried lake but also unearth a few smaller ponds separated from the main lake by strips of dry land, the team says.

M. WIELGUS, D. PESCE, EHT COLLABORATION

Adding to the claim that a lake of liquid water is buried beneath the ice at Mars' south pole (shown), new research suggests the lake is surrounded by smaller pools of water.

"On Earth, there would be no debate" that a bright, flat radar reflection would be liquid water, Orosei says.

But for Mars, there's debate. "There's no way to get liquid water warm enough even with throwing in a bunch of salts," says Purdue planetary scientist Michael Sori. In 2019, he and Bramson calculated that the ice temperature — perhaps as low as about –70° Celsius — is too cold even for salts to melt. The pair argued some local source of geothermal heat is needed, such as a magma chamber beneath the surface, to maintain a lake. That suggestion has led to questions about whether contemporary Mars could supply the necessary heat.

Isaac Smith, a planetary scientist at York University in Toronto, thinks this isn't a problem. As recently as 50,000 years ago, he says, Mars' south pole was warmer because the planet's tilt is constantly changing. The warmth could have propagated through the ice to create pockets of salty liquid. Or the ponds may have been there before the ice formed. Either way, at very high salt concentrations, once water melts, it's hard to freeze again. "The melting temperature is different than the freezing temperature," he says.

If there, such liquid may be unlike what most earthlings are familiar with. "Some supercooled brines at these cold temperatures are still considered liquid but turn into some weird glass," Bramson says.

Resolving these questions will probably require more than radar. Multiple factors, such as the composition and physical properties of the ice, can alter the fate of the second echo from the bottom of the ice, Bramson says. Seismology, gravity and topography data could go a long way to revealing what lurks beneath the ice. ■

MATTER & ENERGY

Physicists calculate sound's max speed

On Earth, the waves top out at about 36 kilometers per second

BY EMILY CONOVER

Sound has a speed limit. Under normal circumstances, sound waves can travel no faster than about 36 kilometers per second, physicists propose October 9 in *Science Advances*.

Sound zips along at different rates in different materials. But under conditions found naturally on Earth, calculations suggest that no material can host sound waves that outpace this ultimate limit, which is about 100 times the typical speed of sound in air.

The researchers' reasoning rests on well-known equations of physics and mathematical relationships. "Given the simplicity of the argument, it suggests that [the researchers] are putting their finger on something very deep," says condensed matter physicist Kamran Behnia of École Supérieure de Physique et de Chimie Industrielles in Paris.

The speed limit's equation depends on fundamental constants, special numbers that rule the cosmos. One such number, the speed of light, sets the universe's ultimate speed limit — nothing can go faster. Another, the fine-structure constant, sets the strength with which electrically charged particles push and pull one another. When combined in the right way with another constant — the ratio of the masses of the proton and electron — the numbers yield sound's speed limit.

Sound waves, which consist of the vibrations of atoms or molecules, travel through a material as one particle jostles another. A wave's speed depends on various factors, including the types of chemical bonds holding the material together and how massive its atoms are.

None of the sound speeds previously measured in a variety of liquids and solids surpass the proposed limit, condensed matter physicist Kostya Trachenko of Queen Mary University of London and colleagues found. The limit applies only to solids and liquids at pressures typically found on Earth's surface. At pressures millions of times that of Earth's atmosphere, sound moves faster and could surpass the limit.

One material expected to boast a high sound speed is hydrogen squeezed hard enough to turn into a solid metal. Because that metal has never been convincingly created, the team calculated the expected speed: Above about 6 million times Earth's atmospheric pressure, the speed limit would be broken.

The role of the fundamental constants in sound's maximum speed results from how the waves move through materials. Sound travels thanks to the electromagnetic interactions of neighboring atoms' electrons, which is where the fine-structure constant comes into play. The proton-electron mass ratio is important because, although the electrons are interacting, atoms' nuclei move as a result.

The fine-structure constant and the proton-electron mass ratio are dimensionless constants; there are no units attached to them, so their value does not depend on any particular system of units. Such constants fascinate physicists, because the values are crucial to the existence of the universe as we know it (*SN: 11/12/16, p. 24*). For example, if the fine-structure constant were significantly altered, stars, planets and life couldn't have formed. But no one can explain why these numbers have the values they do.

"When I have sleepless nights, I sometimes think about this," Trachenko says. ■

EARTH & ENVIRONMENT

Seagrass recovery is a big success

Rapidly revived ecosystem can help combat climate change

A restoration project in coastal Virginia transformed mostly barren sediment into abundant seagrass meadows in just 20 years.

BY JOSEPH POLIDORO

In the world's largest seagrass restoration project, scientists have observed an ecosystem from birth to full flowering.

As part of a 20-plus-year project, researchers and volunteers spread more than 70 million eelgrass seeds over plots covering more than 200 hectares, just beyond the wide expanses of salt marsh off the southern end of Virginia's Eastern Shore. Monitoring of the restored seagrass beds reveals a remarkably hardy ecosystem that is trapping carbon and nitrogen that would otherwise contribute to global warming and pollution, the team reports October 7 in *Science Advances*.

The results are "a game changer," says marine ecologist Carlos Duarte of King Abdullah University of Science and Technology in Thuwal, Saudi Arabia. "It's an exemplar of how nature-based solutions can help mitigate climate change."

The project, led by the Virginia Institute of Marine Science and the Nature Conservancy, has now expanded to cover 3,612 hectares — and counting — in new seagrass beds. The team started with a blank slate, says Robert Orth, a marine biologist at the institute. The seagrass in these inshore lagoons had been wiped out by disease and a hurricane in the early 1930s, but the water was still clear enough to transmit the sunlight plants require.

Within the first 10 years of restoration, Orth and colleagues witnessed an ecosystem rebounding rapidly across almost every indicator of ecosystem health — seagrass coverage, water quality, carbon and nitrogen storage, and invertebrate and fish biomass.

In less than 20 years, the plots were accumulating carbon and nitrogen at rates similar to what natural, undisturbed seagrass beds would have stored. The beds now sequester on average about 3,000 metric tons of carbon per year and more than 600 metric tons of

LIFE & EVOLUTION

How a tardigrade resists radiation

Glowing pigments help shield the microscopic animal

BY JONATHAN LAMBERT

When blasted with ultraviolet radiation, a newly discovered species of tardigrade protects itself by glowing blue.

It's the first experimental evidence of fluorescent molecules protecting an animal from radiation, researchers report in the October *Biology Letters*.

Tardigrades, microscopic animals also known as water bears or moss piglets, are nature's ultimate survivor. They're game for temperatures below –270° Celsius and up to 150° C. They can withstand the vacuum of space, and some are especially resistant to harmful UV radiation.

"Tardigrades' tolerance for stress is extraordinary," says biochemist Sandeep Eswarappa of the Indian Institute of Science in Bangalore, India. "But the mechanisms behind their resistance is not known in most [species]."

He and colleagues investigated these mechanisms in a newfound tardigrade species of the genus *Paramacrobiotus* that the scientists identified and then grew in the lab after plucking it from a mossy wall on campus. After sitting under a germicidal UV lamp for 15 minutes — ample time to kill most microbes and give humans a skin lesion — all of the *Paramacrobiotus* specimens survived, seemingly unfazed by the ordeal.

The secret of how these water bears persisted eluded the researchers until one day when they happened to view a tube of ground-up tardigrades in a UV transilluminator, used to visualize fluorescence in the lab. To the team's surprise, the tube glowed blue. "It was our mini-eureka moment," Eswarappa says.

Molecules fluoresce when they absorb higher-energy light and release lower-energy light. Some biologists have argued that fluorescent pigments could shield certain animals, such as corals (*SN: 12/9/17, p. 32*), from UV radiation, though such powers hadn't been shown in the lab.

Paramacrobiotus specimens varied in how much they fluoresced, and more-fluorescent ones were more resistant to UV light. After one hour of UV exposure, 60 percent of strongly fluorescent individuals survived more than 30 days; less-fluorescent ones died within 20 days.

To further link fluorescence with protection, the team soaked roundworms and another tardigrade species that isn't resistant to UV light in a bath of glowing *Paramacrobiotus* extract. Thus endowed, both animals were more UV tolerant compared with individuals in only water.

The experiments clearly show that the pigments are "a mechanism for

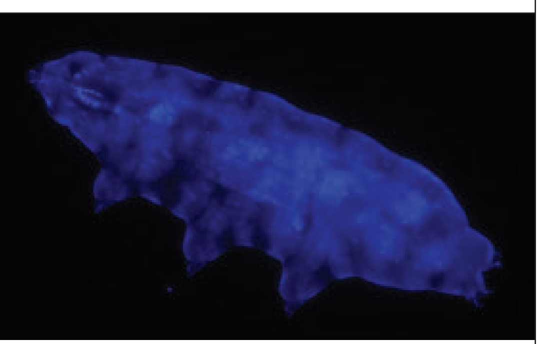
JAY FLEMING

nitrogen, the researchers report.

Seagrass meadows, among the world's most valuable and most threatened ecosystems, are important reservoirs of "blue carbon," the carbon stored in ocean and coastal ecosystems. In fact, these meadows are one of the most efficient storers of carbon on Earth.

"The study helps fill some large gaps in our understanding of how blue carbon can contribute to climate restoration," says study coauthor Karen McGlathery, a coastal ecologist at the University of Virginia in Charlottesville. "It's the first to put a number on how much carbon restored meadows take out of the atmosphere and store" for decades and potentially for centuries.

The restoration is far from finished. But the project offers a blueprint that others can adapt in other parts of the world, McGlathery says. One such place: Florida's Biscayne Bay, once rich in seagrass but now suffering from water quality degradation and widespread fish kills. Once the water is cleaned up, Orth says, "our work suggests that seagrasses can recover rapidly." ■



Fluorescent pigments, which glow blue in this micrograph, help protect a tardigrade species from damaging ultraviolet radiation.

H.R. SUMA

UV tolerance in these animals, and that's a nice step forward," says Paul Bartels, an invertebrate zoologist at Warren Wilson College in Asheville, N.C.

Eswarappa suggests that the pigments absorb UV rays, emitting harmless blue light, though the study doesn't show precisely how the pigments confer protection. The glow itself, for example, may simply be an ancillary effect of the pigments and not involved in UV shielding. ■

LIFE & EVOLUTION

Why were megalodon sharks so big?

Cannibalism in the womb may help explain the extinct fish's size

BY CAROLYN GRAMLING

The largest sharks ever to hunt in the oceans may have gotten so big thanks to their predatory behavior in the womb, scientists report October 4 in *Historical Biology*.

The idea emerged from a study that first analyzed the sizes and shapes of modern and ancient shark teeth, using those data to estimate body sizes of the fish. Paleobiologist Kenshu Shimada of DePaul University in Chicago and colleagues focused on an order of sharks called lamniformes, of which only 15 species still exist today, including fierce, fast great white and mako sharks as well as filter-feeding basking sharks.

Well over 200 lamniform species existed in the past, some of them quite large, Shimada says. But none is thought to have rivaled *Otodus megalodon*, commonly called megalodon, which lived between about 23 million and 2.5 million years ago. Determining just how giant these creatures were is challenging, though, because shark skeletons are made of cartilage, not bone, and so little remains of extinct species but their teeth.

Shimada and colleagues found that the height of megalodon's tooth crowns was an extreme outlier in the data, suggesting a total body length of at least 14 meters, twice as long as any other shark that isn't a filter feeder. Four other extinct lamniform species also exhibited "gigantism," growing to over 6 meters long, Shimada says. Gigantism also occurs in several modern shark species.

How megalodon and its relatives could get so big is unclear. Extinct and modern lamniforms that can grow to these sizes all happen to be warm-blooded. Regulating body temperature enables the sharks to swim faster and catch more-energetic prey. So warm-bloodedness, or endothermy, may be one key to the gigantism.

But Shimada and colleagues thought that explanation was incomplete, because it didn't address why this group of sharks in particular might have developed the endothermy that led to gigantism. In the new study, the team suggests that a behavior unique to this order may also play a role — a kind of cannibalism that occurs in the womb.

In most shark species, embryos develop inside eggs that stay inside the mother until they are ready to hatch. Among all lamniform sharks, the first pups to hatch inside mom eat the rest of the eggs. By the time the pups emerge from the mother, they are already large and ready to defend themselves against predators.

This intrauterine cannibalism, combined with the right environmental conditions such as favorable water temperatures and the availability of food, may give some lamniforms the green light to grow gigantic, the researchers say.

It's an interesting, out-of-the-box idea, says Stephen Godfrey, a paleontologist at Calvert Marine Museum in Solomons, Md. It's possible that intrauterine cannibalism is linked to some lamniforms becoming warm-blooded in the first place, he says. It could help these sharks grow big enough to take on bigger prey — and, in turn, require more energy, such as that provided by an evolutionary adaptation like warm-bloodedness, to maintain such an active lifestyle.

But it still doesn't quite explain the unique super-gigantism of megalodon, Godfrey adds. For that, you also would need a food source. "If there had been no large prey, I very much doubt that there would have been macropredatory giant sharks," he says.

Humberto Férron, a paleobiologist at the University of Bristol in England, agrees. "In my opinion, the evolution of gigantism in megalodon was the result of a combination of factors," he says. Intrauterine cannibalism may have helped the sharks grow big, endothermy would have kept them active and abundant large prey would have kept them fed. ■

LIFE & EVOLUTION

Map predicts spread of invading insect

Washington state officials rush to eradicate the 'murder hornet'

Asian giant hornets may find lots of suitable habitat in the Pacific Northwest, but little is known about how they spread.

BY CURTIS SEGARRA

The race is on to keep Asian giant hornets from spreading in the Pacific Northwest.

After first being spotted in the region in 2019, more than 15 of the so-called "murder hornets" have turned up in Washington state this year, as well as others in British Columbia, Canada. "We're pretty sure there's at least one nest" of the world's largest hornets somewhere near Birch Bay along the Washington coast, says Karla Salp, a spokesperson for the Washington State Department of Agriculture in Olympia.

Efforts are under way to attach a radio tag to a hornet and track it back to a nest. In an October 2 news conference, department officials described catching their first live giant hornet just east of Birch Bay. The team glued a transmitter to the insect's abdomen. But the tag fell off and glue got on the wings, ruining the hornet's ability to fly. On October 12, officials said they had tagged a second hornet, but it flew beyond the trackers' range and was lost before it could be tracked to a nest.

To attract hornets, the department is using live traps and "sentinel hives" — honeybee hives with a grate that allows bees, the target of hornet attacks, to pass through but stops the larger hornet. The goal is to find and destroy any nests, hopefully before hornets that can start nests of their own hatch.

That effort was already urgent thanks to the insects' reputation as honeybee killers (*SN: 7/4/20 & 7/18/20, p. 14*). Now a new study maps where the insects could spread if left unchecked.

Asian giant hornets (*Vespa mandarinia*) thrive where its mild and rainy — which makes large swaths of the Pacific Northwest prime real estate. Farther afield regions of the United States, including along the East Coast, could potentially support the hornets, but it's unlikely they could fly that far on their own, researchers report in the Oct. 6 *Proceedings of the National Academy of Sciences*.

"We really don't know anything about how this species spreads," says entomologist Chris Looney of Washington's agriculture department. Details like how fast the hornets can fly and how their preference for underground nests affects their potential to spread are unknown, he says. "That's the kind of maddening lack of information that makes responding to this species so challenging."

But by looking at the habitat conditions that the hornets prefer in their native range in Japan, South Korea, China and several other Asian countries, Looney and colleagues mapped regions of the United States where the hornets might be able to survive. Then the team simulated the insects' spread using information on how the Asian giant hornet's smaller relative *V. velutina* invaded Europe. That hornet spread at an average rate of about 100 kilometers per year.

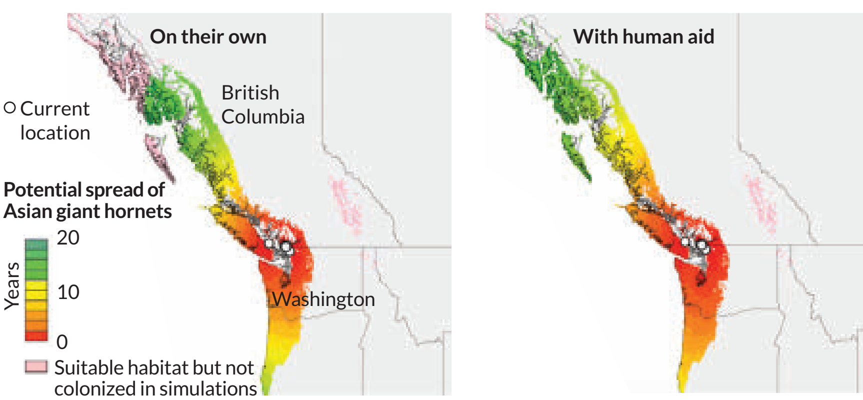
"There is a considerable amount of suitable habitat along the West Coast, and our dispersal simulations of how quickly the invasion might spread were surprising to us," says David Crowder, an entomologist at Washington State University in Pullman.

The simulations present a worst-case scenario. If the hornets are not eradicated, they could reach Oregon on their own in 10 years. In 20 years, the hornets could reach the southern tip of Alaska. Parts of eastern Washington, northern California and northern Idaho are at risk, too. And while much of the eastern United States has suitable habitat, "it is highly unlikely, if not impossible, that the hornet could traverse the continent on its own, given the lack of suitable habitat in much of the central U.S.," Crowder says.

Still, this research is "telling a more positive story than it's being made out to be," says entomologist Douglas Yanega of the University of California, Riverside. "They're talking about two decades before [the hornet] will reach the limits of its distribution. That's a very long time."

And there's still time to stop the insects. "The actual number of colonies out there is so small that if we can find a few of those colonies, we might be able to completely eradicate them," Yanega says. "It doesn't look like the kind of situation that's capable of exploding on us, and it certainly hasn't so far." ■

Hornet homes So far, the Asian giant hornet's invasion of North America appears limited to a few spots in Washington state and British Columbia, Canada (open circles). New simulations predict how far the hornet could travel over the next 20 years, either on its own (left) or with some assistance from humans (right), such as hitching rides on vehicles.



FROM TOP: QUINLYN BAINE/WSDA; G. ZHU ET AL/PNAS 2020

2020 Nobel laureates announced

Honorees studied CRISPR, hepatitis C and black holes

Some scientific advances require decades of work before a discovery is fully realized. Others take just a few years. As this year's winners show, either path can lead to a Nobel Prize.

Developing one of the most powerful tools in genetics earned Jennifer Doudna of the University of California, Berkeley and Emmanuelle Charpentier of the Max Planck Institute for Infection Biology in Berlin the Nobel Prize in chemistry.

Doudna and Charpentier teamed up in 2011 and then reported in 2012 that they had turned the molecular scissors known as CRISPR/Cas9, used by bacteria to fight viruses, into a programmable tool that has proved to be a cheap, versatile way to cut and edit genes.

In just the last eight years, researchers have used this tool to edit the genomes of an array of organisms, as well as to encode data, including storing movies, in bacterial DNA. In 2019, clinical trials testing CRISPR/Cas9's ability to treat cancer, blood disorders and inherited blindness began (*SN: 8/31/19, p. 6*).

But with CRISPR's great power has come great controversy. Most notably, a Chinese scientist edited human embryos, producing twin girls in 2018 (*SN: 12/22/18 & 1/5/19, p. 20*). The backlash was swift, but many people fear the door is already open to "designer babies," health care inequalities and other abuses.

"This enormous power of this technology means that we need to use it with great care," Claes Gustafsson, chair of the Nobel Committee for Chemistry, said at an October 7 news conference. "But it's equally clear that this is a technology ... that will provide humankind with great opportunities."

The discovery of the hepatitis C virus, honored by this year's Nobel Prize in physiology or medicine, has already had a huge impact on health, though, as one of the Nobel laureates put it, it's been a "50-year saga."

Harvey Alter of the National Institutes of Health in Bethesda, Md., worked at a blood bank in the 1960s when the hepatitis B virus was discovered. Blood could be screened so that people wouldn't get the virus from a transfusion, but some patients still developed hepatitis. He and colleagues showed in the mid- and late 1970s that a new virus, dubbed "non-A, non-B," was causing the infection (*SN: 4/1/78, p. 198*).

Just over a decade later, Michael Houghton, now at the University of Alberta in Edmonton, Canada, developed a test to screen out hepatitis C–infected blood. But a question still remained about whether the virus alone was responsible for the infection (*SN: 5/14/88, p. 308*). In the 1990s, Charles Rice, now at the Rockefeller University in New York City, and colleagues stitched together genetic fragments of the virus pulled from the blood of infected chimps into a working virus and showed that it could cause hepatitis in animals. That work also helped lead to the development of drugs that can cure most cases of hepatitis C.

And the story is not yet over: Houghton is now working on developing a vaccine against hepatitis C.

This year's Nobel Prize in physics, awarded to three scientists who cemented the reality of black holes, was also decades in the making.

Roger Penrose of the University of Oxford was honored for his calculations showing that black holes are physically possible. When the strange objects were first proposed, as a consequence of Albert Einstein's general theory of relativity, scientists were skeptical that black holes could actually exist. Penrose's work in the 1960s revealed that black holes, instead of being mathematical artifacts of Einstein's theory, could form in conditions likely to exist in the universe.

Beginning in the 1990s, Reinhard Genzel of the Max Planck Institute for Extraterrestrial Physics in Garching, Germany, and Andrea Ghez of UCLA each led teams that used telescopes to peer at the center of the Milky Way, measuring the orbits of stars that zip around the galaxy's heart. Those stars move so fast, both teams found, that only an incredibly compact, massive object such as a giant black hole could explain their trajectories (*SN: 10/5/96, p. 212*). That work, which has continued in the decades since, helped solidify the existence of black holes and confirm the predictions of general relativity. *— Tina Hesman Saey and Emily Conover*

2020 Nobel laureates

CHEMISTRY

Jennifer Doudna
University of California, Berkeley

Emmanuelle Charpentier
Max Planck Institute for Infection Biology

PHYSIOLOGY OR MEDICINE

Harvey Alter
U.S. National Institutes of Health

Michael Houghton
University of Alberta

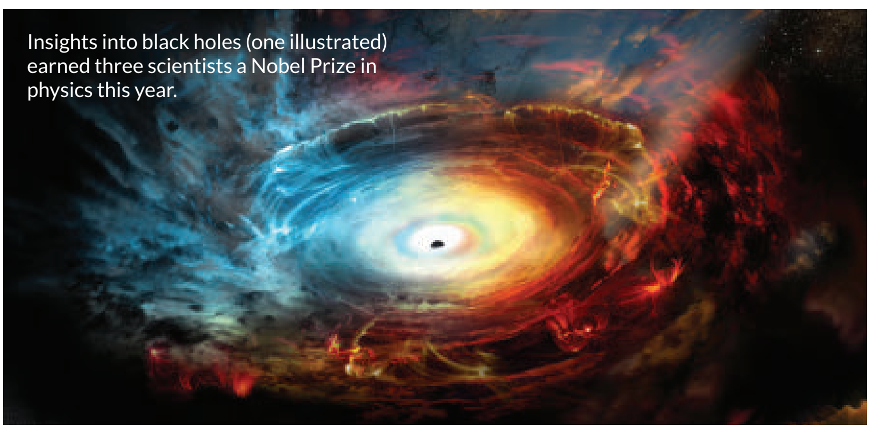
Charles Rice
The Rockefeller University

PHYSICS

Roger Penrose
University of Oxford

Reinhard Genzel
Max Planck Institute for Extraterrestrial Physics

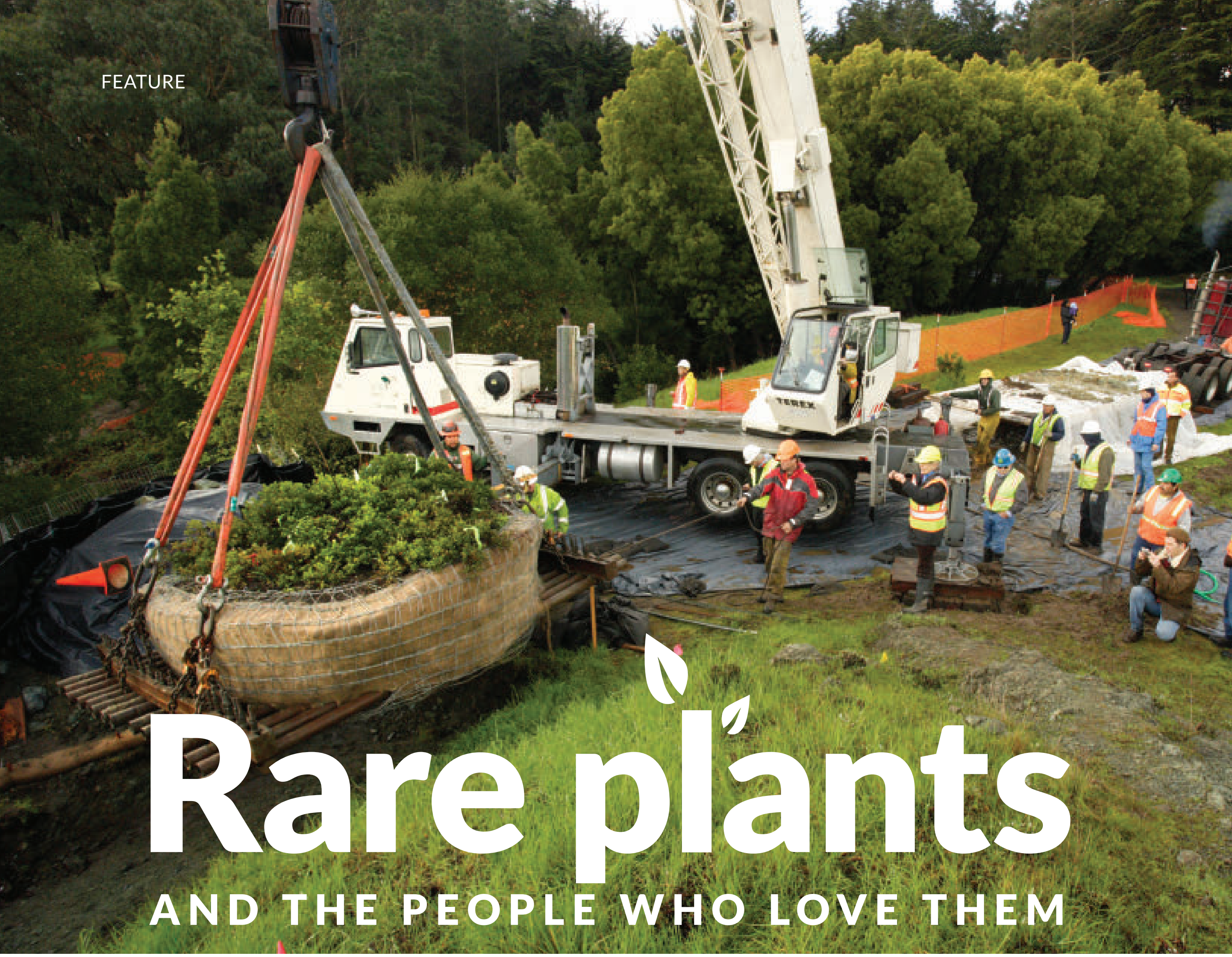
Andrea Ghez
UCLA



Insights into black holes (one illustrated) earned three scientists a Nobel Prize in physics this year.

NRAO, AUI, NSF, D. BERRY/SKYWORKS

FEATURE



Rare plants

AND THE PEOPLE WHO LOVE THEM

More than 60 years after the supposed extinction in the wild of California's Franciscan manzanita, a lone survivor showed up in the path of highway construction. The 2010 transplant of a multi-ton shrub wasn't easy.

JOHN HUSEBY/CALTRANS BAY AREA

Awkward extinctions, drive-by botany and neighborhood treasure hunts **By Susan Milius**

No plant should have to end this way.

North America's various beach plums bear purple-blue, cherry-sized fruits that make for a beloved New England jelly. The small trees' tolerance for salty, wind-blasted shores impresses biologists. But even a beach plum has limits.

One of the plum's distinctive forms, named in 1897 for physician Charles B. Graves who called attention to the plant, may have gone extinct in the wild in large part because people like a little privacy when they need a bathroom break on the beach.

All of the known Graves' beach plums grew in a cluster on a ridge overlooking the Connecticut shore in Groton. It "was the only shade on the beach," says botanist Wesley Knapp, who studies extinctions with the North Carolina Natural Heritage Program in Raleigh. Beachgoers seeking discreet foliage gravitated to *Prunus maritima* var. *gravesii*, relentlessly delivering excess nitrogen. "I can't think of a worse way ... to go extinct," Knapp says.

He has now determined that Graves' beach plum and four other kinds of U.S. plants that have been wiped out in the wild still grow in at least one garden somewhere. Ongoing quests might reveal two more. Dozens of others, however, are gone.

Focusing on U.S. and Canadian green heritage, Knapp and colleagues declared August 28 in *Conservation Biology* that 58 plants are extinct in the wild, with no miracle rescues in gardens. That totals 65 known losses from the wild, about

1.4 per decade, since Europeans started settling in the mid-1500s.

"We are positive it is a gross underestimate," Knapp cautions. The team's methods were conservative: going plant name by name and declaring a loss of a full species or a distinctive lineage within a species only if detailed information existed.

Graves' beach plum experienced one of the more undignified extinctions in the wild. A 1897 drawing shows the shrub's small fruit and distinctive round leaves.

Knapp, however, doesn't come across as a gloomy guy. He calls his motivational spiel about conserving native plants "Tales from the Crypt," and he chats colorfully about plants and the people who love them. Many of his colleagues do too. The possibility of snatching a flower or fern from the jaws of extinction has fired up a community of enthusiasts trying to document and protect what's left of the rarest of native vegetation. The challenge is immense, but sometimes there are wins. It's good practice in the art of hope.

Wild losses

To Anne Frances, a coauthor with Knapp on the extinction tally, "the one that stands out" is the Franciscan manzanita (*Arctostaphylos franciscana*), a sprawling woody plant with seeds that become more likely to sprout when cued by a fire's smoke.

Frances watches over native flora as the lead botanist at NatureServe, a nonprofit based in Arlington, Va., that keeps a giant database on the status of plants in the United States and Canada. She's the person who switches a plant's status to "extinct" in the database, and those keystrokes still get to her.

She was recently pandemic-teleworking and listening to a meeting when she remembered she needed to update the status on a plant that hadn't been seen for decades. The meeting suddenly stopped. Someone inquired if she was OK. She hadn't realized that as she finally clicked the entry to "extinct," she had let out a deep sigh.

The manzanita extinction story, though, has had a happy twist.

Tough, resilient Franciscan manzanita, which belongs to the same family as blueberries and rhododendrons, spreads red-barked, low-growing greenery and dangles pale little urn-shaped flowers. It's one of several manzanitas that once grew on San Francisco's serpentine barrens, dry outcroppings laden with heavy metals from greenish, vaguely snakeskin-textured rocks.

The shrub got its species name in 1905 from Toronto-born botanist Alice Eastwood, a rarity herself in the staggeringly male sciences. At age 6, she lost her mother. Despite her hard-luck childhood trying to look out for two younger siblings and cope with her father's faltering business ventures, she finished high school in Denver. That was the end of her formal education, but she showed great aptitude for botany. During summers she went collecting, preferring to travel solo, even in rugged terrain. She switched from riding side-saddle in voluminous skirts to riding astride in (gasp) denim garments of her own practical design.

Being a woman didn't prevent Eastwood from getting a botanist's job at the California Academy of Sciences in San Francisco. She was recruited by Katharine Brandegee, a town constable's widow who consoled herself by earning an M.D. from the University of California in 1878 and then took charge of the academy's herbarium, a kind of library of preserved plant samples.

Eastwood took over from her, and before retiring at the age of 90, named dozens of species, including the Franciscan manzanita.

The possibility of snatching a flower or fern from the jaws of extinction has fired up a community of enthusiasts.

On the morning of the 1906 earthquake, as fire neared the academy, Eastwood and a few colleagues struggled into the damaged building for last-minute salvaging. The marble staircase was "in ruins and we went up chiefly by holding on to the iron railing and putting our feet between the rungs," she wrote in a letter published in the May 25, 1906 *Science*. She and a helper lowered down with cords more than 1,000 of the most valuable pressed plants from an upper floor, including the definitive specimen of Franciscan manzanita.

Yet, as the city recovered and grew, serpentine barrens and their specialized plants disappeared under roads and buildings. Nurseries sold garden versions of it, but the last wild Franciscan manzanita sighting was recorded in 1947.

Of all places

It wasn't truly the last, we now know. At some unknown point, another manzanita sprouted, unrecognized and in a most awkward spot. Overgrown by weedy Australian tea trees, English ivy and such, the last known wild Franciscan manzanita grew on a traffic island shaped like a teardrop.

On its east side sped six lanes of traffic to and from the Golden Gate Bridge and on the west lay a six-meter drop to a highway on-ramp. This section

PETER H. RAVEN LIBRARY/MISSOURI BOTANICAL GARDEN of Doyle Drive was deemed seismically unsafe, and California OK'd its demolition. Native plant activists didn't protest to save the manzanita. They had no idea it was there.

By 2009, 100,000 vehicles whooshed by every day, oblivious. Even the impassioned protector of native plants and a coauthor on Knapp's extinctions paper, Dan Gluesenkamp, "quite frequently" drove by, he says, on the way from his San Francisco home to 31 plant restoration sites he worked on to the north. "We all missed it," he says.

As highway work progressed, a crew with a great roaring wood chipper arrived on the traffic island to grind up weeds. On this particular day, Gluesenkamp learned, a California highway patrol car had parked at the curb near the manzanita. The landscape crew positioned its machinery to spew chips away from, rather than toward, the law. While the rest of the island's plants ended the day either as mulch or under it, the newly exposed manzanita lived to see another rush hour.

On October 16, Gluesenkamp was driving home from a conference where he had argued that the best strategy for conserving botanical heritage in a changing climate was to find all of California's rare native plants and protect them individually.

"It's really crazy that after making that pitch ... I spotted an extinct plant," he says. Drive-by resurrecting an impossible plant is rare even for him. "I was roaring by at (a little over) freeway speeds, but something just clicked," he says.

Or almost clicked. He recognized an unusual manzanita, but suspected it was a different rarity: *A. montana* ssp. *ravenii*, which still hangs on, barely, elsewhere in the wild. But a new patch of any rare plant is good news. With such pathetically tiny shreds left of any rare plant's original genetic diversity, even a single new wildling could improve a species's chances of coping with our fast-changing world.

Self-taught botanist Alice Eastwood named the Franciscan manzanita species. Shown in 1913 in San Diego County with a plant press in her lap, she didn't let long skirts keep her from field expeditions.

CALIFORNIA ACADEMY OF SCIENCES

Gluesenkamp drove by the traffic island twice more. He made a phone call, and two botanists rushed over, dodging on foot lane after lane of traffic to see the plant up close. Not until a fourth expert weighed in, though, did realization dawn that this could be a species that had supposedly vanished from the wild more than 60 years earlier.

Electrifying as the rediscovery was, it didn't stop highway construction. Conservationists eventually opted to try transplanting the priceless last wild manzanita to San Francisco's Presidio park.

Moving day began on a Saturday in January 2010 at around 3 a.m. in rain with occasional hail. The storm so worried one of the operation's contractors that an employee spent the night on the traffic island to make sure a canopy covering the plant did not blow away. A 75-ton crane nudged into place to pick up the plant with its own minor continent of surrounding soil.

To prepare for transporting this one plant to the park, San Francisco took the extraordinary step of shutting down the MacArthur Tunnel, one of its busiest arteries. While the city slept, Gluesenkamp says, "we had a crazy, slow-moving parade."

He and colleagues described the rediscovery and replanting in a 2009/2010 issue of *Fremontia* in what must be one of the most suspenseful accounts ever published of transplanting shrubbery. Ten years later, Gluesenkamp, now director of the California Native Plant Society, still remembers those hours as "incredibly nerve-racking."

The mother plant has survived so far, he reports. Carefully tended cuttings and shoots are doing well. All this coddling from specialists means the plant no longer really counts as a manzanita living on its own. So it has now gone extinct in the wild — for the second time.

Search parties

The tale of another plant on NatureServe's extinction list follows a different arc. A tiny parasitic flower in a group called fairy lanterns was vanishingly rare to begin with. It's the only one of more than 70 known species to have turned up — briefly — in North America. More people have walked on the moon than are on record as viewing *Thismia americana* growing on Earth. Yet for decades, crowds have shown up to keep searching.

The only places on the planet this *Thismia* has been reported were two marshy scraps of prairie in southeastern Chicago. The city had long drawn botanists of international standing. Classes at the University of Chicago even used one of the plant's wetland homes for field trips. Yet that's not how the discovery played out, according to letters written by the plant's first chronicler, Norma Etta Pfeiffer.

In August 1912, Pfeiffer was a graduate student at the University of Chicago with bad luck in the job market. A college where she had accepted a job teaching botany had withdrawn the offer before she could arrive, according to family lore. The school had found a man willing to take the job after all.

Thus she was heading to the University of North Dakota as a botany instructor. The professor who hired her had been so evasive about exactly what her salary would be that she had agreed to work a second job as governess for his two daughters.

Pfeiffer was also unsure whether she would find plant materials there for her classes. So, before leaving Chicago, she and another female grad student went collecting in a swath of damp prairie called Solvay amid a riot of black-eyed Susan, multiple kinds of goldenrod, wild irises and other plants. It's now concrete-covered cityscape near 119th Street and some railroad tracks.

Down on hands and knees looking for liverworts, "suddenly I saw my first specimen of *Thismia*, a tiny flower half-imbedded in the soil," she wrote.

About half as wide as a pinkie fingertip, *Thismia*'s cup-shaped white flowers, with blue-green tints, sprout three petals that touch at the top, while flaps in between loll down like tongues. The rest of the plant lies underground as ghostly pale strings.

After baffling three of her professors, Pfeiffer tried a fourth. "With all his knowledge of world flora, he had never seen it," she wrote. She had a new thesis topic.

She took specimens with her to her new job. "In North Dakota, I used all the time I was free from earning my living to make preparations and study them," she wrote. In time she realized her odd plant belonged among the extreme parasites in the genus *Thismia*, described in 1844 and named as an anagram for English anatomist Thomas Smith. *Smithia* was already taken.

Norma Etta Pfeiffer started her career in 1913 as the University of Chicago's youngest Ph.D. and later studied lilies (shown) at the Boyce Thompson Institute in New York. She is famous for her student work on a lost *Thismia* species.

Her *Thismia* work earned her a Ph.D. from the University of Chicago in 1913. During a visit the next year, her first prairie site had a barn and no *Thismia*. A letter she wrote years later revealed a second prairie patch, where in 1916, she was the last person to document the plant's presence.

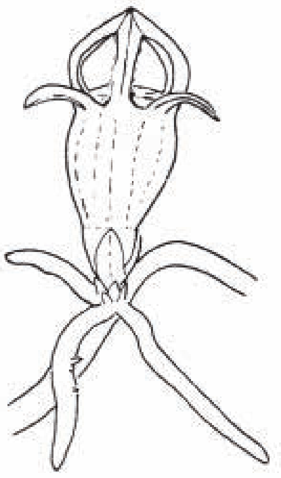
After a decade of teaching in North Dakota with various frustrations, she left and had a long career at the Boyce Thompson Institute in Yonkers, N.Y. (now in Ithaca). Her *Thismia* discovery got a one-sentence mention in her *New York Times* obituary in 1989. The headline read "Norma Pfeiffer, expert on lilies, dies at 100."

By 1951, others were on the lookout for *Thismia* in Chicago. One search featured two lichen specialists, presumably experts in spotting tiny things. Later efforts attracted hot-shot botanists from out of state as well as local talent. The efforts succeeded in adding dozens of previously unnoticed plants to lists of riches in remaining prairies, but not in finding *Thismia*.

More recent searches have shifted to merry public events. "August is when Norma found the plant, so that is when we look for it," says Linda Masters, a leader of multiple hunts and a restoration specialist at the regional conservation group Openlands in Chicago. "August in Chicago is notoriously hot, humid and buggy." Yet usually a little more than 100 people show up. A couple of

Thismia hunts on remaining scraps of prairie in and around Chicago, like one promoted in this poster in 2011, have become public events. The gatherings have enriched knowledge of other local flora.

FROM TOP: BOYCE THOMPSON INSTITUTE; JOE TAYLOR



Tiny flowers of Borneo's parasitic *Thismia neptunis* (photographed in 2017, above right) hadn't been seen for 151 years. Recent sightings raise hopes for finding *T. americana* (illustrated, above left), missing for a mere 104.

FROM LEFT: N.E. PFEIFFER/*BOTANICAL GAZETTE* 1914; M. SOCHOR *ET AL*/*PHYTOTAXA* 2018

times, some promising little mystery nubbin that suggested *Thismia* turned up. "Hearts stopped, and people studied the discovery," Masters says. "But nope."

In 2017, a different long-lost *Thismia*, *T. neptunis*, resurfaced in Borneo. This species may not be astonishingly rare. It's just really hard to spot. "Even if you know roughly what you are looking for, it takes weeks to find the first one," says one of its rediscoverers, Michal Sochor of the Crop Research Institute in Olomouc, Czech Republic.

Variety show

The American *Thismia* ranks as a full species, but variations of species are important too; 14 kinds of plants on Knapp and company's new list are distinct lineages within a species. Consider, for example, Cheatum's Eastern wahoo.

In fall, the leaves and seedpods of Eastern wahoos (*Euonymus atropurpureus*), a kind of shrub native to the central and eastern United States, burst into various candy reds and purples. Botanists can find the species in the wild, and people plant them in their yards.

Conserving plants, however, is not like stamp collecting. Knapp and colleagues aren't looking just for an exemplar or two of a plant. Instead, conservationists now seek genetic variation that gives the plants more options for what the future will throw at them. One taxonomist's variety may be another's "nothing special," so the coauthors of the paper agreed to a voting system that would identify plant variations that the majority agreed were distinctive. Cheatum's Eastern wahoo made the cut.

This wahoo grew in a small area around Dallas. Last reported in 1944, the shrub appears in the assessment as extinct in the wild (possibly done in by insects) but with a question mark about gardens. The last known place on Earth that a Cheatum's Eastern wahoo from Texas might grow is the Jardin des Plantes in Paris. Knapp has his fingers crossed and is waiting to hear.

He's also waiting to hear from the National Botanic Garden of Latvia, the last known hope for, of all things, the Delaware hawthorn, named after its American home state. That small white-flowered tree was named *Crataegus delawarensis* in 1903 by Charles Sprague Sargent, the first director of the Arnold Arboretum of Harvard University and an enthusiastic sharer of plants.

Knapp did hear back from a query that the Morton Arboretum in Lisle, Ill., had what could be another of Sargent's hawthorns, *C. fecunda*. "I was really dubious, because these things can be easily misidentified," Knapp says. Everyone had to wait until the next spring, because an important distinguishing trait shows up in flowers.

When the tree put out its clusters of white petals, Matt Lobdell, Morton's curator of living collections, photographed the white flowers against a white sheet of paper. Scrutinizing the images, the author of a book on southeastern hawthorns decided that Morton's single tree was the last of its species. "It was a real wow moment," Knapp says.

He had three more occasions, while working on the extinction list, to startle caretakers with the news that they were managing catastrophically rare plants. Letting a species or variety dwindle to just a few individuals is a conservation nightmare.

The lone *C. fecunda*, growing at the Illinois arboretum since 1922, no longer shows much vigor, Lobdell says. That doesn't bode well for next spring's efforts to propagate the plant. "If we'd got on top of this ... 70 years ago, we may have had more options," he says.

Lobdell is trying to do just that for future conservation of three oak species, native to the southern United States. He's gone plant collecting from South Carolina to Alabama to start banking oak genetic diversity in the arboretum. "Instead of having just three Georgia oaks, all from the same population, we can maybe have 50 or 200," he says.

Exciting as it is to un-extinct species from a car window or keep hope alive for a miracle in next year's prairie mud, what plants really need from humans is less drama and more smart planning. ■

Explore more

■ Wesley M. Knapp *et al*. "Vascular plant extinction in the continental United States and Canada." *Conservation Biology*. August 28, 2020.

Researchers are re-creating the physics of cosmic explosions using the world's most energetic lasers, such as the one at OMEGA (shown) at the University of Rochester in New York.

EUGENE KOWALUK/UNIV. OF ROCHESTER LABORATORY FOR LASER ENERGETICS

Bringing Supernova Physics **Down to Earth**

Pocket-sized blasts in the lab reveal details of massive stellar explosions **By Emily Conover**

When one of Hye-Sook Park's experiments goes well, everyone nearby knows. "We can hear Hye-Sook screaming," she's heard colleagues say.

It's no surprise that she can't contain her excitement. She's getting a closeup look at the physics of exploding stars, or supernovas, a phenomenon so immense that its power is difficult to put into words.

Rather than studying these explosions from a distance through telescopes, Park, a physicist at Lawrence Livermore National Laboratory in California, creates something akin to these paroxysmal blasts using the world's highest-energy lasers.

About 10 years ago, Park and colleagues embarked on a quest to understand a fascinating and poorly understood feature of supernovas: Shock waves that form in the wake of the explosions can boost particles, such as protons and electrons, to extreme energies.

"Supernova shocks are considered to be some of the most powerful particle accelerators in the universe," says plasma physicist Frederico Fiuza of SLAC National Accelerator Laboratory in Menlo Park, Calif., one of Park's collaborators.

Some of those particles eventually slam into Earth, after a fast-paced marathon across cosmic distances. Scientists have long puzzled over how such waves give energetic particles their massive speed boosts. Now, Park and colleagues have finally created a supernova-style shock wave in the lab and watched it send particles hurtling, revealing possible new hints about how that happens in the cosmos.

Bringing supernova physics down to Earth could help resolve other mysteries of the universe, such as the origins of cosmic magnetic fields. And there's a more existential reason physicists are fascinated by supernovas. These blasts provide some of the basic building blocks necessary for our existence. "The iron in our blood comes from supernovae," says plasma physicist Carolyn Kuranz of the University of Michigan in Ann Arbor, who also studies supernovas in the laboratory. "We're literally created from stars."

Lucky star

As a graduate student in the 1980s, Park worked on an experiment 600 meters underground in a working salt mine beneath Lake Erie in Ohio. Called IMB for Irvine-Michigan-Brookhaven, the experiment wasn't designed to study supernovas. But the researchers had a stroke of luck. A star exploded in a satellite galaxy of the Milky Way, and IMB captured particles catapulted from that eruption. Those messengers from the cosmic explosion, lightweight subatomic particles called neutrinos, revealed a wealth of new information about supernovas.

But supernovas in our cosmic vicinity are rare. So decades later, Park isn't waiting around for a second lucky event.

Instead, her team and others are using extremely powerful lasers to re-create the physics seen in the aftermath of supernova blasts. The lasers vaporize a small target, which can be made of various materials, such as plastic. The blow produces an explosion of fast-moving plasma, a mixture of charged particles, that mimics the behavior of plasma erupting from supernovas.

The stellar explosions are triggered when a massive star exhausts its fuel and its core collapses and rebounds. Outer layers of the star blast outward in an explosion that can unleash more energy than will be released by the sun over its entire 10-billion-year lifetime. The outflow has an unfathomable 100 quintillion yottajoules of kinetic energy (*SN: 2/8/17, p. 24*).

Supernovas can also occur when a dead star called a white dwarf is reignited, for example after slurping up gas from a companion star, causing a burst of nuclear reactions that spiral out of control (*SN: 4/30/16, p. 20*).

In both cases, things really get cooking when the explosion sends a blast of plasma careening out of the star and into its environs, the interstellar medium — essentially, another ocean of plasma particles. Over time, a turbulent, expanding structure called a supernova remnant forms, begetting a beautiful light show, tens of light-years across, that can persist in the sky for many thousands of years after the initial explosion. It's that roiling remnant that Park and colleagues are exploring.

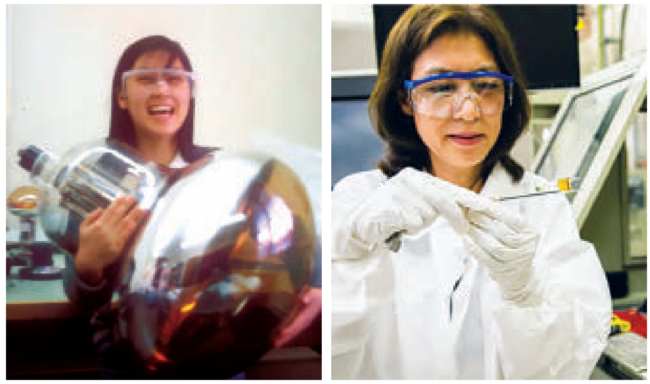
Studying supernova physics in the lab isn't quite the same thing as the real deal, for obvious reasons. "We cannot really create a supernova in the laboratory, otherwise we would be all exploded," Park says.

In lieu of self-annihilation, Park and others focus on versions of supernovas that are scaled down, both in size and in time. And rather than reproducing the entirety of a supernova all at once, physicists try in each experiment to isolate interesting components of the physics taking place. Out of the immense complexity of a supernova, "we are studying just a tiny bit of that, really," Park says.

For explosions in space, scientists are at the mercy of nature. But in the laboratory, "you can change parameters and see how shocks react," says astrophysicist Anatoly Spitkovsky of Princeton University, who collaborates with Park.

The laboratory explosions happen in an instant and are tiny, just centimeters across. For example, in Kuranz's experiments, the equivalent of 15 minutes in the life of a real supernova can take just 10 billionths of a second. And a section of a stellar explosion larger than the diameter of Earth can be shrunk down to 100 micrometers. "The processes that occur in both of those are very similar," Kuranz says. "It blows my mind."

FROM LEFT: JOHN VAN DER VELDE; LANIE L. RIVERA/LAWRENCE LIVERMORE NATIONAL LABORATORY



Physicist Hye-Sook Park, shown as a graduate student in the 1980s (left) and in a recent photo (right), uses powerful lasers to study astrophysics.

Laser focus

To replicate the physics of a supernova, laboratory explosions must create an extreme environment. For that, you need a really big laser, which can be found in only a few places in the world, such as NIF, the National Ignition Facility at Lawrence Livermore, and the OMEGA Laser Facility at the University of Rochester in New York.

At both places, one laser is split into many beams. The biggest laser in the world, at NIF, has 192 beams. Each of those beams is amplified to increase its energy exponentially. Then, some or all of those beams are trained on a small, carefully designed target. NIF's laser can deliver more than 500 trillion watts of power for a brief instant, momentarily outstripping the total power usage in the United States by a factor of a thousand.

A single experiment at NIF or OMEGA, called a shot, is one blast from the laser. And each shot is a big production. Opportunities to use such advanced facilities are scarce, and researchers want to have all the details ironed out to be confident the experiment will be a success.

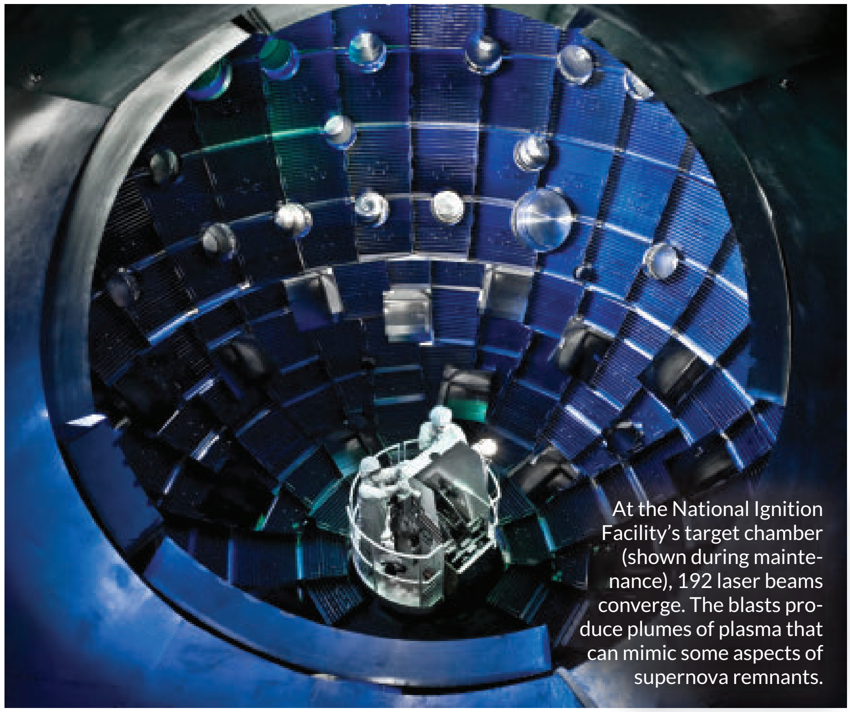
When a shot is about to happen, there's a space-launch vibe. Operators monitor the facility from a control room filled with screens. When the time of the laser blast nears, a voice begins counting down: "Ten, nine, eight ..."

"When they count down for your shot, your heart is pounding," says plasma physicist Jena Meinecke of the University of Oxford, who has worked on experiments at NIF and other laser facilities.

At the moment of the shot, "you kind of want the Earth to shake," Kuranz says. But instead, you might just hear a snap — the sound of the discharge from capacitors that store up huge amounts of energy for each shot.

Then comes a mad dash to review the results and determine if the experiment has been successful. "It's a lot of adrenaline," Kuranz says.

Lasers aren't the only way to investigate supernova physics in the lab. Some researchers use intense bursts of electricity, called pulsed power. Others use small amounts of explosives to set off blasts. The various techniques can be used to understand different stages in supernovas' lives.



At the National Ignition Facility's target chamber (shown during maintenance), 192 laser beams converge. The blasts produce plumes of plasma that can mimic some aspects of supernova remnants.

A real shocker

Park brims with cosmic levels of enthusiasm, ready to erupt in response to a new nugget of data or a new success in her experiments. Re-creating some of the physics of a supernova in the lab really is as remarkable as it sounds, she says. "Otherwise I wouldn't be working on it." Along with Spitkovsky and Fiuza, Park is among more than a dozen scientists involved in the Astrophysical Collisionless Shock Experiments with Lasers collaboration, or ACSEL, the quest Park embarked upon a decade ago. Their focus is shock waves.

The result of a violent input of energy, shock waves are marked by an abrupt increase in temperature, density and pressure. On Earth, shock waves cause the sonic boom of a supersonic jet, the clap of thunder in a storm and the damaging pressure wave that can shatter windows in the aftermath of a massive explosion. These shock waves form as air molecules slam into each other, piling up molecules into a high-density, high-pressure and high-temperature wave.

In cosmic environments, shock waves occur not in air, but in plasma, a mixture of protons, electrons and ions, electrically charged atoms. There, particles may be diffuse enough that they don't directly collide as they do in air. In such a plasma, the pileup of particles happens indirectly, the result of electromagnetic forces pushing and pulling the particles. "If a particle changes trajectory, it's because it feels a magnetic field or an electric field," says Gianluca Gregori, a physicist at the University of Oxford who is part of ACSEL.

Supernova remnants like W49B (shown in X-ray, radio and infrared light) accelerate electrons and protons to high energies in shock waves.

But exactly how those fields form and grow, and how such a shock wave results, has been hard to decipher. Researchers have no way to see the process in real supernovas; the details are too small to observe with telescopes.

These shock waves, which are known as collisionless shock waves, fascinate physicists. "Particles in these shocks can reach amazing energies," Spitkovsky says. In supernova remnants, particles can gain up to 1,000 trillion electron volts, vastly outstripping the several trillion electron volts reached in the biggest human-made particle accelerator, the Large Hadron Collider near Geneva. But how particles might surf supernova shock waves to attain their astounding energies has remained mysterious.

Magnetic field origins

To understand how supernova shock waves boost particles, you have to understand how shock waves form in supernova remnants. To get there, you have to understand how strong magnetic fields arise. Without them, the shock wave can't form.

Electric and magnetic fields are closely intertwined. When electrically charged particles move, they form tiny electric currents, which generate small magnetic fields. And magnetic fields themselves send charged particles corkscrewing, curving their trajectories. Moving magnetic fields also create electric fields.

The result is a complex feedback process of jostling particles and fields, eventually producing a shock wave. "This is why it's so fascinating. It's a self-modulating, self-controlling,

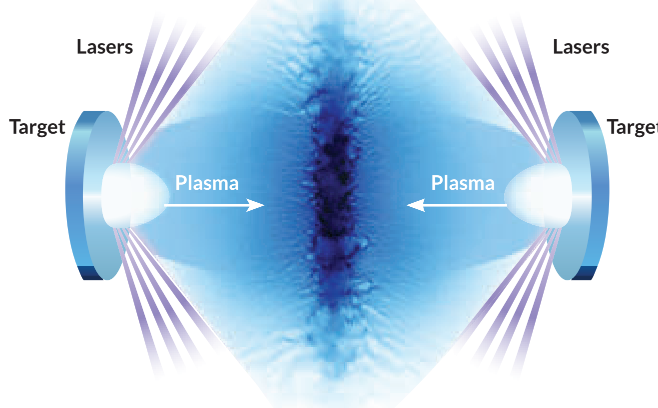
FROM TOP: LAWRENCE LIVERMORE NATIONAL LABORATORY; NASA, CXC, MIT L. LOPEZ *ET AL* (X-RAY), PALOMAR (X-RAY), VLA/NRAO/NSF (RADIO) self-reproducing structure," Spitkovsky says. "It's like it's almost alive."

All this complexity can develop only after a magnetic field forms. But the haphazard motions of individual particles generate only small, transient magnetic fields. To create a significant field, some process within a supernova remnant must reinforce and amplify the magnetic fields. A theoretical process called the Weibel instability, first thought up in 1959, has long been expected to do just that.

In a supernova, the plasma streaming outward in the explosion meets the plasma of the interstellar medium. According to the theory behind the Weibel instability, the two sets of plasma break into filaments as they stream by one another, like two hands with fingers interlaced. Those filaments act like current-carrying wires. And where there's current, there's a magnetic field. The filaments' magnetic fields strengthen the currents, further enhancing the magnetic fields. Scientists suspected that the electromagnetic fields could then become strong enough to reroute and slow down particles, causing them to pile up into a shock wave.

In 2015 in *Nature Physics*, the ACSEL team reported a glimpse of the Weibel instability in an experiment at OMEGA. The researchers spotted magnetic fields, but didn't directly detect the filaments of current. Finally, this year, in the May 29 *Physical Review Letters*, the team reported that a new experiment had produced the first direct measurements of the currents that form as a result of the Weibel instability, confirming scientists' ideas about how strong magnetic fields could form in supernova remnants.

For that new experiment, also at OMEGA, ACSEL researchers blasted seven lasers each at two targets facing each other. That resulted in two streams of plasma flowing toward each other at up to 1,500 kilometers per second — a speed fast enough to circle the Earth twice in less than a minute. When the two streams



Power pulse In a recent experiment at NIF (illustrated above), scientists trained lasers on two targets (white disks in photo at left). Two streams of plasma emerged, producing shock waves (center of illustration) where the plasma streams met.

met, they separated into filaments of current, just as expected, producing magnetic fields of 30 tesla, about 20 times the strength of the magnetic fields in many MRI machines.

"What we found was basically this textbook picture that has been out there for 60 years, and now we finally were able to see it experimentally," Fiuza says.

Surfing a shock wave

Once the researchers had seen magnetic fields, the next step was to create a shock wave and to observe it accelerating particles. But, Park says, "no matter how much we tried on OMEGA, we couldn't create the shock."

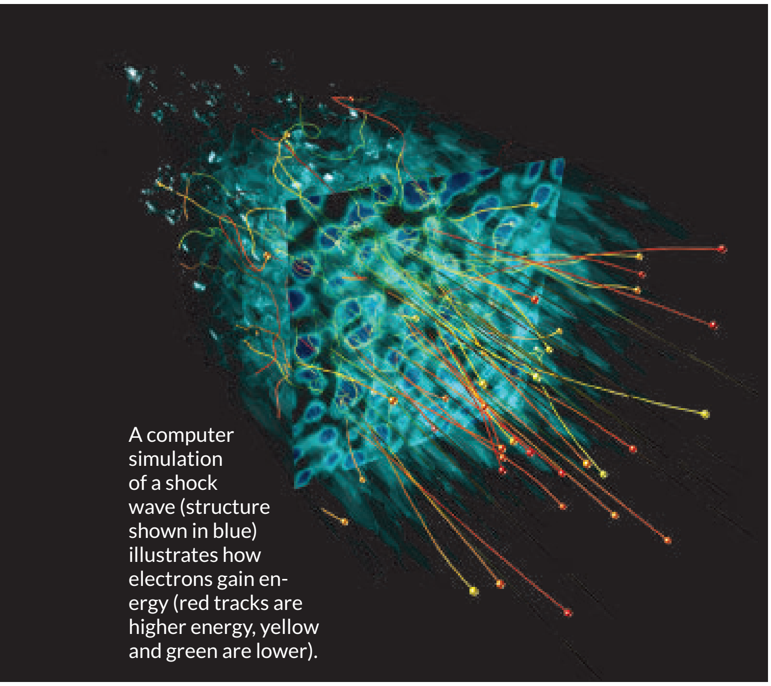
They needed the National Ignition Facility and its bigger laser.

There, the researchers hit two disk-shaped targets with 84 laser beams each, or nearly half a million joules of energy, about the same as the kinetic energy of a car careening down a highway at 60 miles per hour.

Downsizing Supernova remnants and laser experiments exhibit the same physics, despite being very different in their properties, including their size, shock wave speeds and the temperature and density of their electrically charged particles, or plasma. SOURCE: F. FIUZA *ET AL*/*NATURE PHYSICS* 2020

	Typical supernova remnant	NIF laser experiments
Diameter	300,000,000,000,000 kilometers	2.5 centimeters
Shock wave velocity	3,000–5,000 kilometers/second	1,000–2,000 kilometers/second
Plasma temperature	11,000° Celsius	5,800,000° Celsius
Plasma density	0.2 particles per cubic centimeter	50,000,000,000,000,000,000 particles per cubic centimeter

FROM TOP: F. FIUZA *ET AL*/*NATURE PHYSICS* 2020; NIF TARGET OPERATIONS TEAM



A computer simulation of a shock wave (structure shown in blue) illustrates how electrons gain energy (red tracks are higher energy, yellow and green are lower).

F. FIUZA/SLAC NATIONAL ACCELERATOR LABORATORY

Two streams of plasma surged toward each other. The density and temperature of the plasma rose where the two collided, the researchers reported in the September *Nature Physics*. "No doubt about it," Park says. The group had seen a shock wave, specifically the collisionless type found in supernovas. In fact there were two shock waves, each moving away from the other.

Learning the results sparked a moment of joyous celebration, Park says: high fives to everyone.

"This is some of the first experimental evidence of the formation of these collisionless shocks," says plasma physicist Francisco Suzuki-Vidal of Imperial College London, who was not involved in the study. "This is something that has been really hard to reproduce in the laboratory."

The team also discovered that electrons had been accelerated by the shock waves, reaching energies more than 100 times as high as those of particles in the ambient plasma. For the first time, scientists had watched particles surfing shock waves like the ones found in supernova remnants.

But the group still didn't understand how that was happening.

In a supernova remnant and in the experiment, a small number of particles are accelerated when they cross over the shock wave, going back and forth repeatedly to build up energy. But to cross the shock wave, the electrons need some energy to start with. It's like a big-wave surfer attempting to catch a massive swell, Fiuza says. There's no way to catch such a big wave by simply paddling. But with the energy provided by a Jet Ski towing surfers into place, they can take advantage of the wave's energy and ride the swell.

"What we are trying to understand is: What is our Jet Ski? What happens in this environment that allows these tiny electrons to become energetic enough that they can then ride this wave and be accelerated in the process?" Fiuza says.

The researchers performed computer simulations that suggested the shock wave has a transition region in which magnetic fields become turbulent and messy. That hints that the turbulent field is the Jet Ski: Some of the particles scatter in it, giving them enough energy to cross the shock wave.

Wake-up call

Enormous laser facilities such as NIF and OMEGA are typically built to study nuclear fusion — the same source of energy that powers the sun. Using lasers to compress and heat a target can cause nuclei to fuse with one another, releasing energy in the process. The hope is that such research could lead to fusion power plants, which could provide energy without emitting greenhouse gases or dangerous nuclear waste (*SN: 4/20/13, p. 26*). But so far, scientists have yet to get more energy out of the fusion than they put in — a necessity for practical power generation.

So these laser facilities dedicate many of their experiments to chasing fusion power. But sometimes, researchers like Park get the chance to study questions based not on solving the world's energy crisis, but on curiosity — wondering what happens when a star explodes, for example. Still, in a roundabout way, understanding supernovas could help make fusion power a reality as well, as that celestial plasma exhibits some of the same behaviors as the plasma in fusion reactors.

At NIF, Park has also worked on fusion experiments. She has studied a wide variety of topics since her grad school days, from working on the U.S. "Star Wars" missile defense program, to designing a camera for a satellite sent to the moon, to looking for the sources of high-energy cosmic light flares called gamma-ray bursts. Although she is passionate about each topic, "out of all those projects," she says, "this particular collisionless shock project happens to be my love."

Early in her career, back on that experiment in the salt mine, Park got a first taste of the thrill of discovery. Even before IMB captured neutrinos from a supernova, a different unexpected neutrino popped up in the detector. The particle had passed through the entire Earth to reach the experiment from the bottom. Park found the neutrino while analyzing data at 4 a.m., and woke up all her collaborators to tell them about it. It was the first time anyone working on the experiment had seen a particle coming up from below. "I still clearly remember the time when I was seeing something nobody's seen," Park recalls.

Now, she says, she still gets the same feeling. Screams of joy erupt when she sees something new that describes the physics of unimaginably vast explosions. ■

Explore more

- Lawrence Livermore National Laboratory. What is the National Ignition Facility? bit.ly/whatisNIF
- University of Rochester Laboratory for Laser Energetics. OMEGA Laser Facility. bit.ly/Rochester-OMEGA
- Uppsala University Department of Physics and Astronomy. Collisionless shocks. bit.ly/Uppsala-Cshock

Tuataras are proof that, for some species, the penis is not an essential organ.

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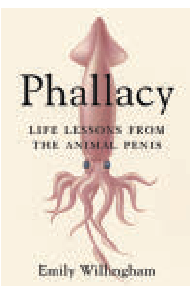
BOOKSHELF

Phallacy deflates myths about the penis



Phallacy
Emily Willingham
AVERY, $27

We humans are kind of penis obsessed. The organ appears in religious texts, laws, daily speech and even in photos sent, often uninvited, to people's phones. But when we compare our species to the wild diversity of life, the human penis is comparatively unremarkable, making our infatuation seem even more misplaced.

In *Phallacy*, biologist and science writer Emily Willingham takes readers on a historical, evolutionary and often hilarious tour of the penises of the planet. "Nothing gets clicks like a story about dicks," she writes. "Even if it's about a penis that's 1.5 millimeters long and millions of years old." Along the way, she puts the human penis into much-needed perspective.

> Male domination of science has produced research focused on the male parts, and that leaves out fully half of the story of reproduction.

For a true exploration of the animal kingdom, the word "penis" just won't suffice. Willingham coins a new term, intromittum, to describe organs that transmit gametes — the eggs or sperm — from one partner to the other. The neutral noun, derived from Latin verbs meaning "into" and "send," can apply to any sex and to any body part. This word comes in handy when discussing argonauts, cephalopods also known as paper nautiluses, which use an arm as a detachable mating device, or extinct types of mites, in which the females used a "copulatory tube" to pick up sperm from the males.

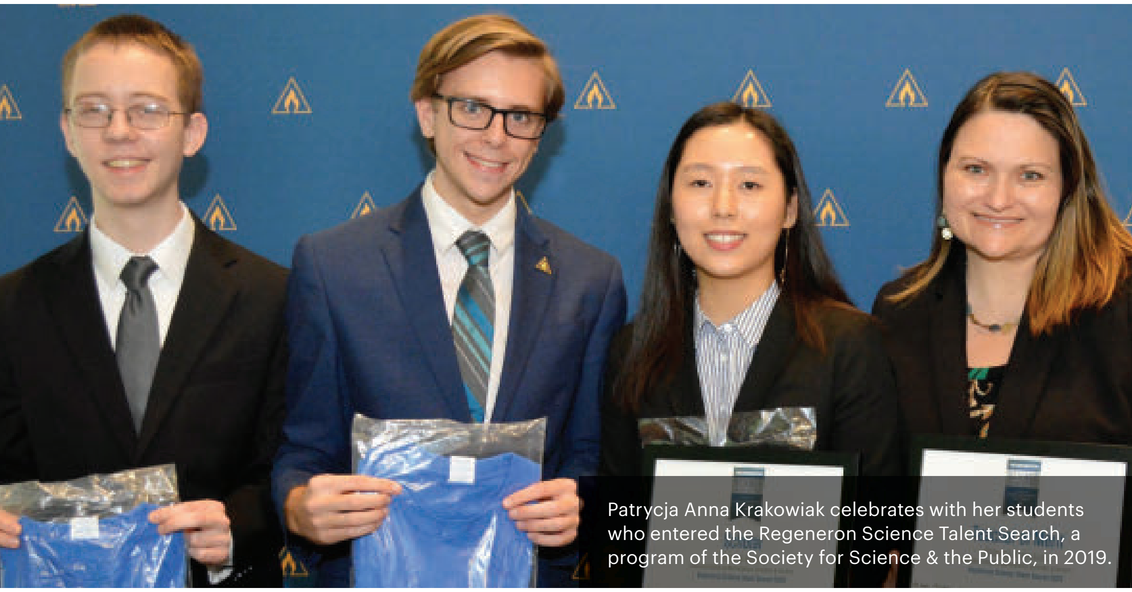
There's great variety in intromitta because they — like every other part of an organism — have been shaped by evolutionary pressures. Willingham delves into why life on the seafloor might have given a tiny ancient crab a "large and stout copulatory organ," or why a lack of selective pressure might have helped animals like the tuatara, a lizardlike reptile, get along without a penis (*SN: 11/28/15, p. 15*). She also offers examples of the many species that have taken intromitta to amusing and terrifying extremes. They come spiraled, mace-tipped, needle-barbed and multiheaded. Several species even exhibit members that are larger than the males that wield them.

In contrast, Willingham points out, the human penis is distinctly lackluster. It isn't covered in spines and has no penis bone, or baculum. It's not excessively large for the human body size. But that mediocrity reveals something crucial about ourselves. The human penis's lack of weaponry and its fleshy texture show that humans don't engage in large amounts of mating competition, with a male using his penis as a fencing foil or to scoop out a rival's semen. Instead, Willingham notes, it points to our tendency toward prolonged mating bonds within a social network.

What might surprise some readers is how much of the book is devoted, not to intromitta, but to the things they intromit into, and how very little we know about them. "When scientists do look into a vagina," Willingham writes, "it's usually to see *if* a penis will fit into it and *how* and nothing more." In highlighting our culture's overemphasis on the penis and the relative dismissal of the vagina, Willingham shows how the male domination of science has produced research that has focused on, well, the male parts, and how that leaves out fully half of the story of reproduction.

In addition to looking at the role society plays in how the penis is studied, *Phallacy* digs into how the penis has been thrust into society. Willingham notes that history, science and culture have overemphasized the role of the member in our lives. Men, Willingham argues, have been reduced to their penises, which are assumed to drive their behavior, their confidence and any efforts men make to compensate for supposed deficiencies. But "the penis is not the throbbing obelisk of all masculinity," she writes. And to make it one is an insult, both to the penis and to the person who owns it. So Willingham calls for the penis to be put in its place. "It's time to decenter the organ and focus on the person and their behavior," she says. The penis is not unimportant. But it also isn't the measure of a man. — *Bethany Brookshire*

Science News helps teachers navigate VIRTUAL CLASSROOMS



Patrycja Anna Krakowiak celebrates with her students who entered the Regeneron Science Talent Search, a program of the Society for Science & the Public, in 2019.

"More than ever, students need access to resources that help them understand complex topics while captivating their imaginations and letting them see how science applies to and affects their daily lives — *Science News* amply fulfills these roles."

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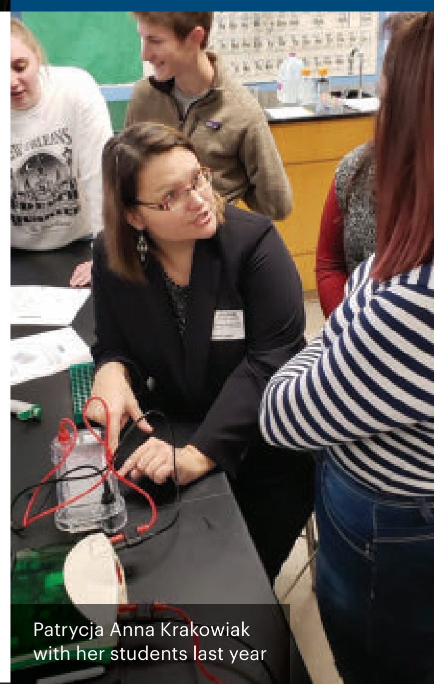
In virtual and in-person classrooms, the *Science News* in High Schools (*SNHS*) program brings *Science News* magazine and related educational resources to high schools across the United States.

Just like educators across the country, Arkansas teacher Patrycja Anna Krakowiak, who leads a cohort of STEM educators from 43 Arkansas high schools, is challenged to keep her students engaged in a new virtual learning environment. Patrycja recently shared how she has been using *SNHS* resources to continue STEM education while her students are learning from home.

"I have been using *SNHS* resources for the past three years. I use articles as main assignments together with questions from the Educator Guides. I pick *Science News* articles of a specific topic and give students a choice to read one, summarize it in 200 words and critique or ask questions about it.

"We have also started working with students on new research questions and had them search the *Science News* website for ideas. Finally, I use *Science News* as an introduction and springboard into virtual labs (using simulations from Labster and Howard Hughes Medical Institute resources) and analytical assessments (using case studies)."

Schools are able to receive *SNHS* resources thanks to donors from across the country who have sponsored more than 5,000 schools during the 2020–2021 school year.



Patrycja Anna Krakowiak with her students last year

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SEPTEMBER 12, 2020

Dance of the doomed particles

Scientists are puzzled by an unexpectedly large gap in the energy levels of an exotic "atom" called positronium, which consists of an electron and a positron, ***Emily Conover*** *reported in "Positronium result baffles physicists"* (SN: 9/12/20, p. 14).

Reader **Lee Skinner** asked why the electron and its antimatter counterpart, the positron, don't just annihilate each other when they collide.

Eventually, the electron and positron do annihilate one another, **Conover** says. As a result, positronium doesn't stick around forever. "The two particles do a little orbital dance with each other for a period of time before they meet up and annihilate," she says. "That's actually part of how the researchers made the measurement, though I didn't have the space to include those details in the story." The team measured how long it took electrons and positrons to annihilate, which depends on the atoms' energy level. "Timing that annihilation revealed whether the positronium atoms had jumped to a new energy level or not," **Conover** says.

What's the buzz?

Pollination by wild bees accounts for about $1.5 billion worth of yields for six U.S. crops, ***Susan Milius*** *reported in "Wild bees are moneymakers for some U.S. farms"* (SN: 9/12/20, p. 5).

Reader **Steve Robinson** wondered what species of wild bees the researchers observed.

Milius is glad that readers recognize there are many kinds of wild bees. "Common groups spotted in the survey included bumblebees, carpenter bees, *Andrena* mining bees and squash bees — named for some of their favorite flowers," she says.

Hot and cold

A study of glass beads hints at how hot water can freeze faster than cold water, ***Emily Conover*** *reported in "Hot beads chilled faster than cool ones"* (SN: 9/12/20, p. 16).

"Makes you wonder about warming. Has anybody done the opposite experiment?" reader **Robert Chester** asked.

Conover hasn't seen experimental evidence for cold water warming faster than hot water, but she says there is a theoretical study that suggests the effect is possible. For certain idealized materials, scientists have shown mathematically that atoms could heat up faster after a precooling phase. Scientists eventually may look for the effect in real materials such as magnetic alloys (*SN Online: 2/13/20*).

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D. CASTRANOVA, B. WEINSTEIN AND B. SAMASA/NIH, NIKON SMALL WORLD

Glowing fish gives up its anatomical secret

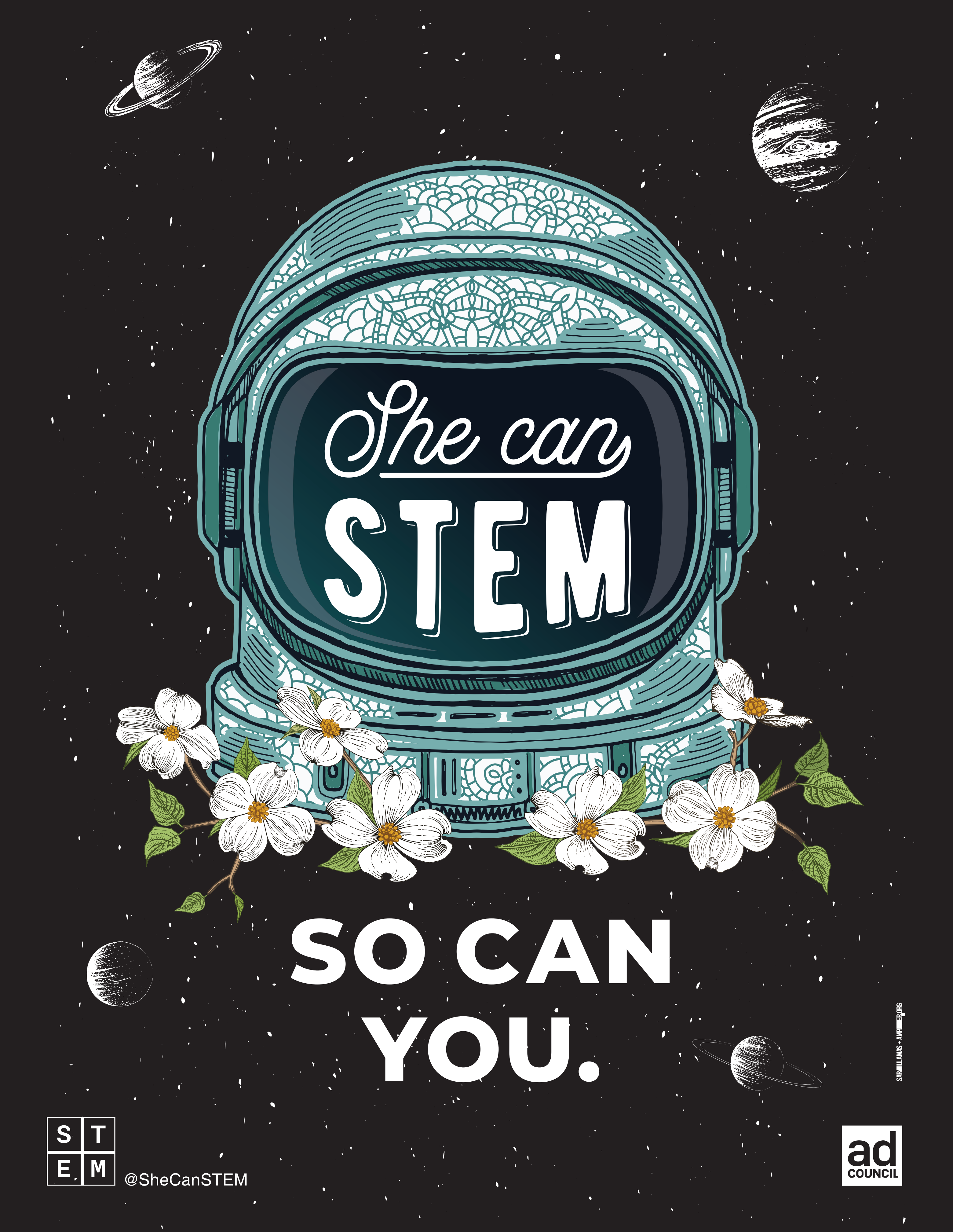
While seeking answers to scientific questions, it's worth occasionally taking a step back to appreciate the world's exquisiteness.

Daniel Castranova, Bakary Samasa and Brant Weinstein, all developmental biologists, found some of that delicate beauty inside a zebrafish. While working in Weinstein's lab at the National Institutes of Health in Bethesda, Md., Castranova and Samasa captured images of this young zebrafish under a microscope (shown at four times magnification), illuminating never-before-seen parts of a fish's lymphatic system.

The photo, which snagged first place in the 46th annual Nikon Small World photomicrography contest on October 13, comes from research that sought to determine whether zebrafish have lymphatic vessels inside the skull. The lymphatic system helps clear toxins and waste from the body, and previously, researchers thought only mammals had these vessels close to the brain.

But the fish have those vessels too, which the team found by studying zebrafish genetically modified to have lymphatic vessels that fluoresce orange and skeletons and scales that glow blue. Fish are easier than mammals to raise in the lab, Castranova says, so the finding could help reveal the role of the brain's lymphatic system in neurological diseases like Alzheimer's. *— Erin Garcia de Jesus*

See other photos from the Nikon Small World contest at **bit.ly/SN_2020Nikon**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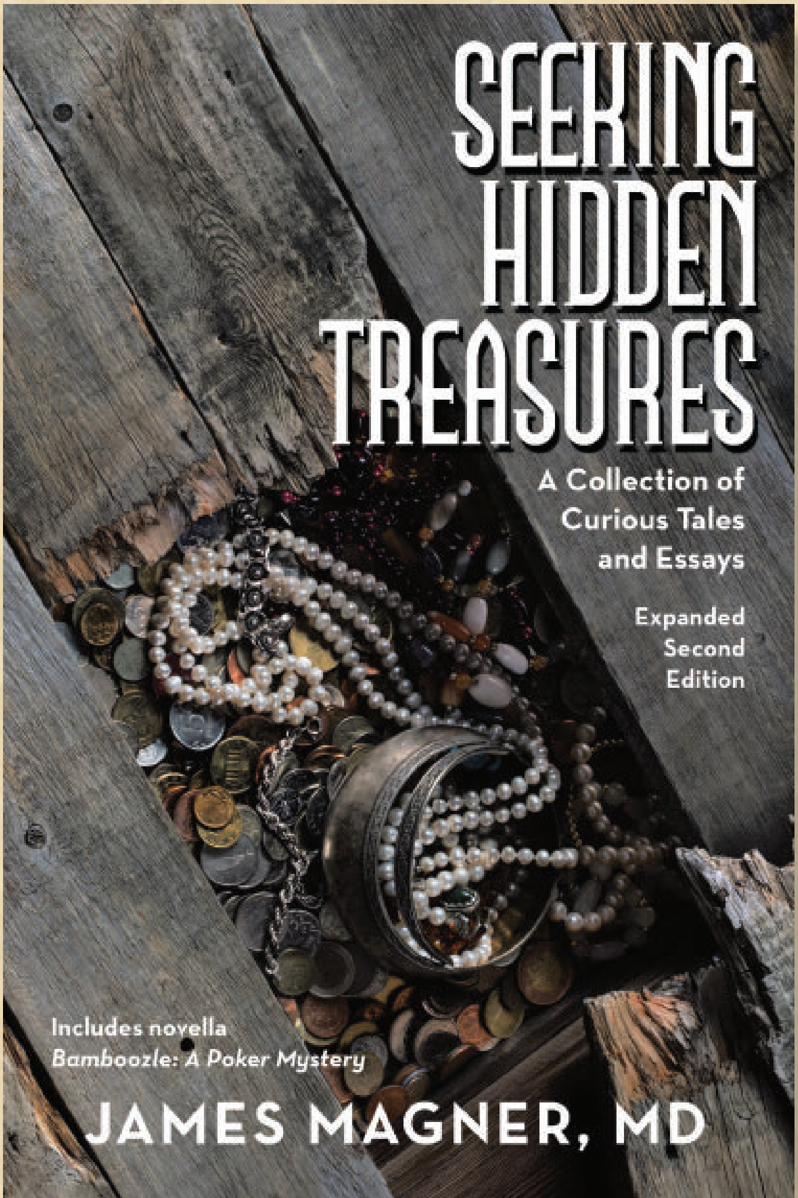

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